

ADDRESSING MISCONCEPTIONS THROUGH INQUIRY  
IN FIRST GRADE SCIENCE

by

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## ABSTRACT

Inquiry-based teaching harnesses students' innate curiosity and ability to be natural scientists. Students have misconceptions that may interfere with learning about scientific concepts, whether learning through their own experiences or from friends, family, or school. Many students retain or revert back to their misconceptions, even after instruction designed to challenge old ideas and accept the new ideas. Although inquiry-based learning is recommended, it is far from the norm and many teachers show apprehension about teaching through inquiry. Different forms of inquiry may or may not be effective at repairing student misconceptions. This classroom research project analyzed the effectiveness of four types of inquiry-based instruction in repairing scientific misconceptions in a first grade class. A demonstrated inquiry unit was taught on the movements of the sun, moon, and Earth across the sky. The second unit was about the seasons and taught as structured inquiry. Then a 5E guided inquiry unit was taught about light. The last unit was an open inquiry on sound. At the beginning, the end, and one month following each unit, a series of misconception probes were administered. The probes measured nine targeted concepts along with student confidence in the concepts. Students' perception of their learning was measured using daily administered Likert surveys on engagement and control of learning. The results of the study indicated that students learned some of the new concepts, but they also retained many of the misconceptions. Some misconceptions were created or became more popular throughout the treatment. The results also indicated that many students had a better understanding of some of the topics a month after the unit was completed. Overall students perceived inquiry-based instruction to be engaging.

## INTRODUCTION AND BACKGROUND

I teach first grade at Birch Lane Elementary School in Davis, California. Davis is a college town, home to University of California, Davis, with a population of 68,107 (city-data.com, 2018). The City of Davis (2017) states on its website that it has the highest level of education of any city in California, based upon the number of years of college completed. The racial makeup of Davis is the following: 58.9% White, 21.7% Asian, 12.5% Hispanic, 2.2% Black, and 4.1% two or more races (city-data.com, 2018).

Birch Lane Elementary has about 600 students enrolled in kindergarten through sixth grade (greatschools.org, 2017). Birch Lane is one of the oldest schools in Davis and has many established science programs including a one acre arboretum, chicken coops, a fruit orchard, a vineyard, and many vegetable plots. According to the National Center for Education Statistics (2017), 26% of Birch Lane's students are eligible for free or reduced price lunch. Birch Lane Elementary school was named a California Distinguished School in 2014 (Birch Lane, 2017).

I teach all subjects, including science, to a first grade class of 22 students, including six English Learners. The students have a wide range of backgrounds and abilities. Some are not yet able to read or write independently, while many read and perform significantly beyond grade level standards. The students have varied backgrounds in science education. Some students come from preschools that advertise a science focus or have parents who are scientists and other students have limited formal science backgrounds outside of kindergarten. Most students in my class attended

kindergarten at Birch Lane in a play-based classroom with teachers who strive to foster curiosity.

Before teaching first grade in Davis, I taught young preschoolers; 4<sup>th</sup> to 11<sup>th</sup> graders at a Mongolian public school, 5<sup>th</sup> grade science and English, and kindergarten at The International School of Ulaanbaatar (ISU), Mongolia. It was at ISU that I became introduced to inquiry. All teachers' instruction was guided by The International Baccalaureate's Primary Years Programme (PYP). The PYP focuses on developing inquiry skills in children inside and outside the classroom and focuses on student-led inquiry (International Baccalaureate, 2017). Since 2014, when I began to teach again in the United States, I have been introduced to several forms of inquiry that are more teacher-led, including demonstrated inquiry, structured inquiry, and guided inquiry.

I was first introduced to misconceptions about elementary science topics in science education classes while studying to be a teacher at California State University, Chico. After learning about common misconceptions in class, I would come home to share my newfound knowledge with my roommates who would defend their misconceptions and had difficulty accepting the new concepts. It became apparent through several misconception probes and student interviews that students come into class with many misconceptions about science. Some students retain the misconceptions even after they have been challenged by lessons addressing the misconceptions.

Through this action-research based classroom project I hoped to identify, challenge, and correct misconceptions with various models of inquiry. The lessons were Next Generation Science Standards (NGSS) aligned, but Davis Joint Unified School

District has neither adopted the NGSS standards nor bought NGSS aligned curriculum. My experience with my class led to the creation of my focus question: How effectively can inquiry-based-instruction repair student misconceptions in science? Additionally, I explored the secondary question of How did students perceive their learning as they participated in inquiry?

## CONCEPTUAL FRAMEWORK

### Background on Inquiry

Numerous experts and authorities in science education, including The National Research Council (NRC), recommended teaching through scientific inquiry over 20 years ago. The NRC originally defined inquiry as “a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories” (National Research Council, 1996, p. 214).

In the last couple of decades, inquiry has been defined many different ways. This has led to many types of instruction being labeled as inquiry (National Research Council, 2012). According to the Next Generation Science Standards (NGSS), “Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings” (NGSS Lead States, 2013, p. 432). Teachers have different beliefs as to what inquiry is, ranging from giving students hands-on materials to students posing questions and guiding their own research (Huang 2015; Llewellyn 2014). However

inquiry is defined, scientific inquiry, or inquiry-based science, is at the forefront of modern science education.

From a first grade teacher's perspective, student-centered inquiry-based instruction could be a useful teaching tool to help engage students by using their innate curiosity. It could also be a daunting task for teachers to start implementing. In one study, 50% of elementary and middle school science teachers responded that they felt intimidated by inquiry lessons (Suarez, 2011). A study of second grade teachers in Michigan found that only about five percent of instruction in science, language arts, and social studies was inquiry-based (Billman, 2008). Inquiry-based-instruction may seem too daunting for lower elementary teachers, but it is an important teaching tool.

#### Misconceptions in the Classroom

Misconceptions are a major factor that prevents students from learning new scientific concepts. A misconception is a "student conception that produces a systematic pattern of error" (Smith, diSessa & Rochelle, 1993, p. 119). Misconceptions are ideas students have prior to instruction that conflict with or hinder the learning of new science concepts. Previous experiences from everyday life lead to the development of preconceived notions. Non-scientific sources of information, such as myths or religious teachings, instill non-scientific beliefs in students. Conceptual misunderstandings are created when learners' non-scientific beliefs and preconceived notions conflict with scientific information. Scientific language with different meanings in everyday language can lead to vernacular misconceptions. False information learned at a young age, but never corrected, create factual misconceptions (National Research Council, 1997).

Naïve conceptions are similar to misconceptions in that they are ideas that can interfere with learning, even if challenged by new information. Naïve conceptions are usually developed as early as infancy and children “consider them unquestionable truths about the way the physical world operates” (Vosniadou, 1994, p. 67). Naïve conceptions and misconceptions can both be replaced through a process called conceptual change. During this process students experience a phenomenon that conflicts with their misconception creating dissatisfaction between the misconception and the event. The dissatisfaction piques student curiosity and motivates learning. The new concept needs to seem plausible and be more attractive to the student than the misconception. The replacement concept also needs to be able to explain and predict the student’s world (Stepans, 2006). Many students retain misconceptions after they have gone through conceptual change lessons or discussions focused on repairing the misconceptions (Eryilmaz, 2002).

#### Inquiry and its Effectiveness

Elementary teachers have a wide range of experiences with misconceptions, but few list it as something that could impede students learning future science concepts (Gomez, 2008). In fact, college graduates retain misconceptions about first grade science topics, such as what creates the seasons (Stepans, 2006). Challenging students’ previous ideas can create dissatisfaction with misconceptions, and may be required for learning new concepts that conflict with earlier held misconceptions (Posner, Strike, Hewson, & Gertzog, 1982). Many misconceptions are ingrained in students and should be repaired so that they do not conflict with new concepts (National Research Council, 1997). If

student-centered inquiry is to be adopted by teachers, it should effectively repair student misconceptions.

Inquiry is an important teaching tool because research has demonstrated that inquiry can increase student engagement and increased engagement can lead to a better understanding of science concepts (Pedro, 1999). Inquiry-based activities are recommended for teachers of young children because they increase engagement (Sackes, Trundle, Bell, & O'Connell, 2010). Much of the research on inquiry does not differentiate between what type of inquiry was used, but there have been strong correlations between using inquiry and academic achievement (Suarez, 2011). A recent meta-analysis study of 37 inquiry-based science teaching studies from 11 countries found that in most studies inquiry-based instruction had a positive effect on student learning in elementary, middle, and high school. The meta-analysis also found that teacher-led inquiry studies had a greater positive effect than student-led inquiry studies (Furtak, Seidel, Iverson, & Briggs, 2012).

Inquiry-based instruction has been shown to work better with certain common classroom practices. Asking open questions has been shown to help students acquire and process data into information (Blosser, 2000). The use of phenomena, previously called discrepant events, prompted learners to start asking questions (Llewellyn, 2014; Longfield, 2009). Phenomena are recommended by Llewellyn (2014) for all types of inquiry, but they have been found to be especially effective at prompting student questions in open inquiry.

Inquiry-based instruction is supported by constructivist educational theory. In constructivist educational theory, learners build constructs and internalize knowledge by assimilating it with what is already known (Piaget, 1971). In a constructivist classroom, the role of the teacher is to facilitate learning by helping students collect, sort, analyze, and reflect on their learning. The students' role is to ask questions, discuss with their peers, and create their own meaning (Fosnot, 2005). While participating in inquiry, students construct their understanding based upon prior knowledge (Murdoch, 2015). According to some educational psychologists, even though constructivist teaching styles, such as inquiry-based instruction, are popular, they are not effective, especially when the learners have less prior knowledge (Kirschner, Sweller, & Clark, 2006).

Researchers at middle schools in Indonesia found that discovery inquiry was effective at repairing misconceptions (Tompo, Ahmad, Muris, 2016). In Turkey, an open, student-centered, and inquiry-based approach improved student conceptual understanding (Krueger, Anderson, Lyle, & Nyenhuis, 2010). However, not all research has supported teaching through inquiry. At the university level, inquiry-based instruction has been criticized for being unable to consistently repair misconceptions. University level engineering students were able to repair misconceptions through inquiry, but the inquiry lesson also reinforced some misconceptions and created new misconceptions (Adam, Self, Widmann, Coburn, & Saoud, 2015).

There are many forms of inquiry with different definitions. Some forms of inquiry are student centered, where the students ask questions, and other forms are more teacher centered with teachers asking or directing students in what questions to ask.

Demonstrated inquiry is teacher-centered and predetermined by the teacher, who models the inquiry process by leading the class through the cycle step by step, typically seen in chemistry and physics demonstrations. In structured inquiry the teacher gives the students a question and a procedure to follow using hands on materials. The students collect and analyze the data to report their findings, which is expected but not predetermined.

Science labs are very often structured inquiry. In guided inquiry the teacher provides the question, but the students plan and carry out the investigation. An example of this is the 5E instructional model. Open inquiry, sometimes called self-directed inquiry or true inquiry, is when students ask the questions as well as plan and carry out the investigations. Some teachers think that students are not able to do higher level inquiry until they have practiced by using lower levels of inquiry (Banchi & Bell, 2008; Llewellyn, 2014).

The 5E instructional model's link to increased engagement and understanding of science concepts, including repairing misconceptions, is documented more thoroughly than other types of inquiry. The 5E instructional model was created by Bybee and the BSCS team for elementary science and health education. The 5E instructional model takes students through five steps of the inquiry process: engagement, exploration, explanation, extension, and evaluation (Bybee et al., 2006). Blomquist (2013), in her classroom research project, found that 5E instructional model, inquiry-based lessons led to increased engagement in first grade students. Guided inquiry, as part of a "highly rated science curriculum" has been shown to increase student engagement and mastery of core content on diverse populations (Lynch, Kuipers, Pyke, & Szesze, 2005). A team at

Binghamton University found that guiding third, fourth, fifth, and sixth grade teachers through 5E instructional model inquiry science units reduced student misconceptions in science (Stamp & O'Brien, 2005). Researchers found that both the 5E instructional model and conceptual change model were more effective than traditional instruction, based on lecture and discussion, at eliminating misconceptions about photosynthesis (Balci, Cakiroglu, & Tekkaya, 2006).

## METHODOLOGY

This classroom research project attempted to determine the effectiveness of four types of inquiry-based instructional strategies on repairing common student misconceptions. It was conducted in my first grade class at Birch Lane Elementary School in Davis, California. Twenty-two students, ages six and seven, participated in the classroom research project. The treatment units were administered from the return of winter vacation in January to the beginning of spring break in March. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

Each of the four units (Table 1) was taught independently using increasingly student-centered forms of inquiry (Llewellyn, 2014). For the purpose of this classroom research project, inquiry-based instruction focuses on students answering questions to guide learning, using real world or hands on experiences. The conceptual change process for repairing misconceptions (Stepans, 2006) guided the units' timing. Each of the four units covered an Earth or physical science topic from the first grade Next Generation

Science Standards, including the science and engineering practices (NGSS Lead States, 2013).

Table 1  
*Overview of Inquiry-Based Units*

	Unit Name	Type of Inquiry	Topic	Misconception Probes
1/8-1/25	Movement in the Sky (Appendix B)	Demonstrated inquiry	Path of Moon, Sun, and Stars	Objects in the Sky Darkness at Night Where Do Stars Go Me and my Shadow Gazing at the Moon Going Through A Phase (Appendix C)
2/2-2/22	Seasons (Appendix D)	Structured inquiry	Seasons	Sunrise Direction Earth's Tilt Length of Day Temperature in Day The Sun's Angle Different Seasons Timing of the Seasons Cause of the Seasons Temperature in Seasons (Appendix E)
2/26-3/9	Light (Appendix F)	5E instruction model, guided inquiry	Light and Color	Birthday Candles Shadows Apple in the Dark Light's Color Paper Window Magnifying Glass Moonlight Mirrors Can it Reflect Light? (Appendix G)
3/12-3/23	Sound (Appendix H)	Open student directed Inquiry	Sound	How Sound is Made Hitting Bell Vocal Cords Tuning Fork Sound Waves Speed of Sound Headphones Firetruck Making Sound (Appendix I)

In the first unit, Movement in the Sky (Appendix B), students investigated how objects move across the sky. Initially, the students completed a series of misconception probes (Appendix C). Next, the students exposed their beliefs by sharing their predictions in a whole class discussion. During this discussion, pie charts of student responses on the misconception probes were displayed to encourage the sharing of diverse answers. These answers were recorded in field notes. Then, students were challenged to confront and test their beliefs by observing real life phenomena and phenomena with the teacher in a demonstrated inquiry style. Furthermore, the misconceptions and correct conceptions were not challenged simultaneously; students resolved conflicts about some misconceptions as they were challenging others. Then, students connected the new concept with their lives, including the basis for our calendar. Lastly, students were given an opportunity to extend their understanding of the movement of the sun and moon in relation to the sun with the movements of the other planets in our solar system.

In the second unit, Seasons (Appendix D), students investigated why the amount of daylight and weather changes with the seasons. First the students completed a series of misconception probes (Appendix E). Next, the students exposed their beliefs by sharing their predictions in a whole class discussion. During this discussion, pie charts of student responses on the misconception probes were displayed to encourage the sharing of diverse answers, which were recorded in field notes. Then, students were challenged to confront and test their beliefs by observing real life phenomena, observing phenomena in media, conducting simple investigations and analyzing data presented by the teacher through structured inquiry. Furthermore, the misconceptions and correct conceptions

were not challenged simultaneously; students resolved conflicts about some misconceptions as they were challenging others. Then, students connected the new concept with their lives, including sunrise, sunset. Last, students were given an opportunity to extend by comparing earth with climates on other planets.

In the third unit, Light (Appendix F), students investigated the properties of light. First the students completed a series of misconception probes (Appendix G). Next, the students exposed their beliefs by sharing their predictions in a whole class discussion. During this discussion, pie charts of student responses on the misconception probes were displayed to encourage the sharing of diverse answers, which were recorded in field notes. Then, students were challenged to confront and test their beliefs by observing phenomena, planning activities, and conducting experiments in a 5E guided inquiry style. Furthermore, the misconceptions and correct conceptions were not challenged simultaneously; students resolved conflicts about some misconceptions as they were challenging others. Then, students connected the new concept with their lives by investigating mirrors, lenses. Last, students were given an opportunity to extend by asking their own questions to conduct experiments.

In the fourth unit, Sound (Appendix H), students investigated how sounds are created, transmitted, and used. First the students completed a series of misconception probes (Appendix I). Next, the students exposed their beliefs by sharing their predictions in a whole class discussion. During this discussion, pie charts of student responses on the misconception probes were displayed to encourage the sharing of diverse answers, which were recorded in field notes. Then, students were challenged to confront and test their

beliefs by observing phenomena, observing media, planning and carrying out investigations, and analyze their own data in an open inquiry style. The order that students asked questions dictated the order of instruction. Furthermore, the misconceptions and correct conceptions were not challenged simultaneously; students resolved conflicts about some misconceptions as they were challenging others. Then, students connected the new concept with their understanding of light from unit 3 by comparing the speed of light to the speed of sound. Last, students were given an opportunity to extend by investigating the Doppler Effect, which did not arise from student questions. Students also extended by asking additional questions and answering them by conducting additional investigations.

A series of misconception probes (Appendix C, E, G, I) were administered at the beginning and at the end each unit to measure their effectiveness at repairing misconceptions. The misconception probes were also administered one month after the conclusion of each unit to measure how many students reverted back to their misconceptions. Nine concepts and their related misconceptions were assessed for each of the four units. Each misconception probe consisted of a question and multiple choice answers. The incorrect answers on the multiple choice questions were common misconceptions about each of the assessed concepts. Some of the misconception probes were taken from Page Keely's books while others were self-created.

The student's scores from each administration of the Misconception Probes were compared via box and whisker plots. The normalized gains, developed by Hake (1998) to better understand student growth based upon the potential for learning, were compared

between the Pretest to the Posttest, the Pretest to the Followup Test, and the Posttest to the Followup Test via means and box and whisker plots. The change in scores for each question was compared via grouped bar graphs. Individual concepts and their related misconceptions were compared using stacked bar charts. Each misconception probe included a Likert item survey of confidence. Students responded whether they were Not Sure, A Little Sure, Somewhat Sure, or Very Sure of their answer. The confidence scores were compared with the consistency of answers between misconception probes, along with student statements from field notes and misconception interviews.

A Daily Likert Item Survey of Fun and Control of Learning (Appendix J) was administered to measure student perception of learning. Student engagement in the lessons was rated through students rating how fun the lesson was. The survey asked, “How fun was today’s lesson?” and included the choices Not Fun, A Little Fun, Somewhat Fun, and Very Fun. Students also rated who they thought controlled the learning by answering, “Who controlled the learning in today’s lesson?” and students chose teacher controlled all, teacher controlled most, students controlled most, or students controlled all. The frequency of answers was compared to determine how much control students felt like they had over the learning, and how much they enjoyed it. The frequency of answers for fun and control of learning were demonstrated with bar graphs. I used a chi square test of independence to see if there was a link between fun and control over the learning.

At the completion of each unit, students were chosen at random to participate in an interview by the teacher about their misconceptions and their perception of learning

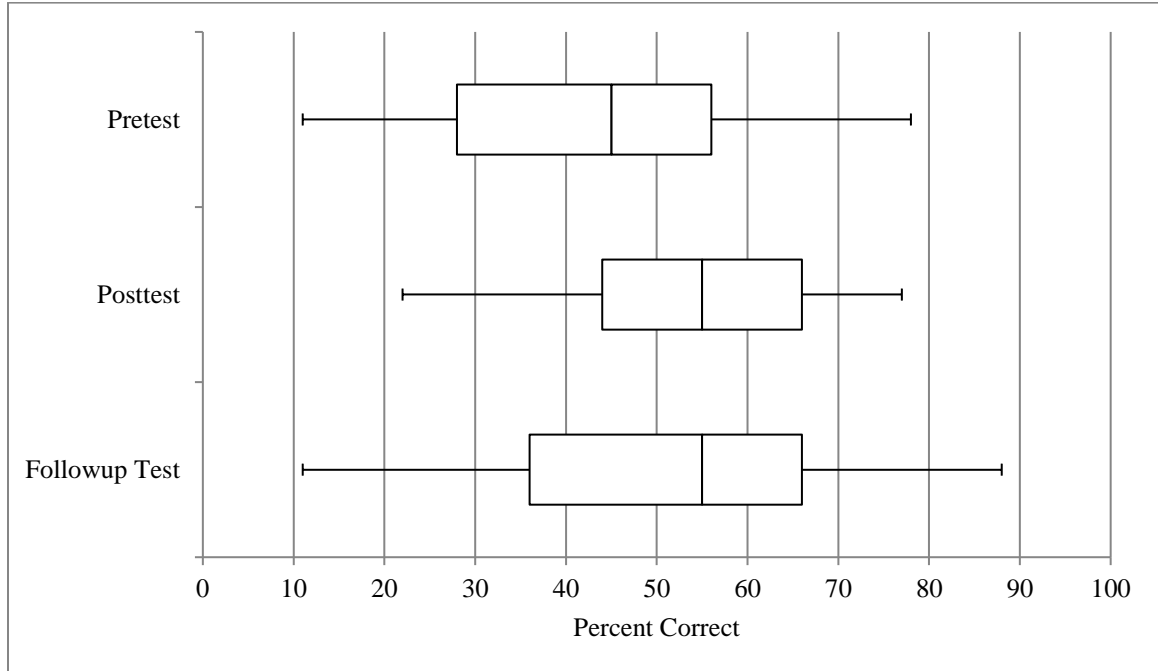
(Appendix K). Followup Test interviews were also conducted during the data analysis phase to delve deeper into student understanding. Qualitative field notes, taken during the classroom research project, included student beliefs that were exposed during the class discussion. The data collection methods and the focus questions are displayed in the Triangulation Matrix (Table 2).

Table 2  
*Data Triangulation Matrix*

Research Question	Data Source 1	Data Source 2	Data Source 3
How effectively can inquiry-based-instruction repair student misconceptions in science?	Misconception Probes including Likert item scale of confidence	Field Notes	Misconception Interviews
How do students perceive their learning as they participate in inquiry?	Daily Likert Item Survey On Fun And Control Of Learning	Field Notes	Misconception Interviews

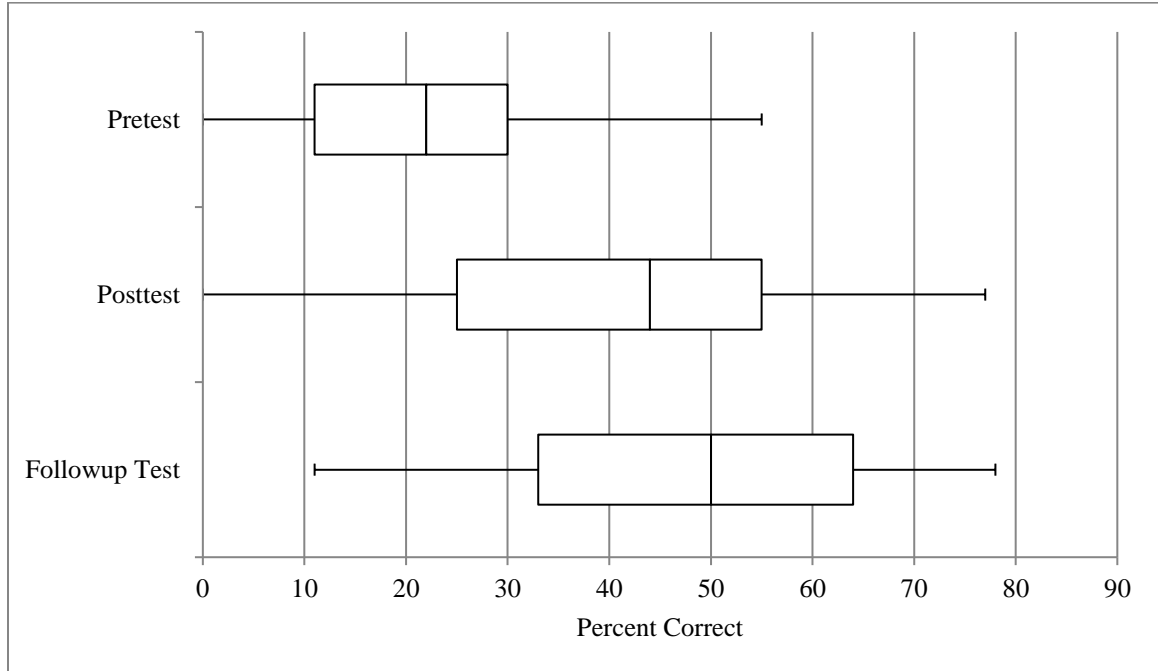
## DATA AND ANALYSIS

The Movement in the Sky Misconception Probes (Appendix C), administered during the demonstrated inquiry unit on objects in the sky, indicated the treatment raised the mean number of correct answers from 43% on the Pretest to 55% on the Posttest and back down to 53% on the Followup Test ( $N=22$ ). The Posttest had the narrowest range of 22% to 78%. The highest single score was on the Followup Test administration of the misconception probes (Figure 1).



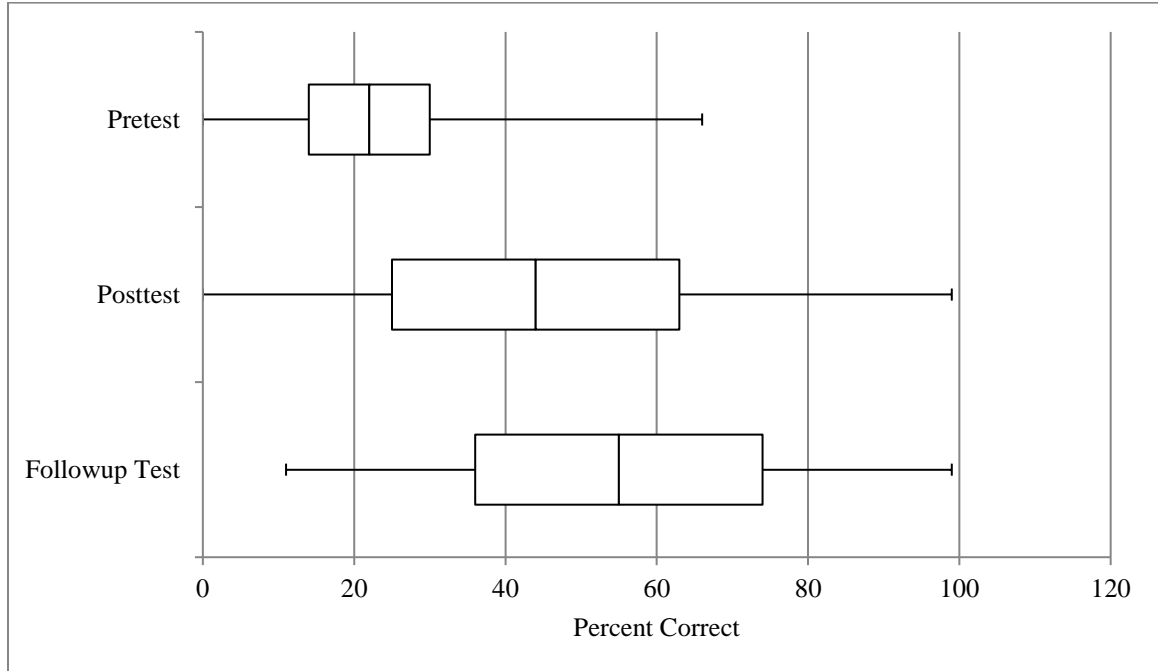
*Figure 1.* Comparison of movement in the sky misconception probe scores, ( $N=22$ ).

The Seasons Misconception Probes (Appendix E), administered during the structured inquiry unit on the cause of the seasons, indicated that the mean for correct answers on the Pretest was 22%. The Posttest mean was 41% and the follow up mean increased to 47%. The highest scores were on the Posttest and Followup Test (Figure 2).



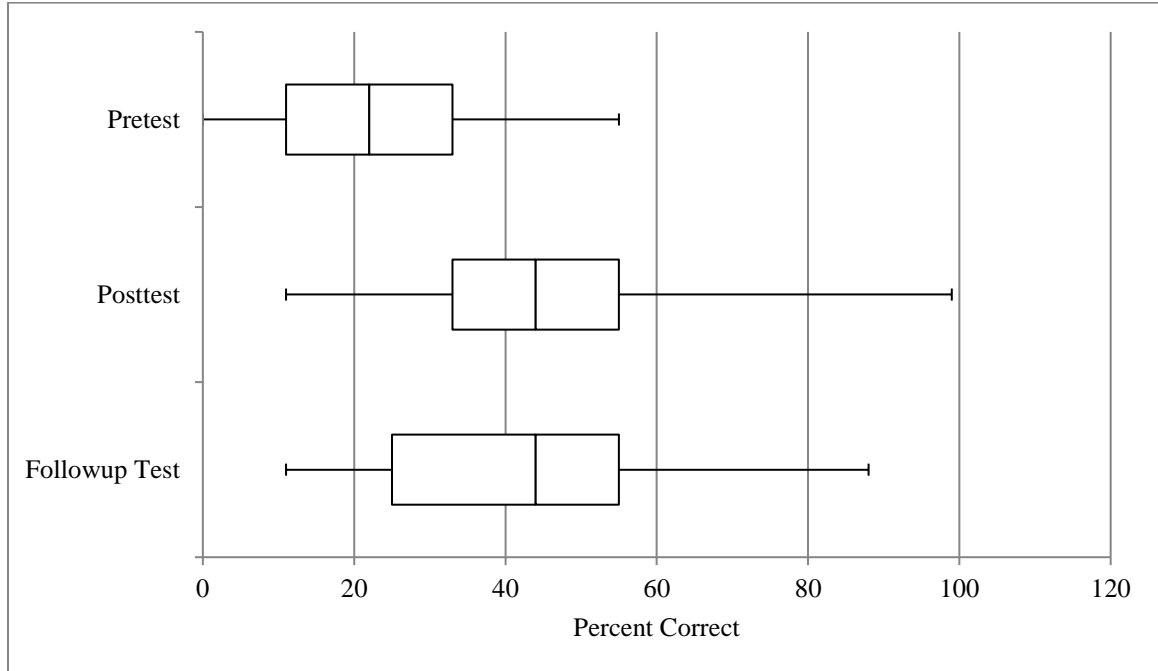
*Figure 2.* Comparison of seasons misconception probe scores, ( $N=22$ ).

On the Light Misconception Probes (Appendix G), administered during the 5e guided inquiry unit on light, the mean on the Pretest of 27% increased to 45% on the Posttest and 55% on the Followup Test. The highest scores were on the Posttest and Followup Test (Figure 3).



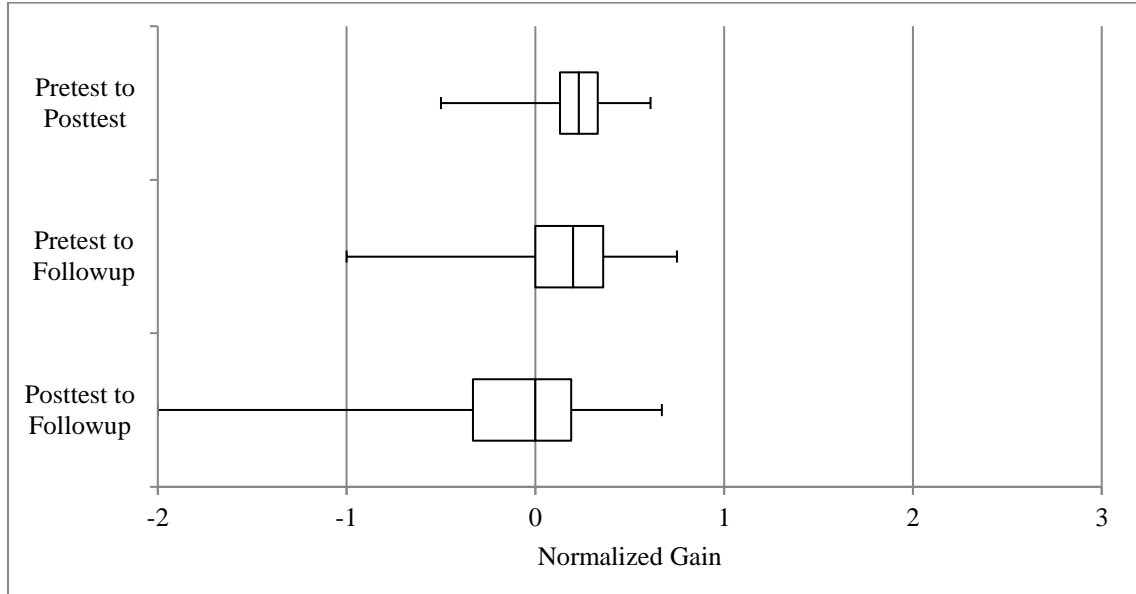
*Figure 3.* Comparison of light misconception probe scores, ( $N=22$ ).

The Sound Misconception Probes (Appendix I), administered during the open inquiry unit on sound, indicated that the mean percent correct rose from 26% on the Pretest to 45% on both the Posttest and Followup Test. The highest score was on the Posttest (Figure 4).



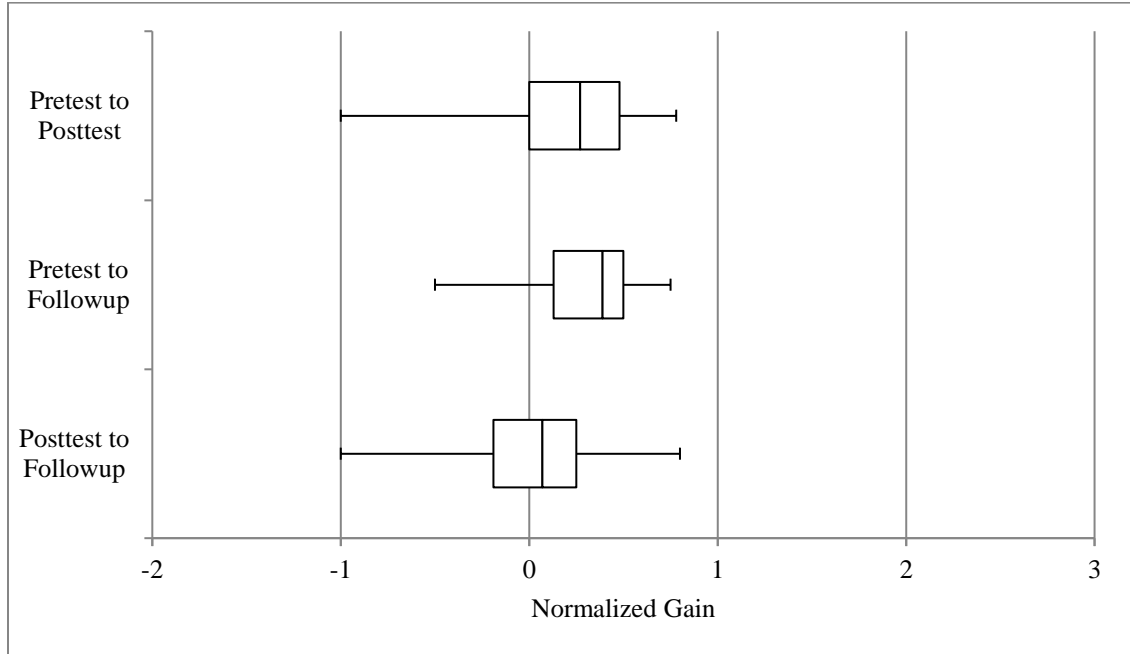
*Figure 4.* Comparison of sound misconception probe scores, ( $N=22$ ).

Normalized gains were calculated for each student to better understand student. The mean average normalized gain on the Movement in the Sky Misconception Probes from the Pretest to the Posttest was .17 and the Pretest to Followup Test was .12 indicating a low gain. Seven students had positive gains from the Posttest to the Followup Test and another seven students' scores showed no change. The median average normalized gain from Posttest to Followup Test was zero and the mean average was a loss of .15 (Figure 5).



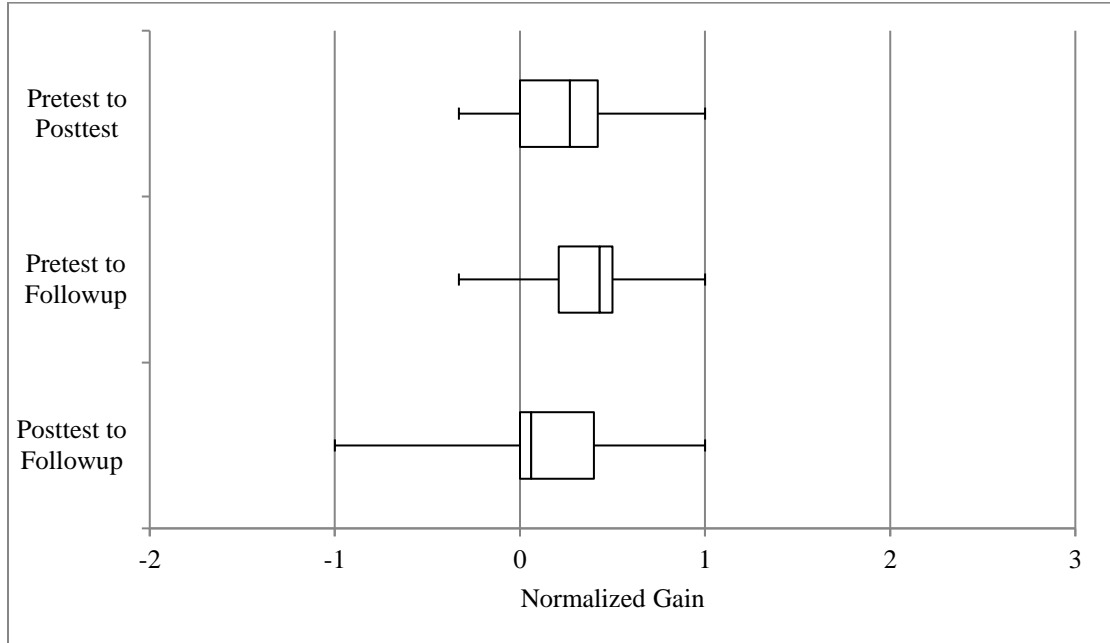
*Figure 5.* Comparison of movement in the sky misconception probe normalized gains, ( $N=22$ ).

The Seasons Misconception Probes, administered during the structured inquiry unit on the seasons, showed a mean normalized gain from the Pretest to Posttest of .19. The normalized gain from the Pretest to Followup Test was .31. Thirteen students showed positive gains between the Posttest and the Followup Test, five students showed no change, and six students showed negative gains (Figure 6).



*Figure 6.* Comparison of seasons misconception probe normalized gains, ( $N=22$ ).

On the Light Misconception Probes, administered during the 5e guided inquiry unit on light, the normalized gains from the Pretest to the Posttest was .25 and the Pretest to Followup Test was .38. Eleven students showed positive gains from the Posttest to the Pretest, six students showed no change, and five students showed negative gains. The mean normalized gain from Posttest to Followup Test was .13 (Figure 7).



*Figure 7.* Comparison of light misconception probe normalized gains, ( $N=22$ ).

The Sound Misconception Probes, administered during the open inquiry unit on sound, indicated that the mean average normalized gain from Pretest to Posttest was .23 and the mean normalized gain from Pretest to Followup Test was also .23. Although the mean normalized gain from Posttest to Followup Test was .01, only four students showed no change. Ten students showed positive gains and eight students showed negative gains (Figure 8).

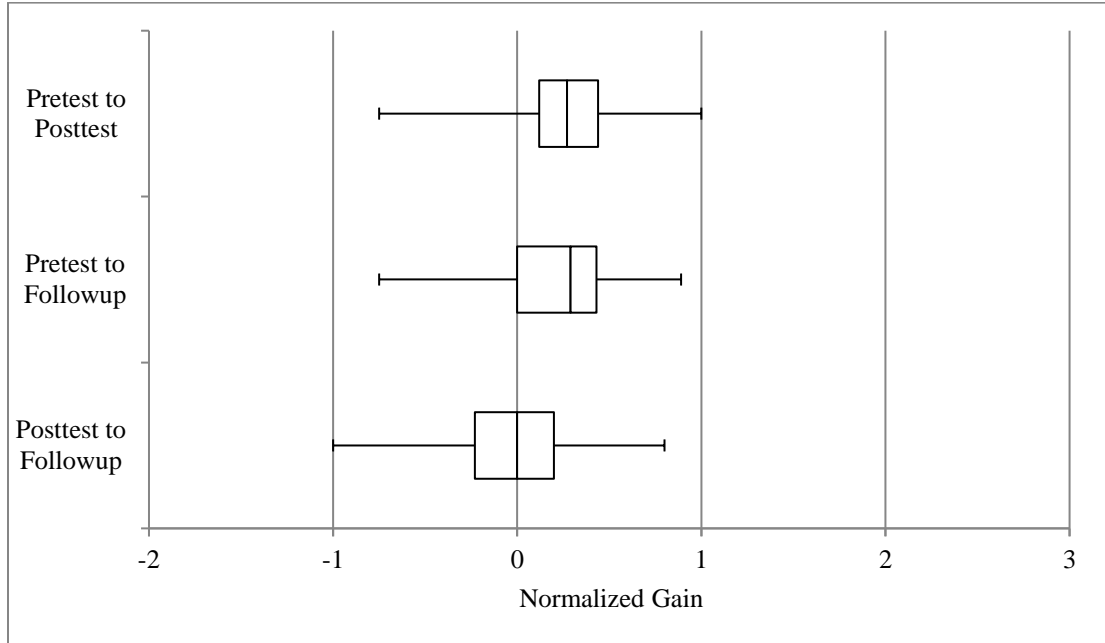


Figure 8. Comparison of sound misconception probe normalized gains, ( $N=22$ ).

The demonstrated inquiry unit, *Movement in the Sky*, was effective at repairing certain misconceptions. Some concepts, such as when we can see the sun, moon, or stars in the sky showed almost no improvement. Although some students knew the correct answer, they showed some major misconceptions in their reasoning. One student correctly stated that we can only see the sun during the day, but her reasoning was incorrect. She stated, “We can see the sun only during the day, because the moon is behind it.” This student correctly indicated on the Pretest that the sun can only be seen during the day with a confidence rating of very sure. On the Posttest she incorrectly indicated that the sun can be seen during both the day and night with confidence scores of somewhat sure on the Posttest and very sure on the Followup Test. Another student stated that you can see the moon in the daylight but also included, “The sun is behind the moon and it is sleeping.” She correctly indicated that the moon can be seen at both day and night with a very sure confidence rating on the Pretest, Posttest, and Followup Test.

Another student incorrectly indicated that the moon can only be seen at night on the Pretest, that it can be seen at both night and day on the Posttest, and then that it can only be seen at night on the Followup Test. During the interview, conducted about an hour after the Posttest where she said that the moon can be seen at both day and night, the student stated, “The moon can only be seen at night because I saw it when I woke up at midnight” (Figure 9).

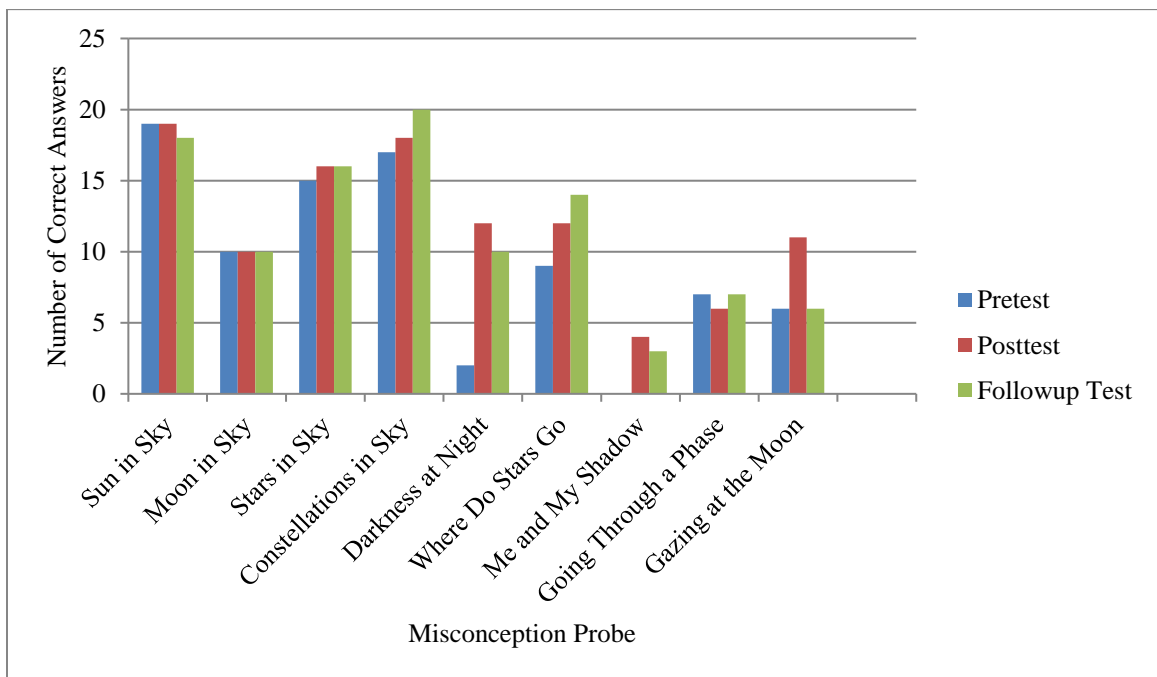


Figure 9. Comparison of movement in the sky misconception probe answers, ( $N=22$ ).

The Darkness at Night Misconception Probe, administered during the demonstrated inquiry unit Movement in the Sky, indicated that the most popular response on the Pretest was that the sun moves around the Earth once per day. As a class average, this misconception was corrected to the Earth spins around once per day as the most popular response on the Posttest and Followup Test. During the class discussion one student stated, “At night the clouds block the sun and the sun shines on the other side,”

after indicating the clouds block the sun with a somewhat sure confidence rating on the Misconception Probe. He correctly indicated that it is dark at night because the Earth spins once per day with very sure confidence ratings on the Posttest and Followup Test. Another student who incorrectly indicated that the sun goes around the Earth once per day with a very sure confidence rating defended her answer by stating, “God made the world and he has power to make it rain, dark, and other stuff.” After correctly indicating on the Posttest that it is night because the Earth spins, she stated, “The Earth rotates one time a day. If it is night here then it is morning elsewhere. I know because you showed us the paper moon and the moon shapes.” On the Followup Test she incorrectly indicated that the Earth goes around the sun once per day. The misconceptions that the Earth moves around the sun once per day and the clouds cover the sun had higher rates of response on the Posttest and Followup Test than on the Pretest (Figure 10).

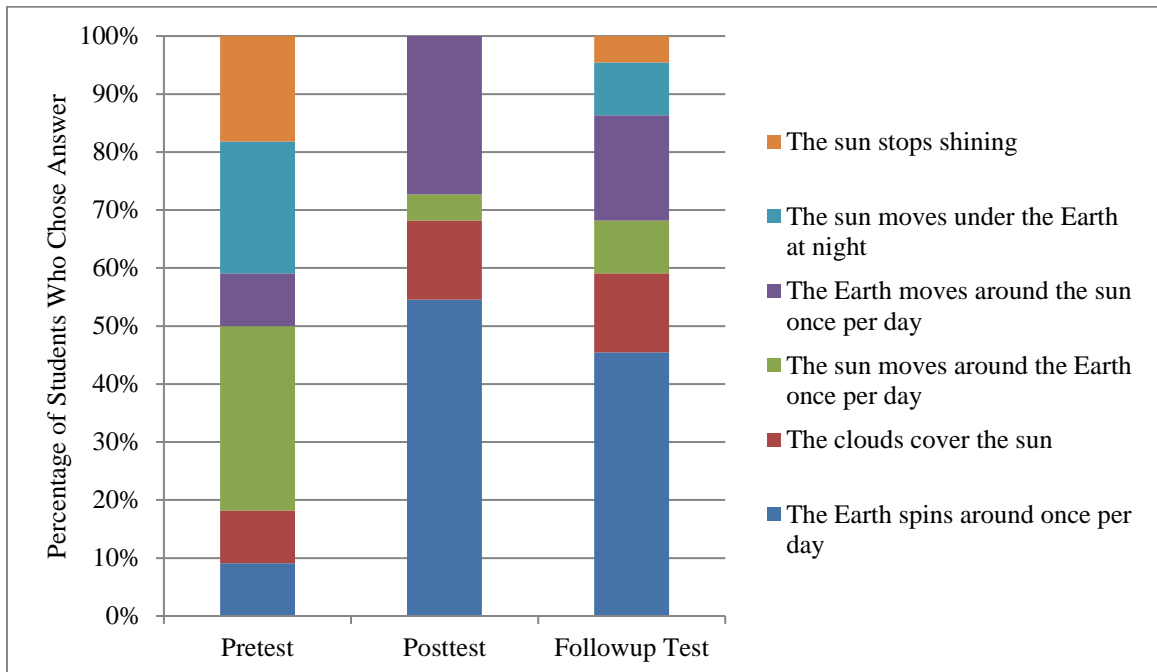


Figure 10. Comparison of answers on darkness at night, ( $N=22$ ).

On the Me and My Shadow Misconception Probe, administered during the demonstrated inquiry unit Movement in the Sky, no students correctly indicated that shadows get longer then shorter throughout the course of a day. The most common response on the Pretest was that shadows will stay the same and all three students who gave answers during the class discussion incorrectly indicated that shadows would stay the same. The most common response on the Posttest and Followup Test were that a shadow gets longer until it reaches its longest, then it starts getting shorter. In the Misconception Interview, administered after the Posttest but before the Pretest, one student stated that, “(My shadow) will get long until it’s longest, then shorter because I have seen my shadow.” Another student stated, “It will get longer and then shorter because the higher sun points down and makes a shadow longer.” Both of these students incorrectly indicated on the Pretest that their shadow would stay the same with confidence ratings of not sure, and somewhat sure. Both students incorrectly indicated that their shadows would get longer then shorter on the Posttest with a very sure confidence rating and that their shadows would get longer then shorter on the Followup Test with somewhat sure confidence ratings (Figure 11).

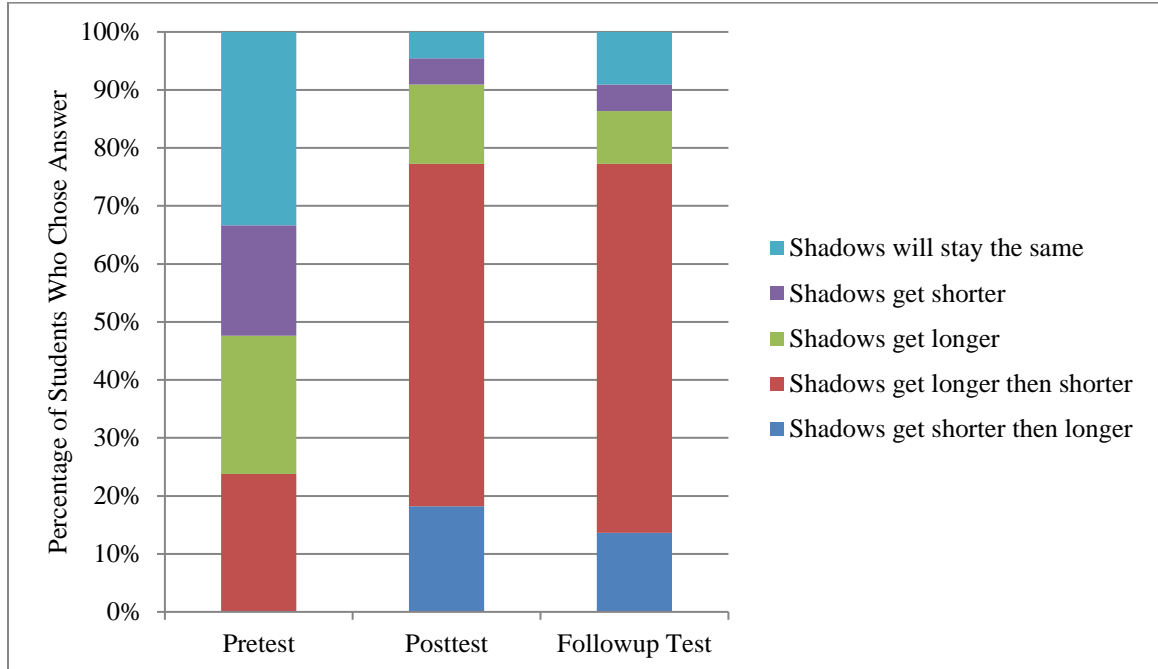


Figure 11. Comparison of answers on me and my shadow, ( $N=22$ ).

On the Gazing at the Moon Misconception Probe, administered during the demonstrated inquiry unit Movement in the Sky, the most popular answer on the Pretest, Posttest, and Followup Test was correct in that a person in another hemisphere would also see the same moon. Of the six students who answered correctly on the Pretest, only two students answered correctly on the Posttest, and neither of those two answered correctly on the Followup Test. Overall 15 out of 22 students answered correctly at least once, six students answered correctly twice, and no student answered correctly all three times. One student, who correctly indicated on the Pretest with a not sure confidence rating and on the Posttest with a very sure confidence rating that they would both see a full moon, correctly stated during the Misconception Interview that, “See the same moon, because it is not different.” This student incorrectly indicated on the Followup Test that one would see a half moon with a very sure confidence rating (Figure 12).

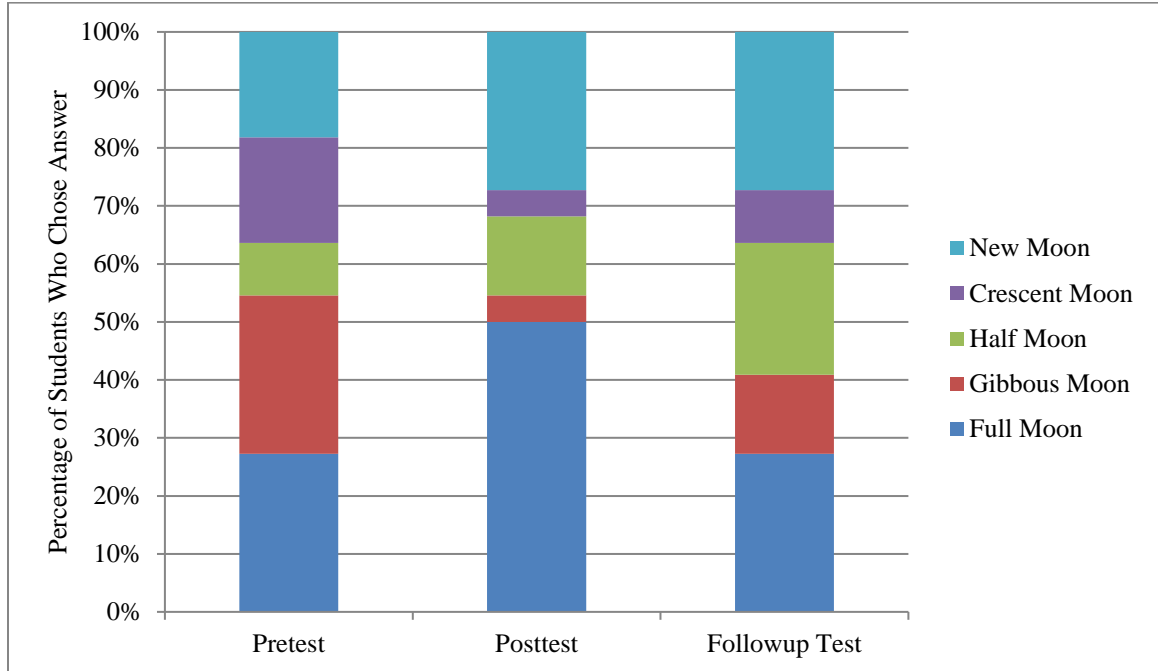


Figure 12. Comparison of answers on gazing at the moon, ( $N=22$ ).

The Seasons Misconception Probes, administered during the structured inquiry unit on the seasons, showed that the treatment increased the amount of students who were able to choose the correct concept on many of the questions. The Followup Test scores were higher for most of the questions. The Sun's Angle, Sunrise Direction, and The Earth's Tilt all increased from very few students choosing the correct answer, to over half of the class being able to choose it by the Followup Test. On the Pretest most students incorrectly indicated that they thought that the sun rises in the East and sets in the West. During the class discussion on Sunrise Direction students said, "(The sun and moon) rise in East and set in the West. East is opposite of West. The sun and moon rise in the same direction." The other student who volunteered an answer agreed with her. When asked for clarification, both students said that the sun rises in the same place every day. During

the Misconception Interview a student said, “(They rise) not in the same place, it moves like 1 inch. I know from the video on sunrise and sunset,” (Figure 13).

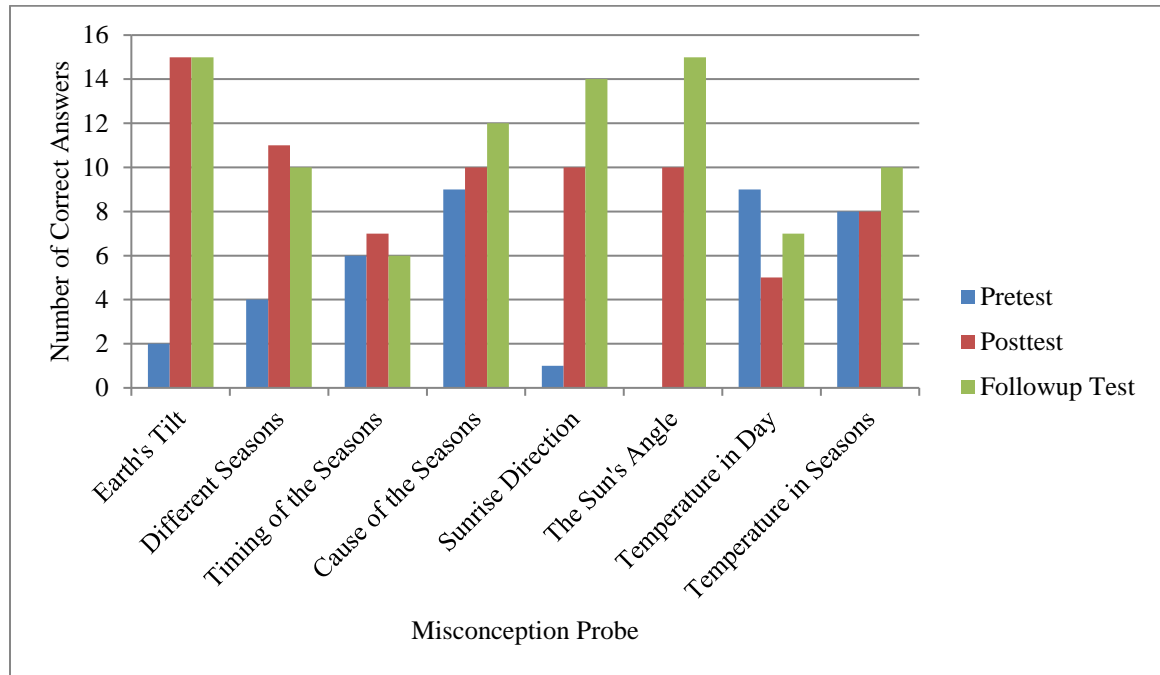


Figure 13. Comparison of seasons misconception probe answers, ( $N=22$ ).

On Pretest administration of Earth's Tilt Misconception Probe, administered during the structured inquiry unit on the cause of the seasons, two students correctly indicated that the Earth is tilted a small amount, with the other answers evenly distributed. During the class discussion two out of the five students who responded indicated that they thought the Earth was tilted a little. One student who answered that the Earth rotates straight up and down on the Pretest said that he, “had a feeling,” when he correctly explained the Earth's tilt during the class discussion. He incorrectly indicated that the Earth wobbles like a top on the Posttest and correctly indicated the Earth's tilt on the Followup Test. Another student, who answered correctly all three times, used the process of elimination during the class discussion. Her confidence score on the Pretest

was not sure, which increased to very sure on the Posttest, decreased back to not sure on the Followup Test. On the Posttest and Followup Test, most students chose the correct answer. In the interviews conducted after the misconception probe, one student who incorrectly chose the Earth wobbles like a top on the Pretest, Posttest, and Followup Test, indicated that he knows the Earth is tilted a little because, “My dad told me.” His confidence score started as somewhat sure on the Pretest and decreased to not sure on the Posttest, but it increased to very sure on the Followup Test (Figure 14).

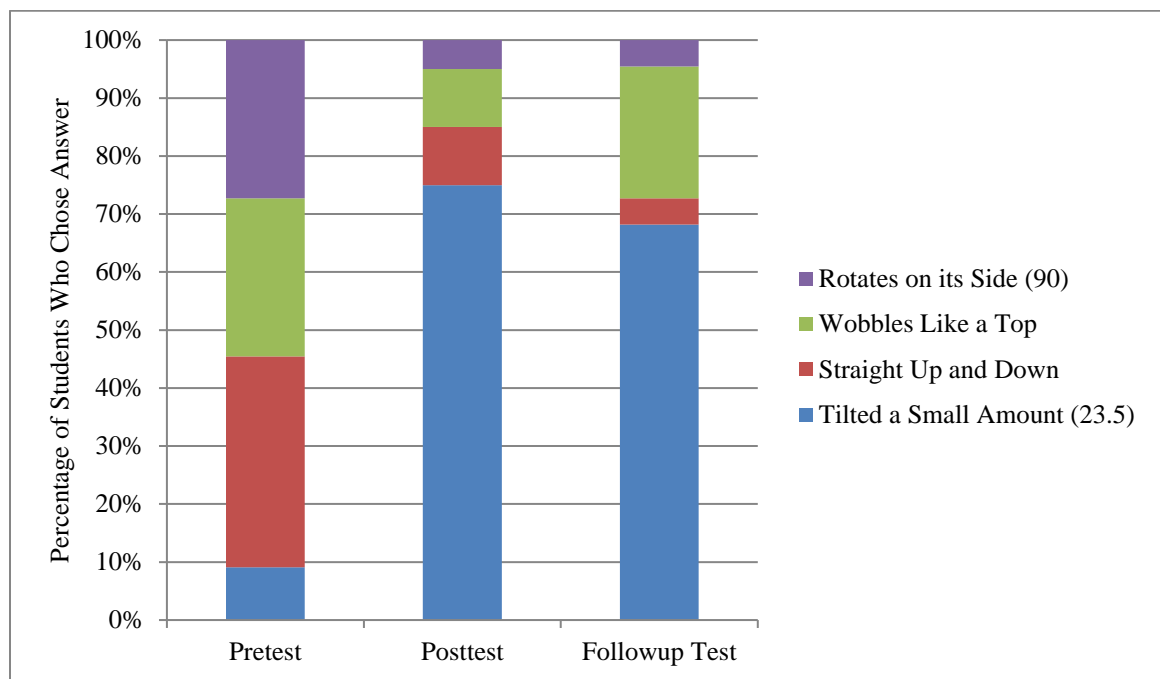


Figure 14. Comparison of answers on Earth’s tilt, (N=22).

The number of students who chose the correct response on Different Seasons, administered during the structured inquiry unit Seasons, increased from the Pretest to the Posttest and slightly decreased to the Followup Test. The misconception that every place has the same seasons was the most popular response on the Pretest and five students defended it. They mostly said it was because that was, “fair.” The number of students

who chose it decreased for the Posttest and Followup Test. The misconception that some places only have summer and winter increased over time. During the class discussion, a student, who incorrectly responded that it is always winter in the Arctic and Antarctic, said, “It’s always winter in the arctic, because how else would animals survive?” She incorrectly indicated the same thing on the Posttest but she chose the correct answer on the Followup Test. Another student who incorrectly indicated that all places have the same seasons on the Pretest said, “Tropics have wet season and a dry season, the others have normal seasons. I have a feeling I know.” Then, on the Posttest he responded correctly. On the Misconception Interview, he said, “(There are) four seasons, but Antarctica has no summer,” then incorrectly chose that some places only have summer and winter on the Followup Test (Figure 15).

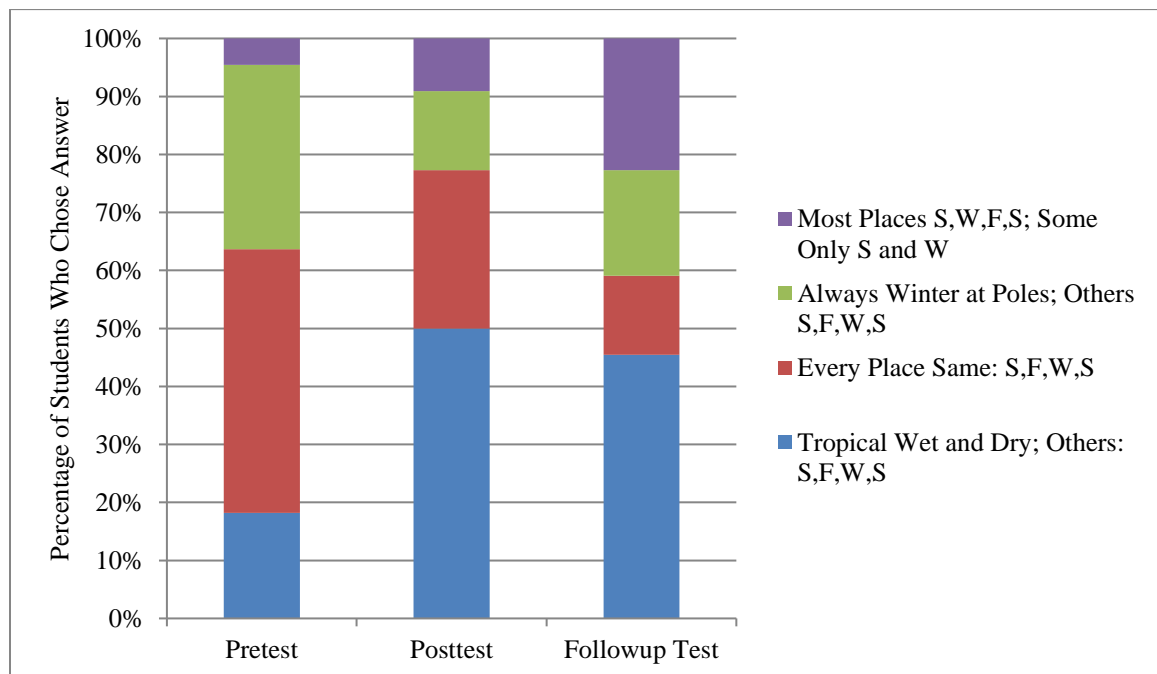


Figure 15. Comparison of answers on different seasons, (N=22).

On the Temperature in Day Misconception Probe, administered during the structured inquiry unit Seasons, the most common response was that midnight is the coldest time. During the class discussion one student said, “Midnight (is the coldest) because it is one of the only times when the sun isn’t out. Another student said, “Midnight (is the coldest) because it feels cold then.” The amount of students who chose the misconception that midnight is coldest was reduced on the Posttest from the Pretest, but the Followup Test had the highest rate of response. During the Misconception Interview a student said, “Middle of the night (is coldest). I learned from the teacher!” (Figure 16).

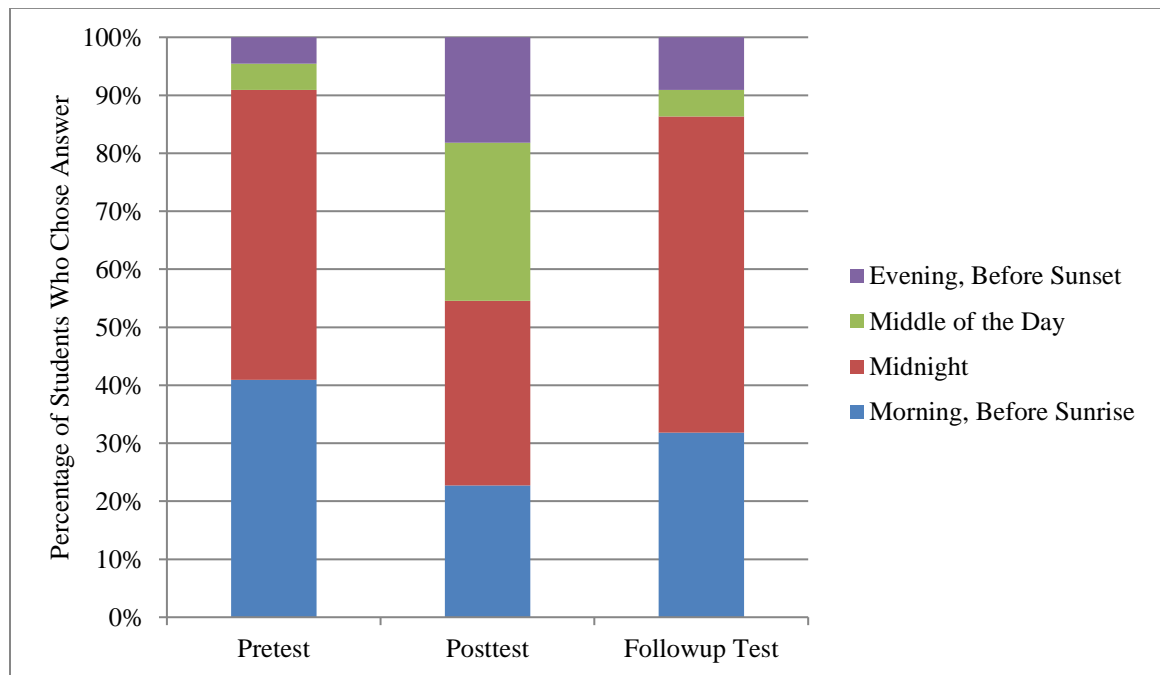


Figure 16. Comparison of answers on temperature in day, ( $N=22$ ).

On the Light Misconception Probes, administered during the 5e guided inquiry on light, the number of students who chose the correct answer increased from the Pretest to the Posttest and Followup Test except for Paper Window. During the class discussion

about paper window, students used the explanation of transparent in their answers, including, “You can see the light in the window but you can’t see the details,” and “Light (is) coming through paper but no details,” (Figure 17).

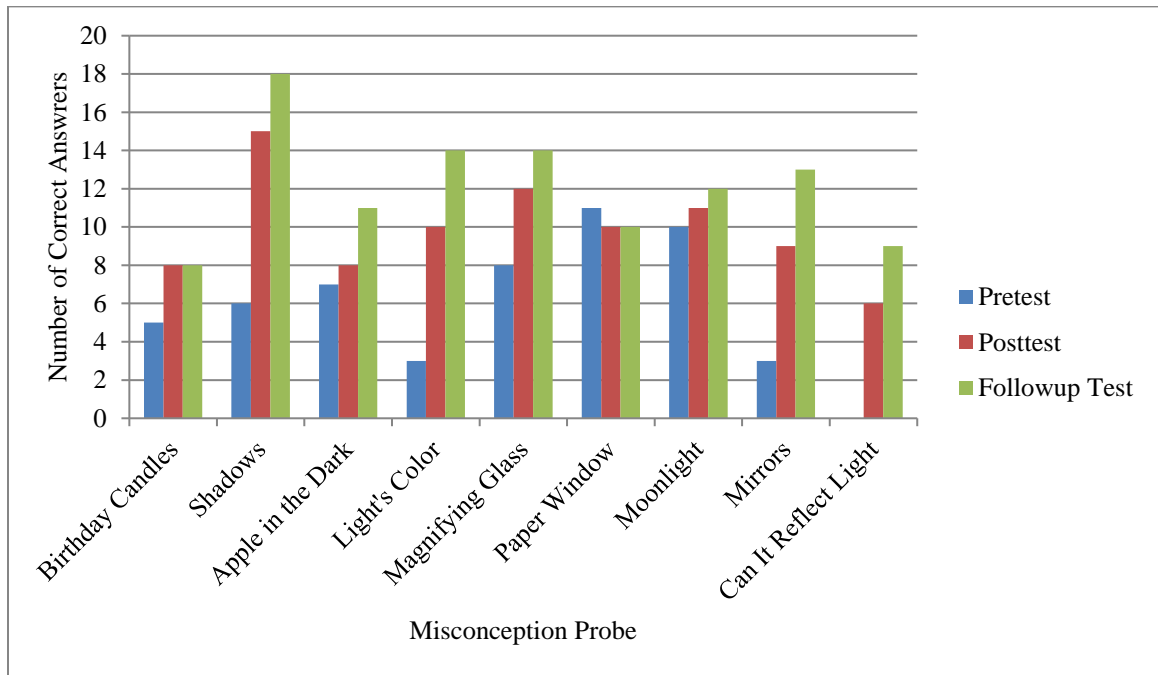


Figure 17. Comparison of light misconception probe answers, ( $N=22$ ).

On the Birthday Candles Misconception Probe, administered during the 5e guided inquiry on light, the misconception that light stays on the flames increased from the Pretest to the Posttest and Followup Test. One student, who incorrectly indicated on the Pretest that the light travels one meter, said, “Not at all, if the light travels the wind will blow it out.” He then incorrectly chose that the light will only travel a few centimeters on the Posttest and Followup Test. Another student, who incorrectly chose the light will travel a few centimeters on the Pretest, said, “If it goes all the way it would pass people.” She correctly chose on the Posttest that light would travel all the way with a somewhat

sure confidence rating, but on the Followup Test she incorrectly chose that the light would stay on the candle flames (Figure 18).

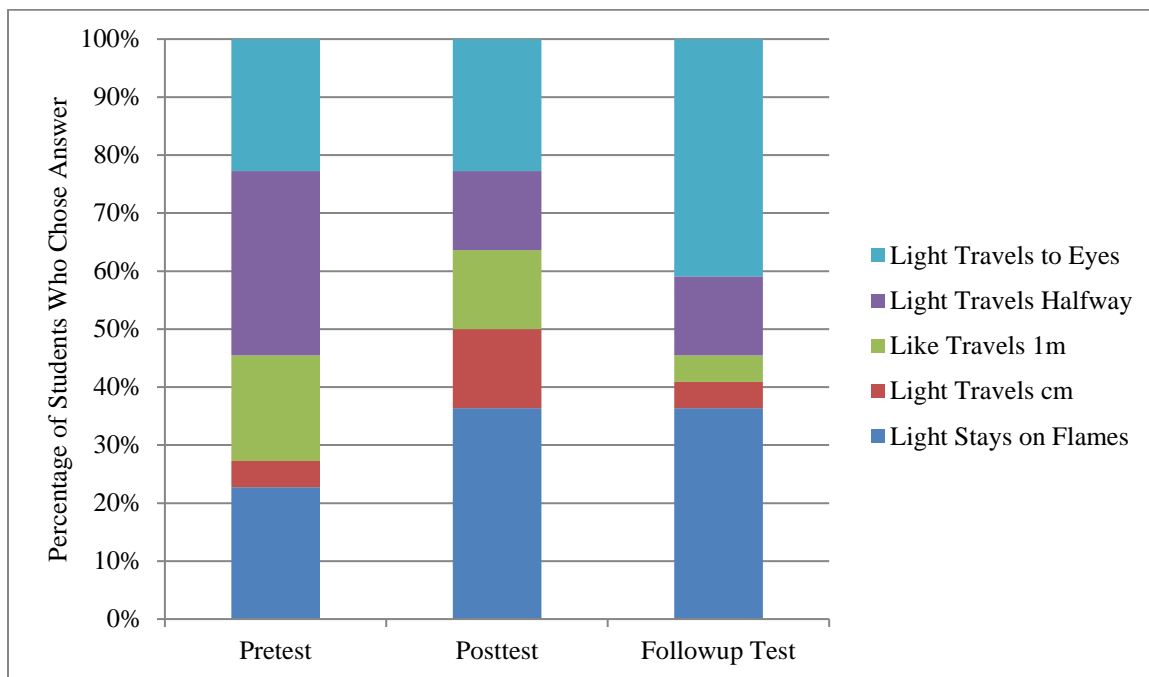


Figure 18. Comparison of answers on birthday candles, ( $N=22$ ).

On the Light's Color Misconception Probe, administered during the 5e guided inquiry on light, the most common misconception was the white light has no color unless filtered. One student who incorrectly responded on the Pretest that white light is pure and has no color with a somewhat sure confidence rating said, "The filter will add red to the light." Another student who correctly indicated on the Pretest that the red filter removes all other colors with a very sure confidence rating, said, "When you have a white light bulb and you add red to it, it will look red but still be white." Both students responded correctly on the Posttest and Followup Test. As a class-wide trend, the misconception was replaced by the correct concept that a red filter removes every color except red when placed over a white light (Figure 19).

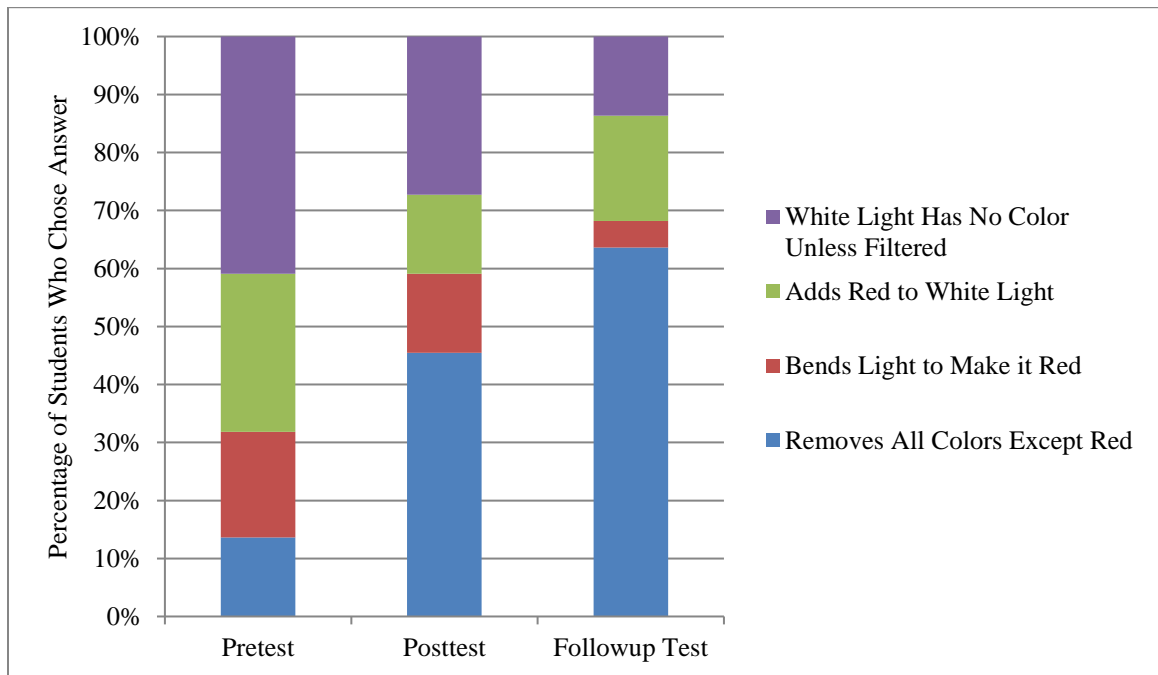


Figure 19. Comparison of answers on light's color, ( $N=22$ ).

On the Can It Reflect Light Misconception Probe, administered during the 5e guided inquiry on light, students were scored correct only if they indicated that every object was able to reflect light. One student who responded that only some were able to reflect light with a very sure confidence rating on the Pretest and that all were able to reflect light with a very sure confidence rating on the Posttest said, "Everything you see can reflect light! I learned from school," On the Followup Test she correctly indicated that all objects could reflect light, but her confidence rating decreased to somewhat sure (Figure 20).

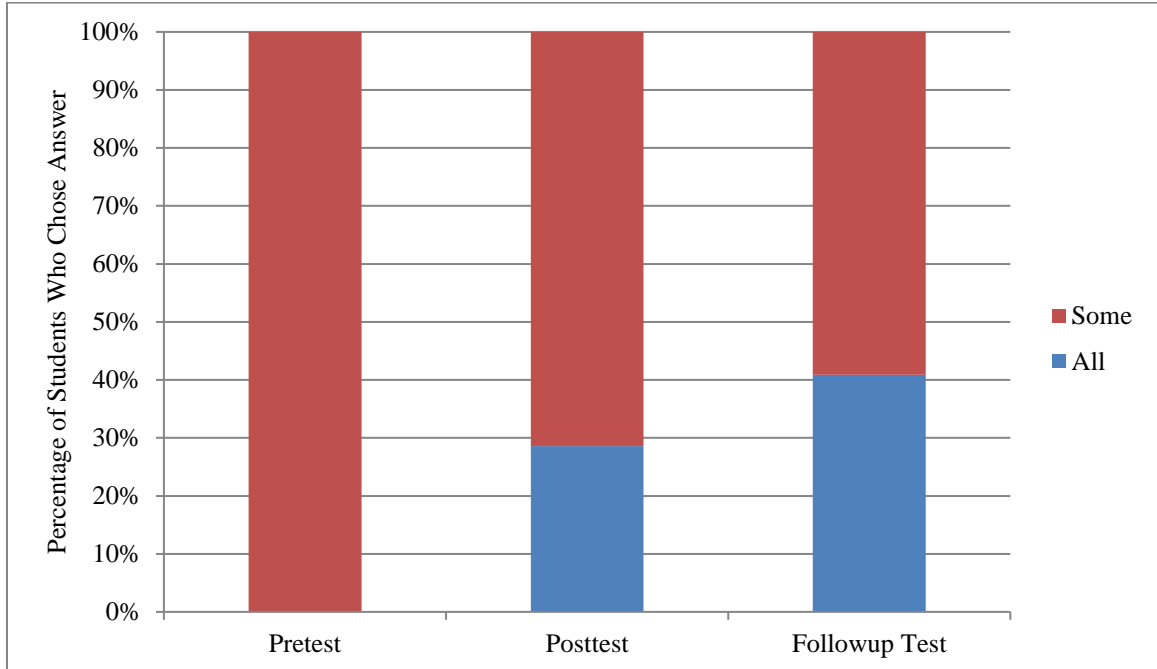


Figure 20. Comparison of answers on can it reflect light, ( $N=22$ ).

On the Sound Misconception Probes, administered during the open inquiry unit on sound, five questions had higher Posttest scores than Pretest scores and higher Followup Test scores than Posttest scores. Tuning Fork and Making Sound had higher Posttest scores than Pretest scores, but it had lower Followup Test scores than Posttest scores. Hitting Bell's Posttest score was lower than the Pretest or the Followup Test. In the class discussion, most students said that the bell would be louder the second time, but only one of these students correctly chose louder on the Hitting Bell Misconception Probe. None of these students correctly chose louder on the Posttest, and only one correctly chose louder on the Followup Test. The class discussion demonstrated other misconceptions, such as every student incorrectly said that the noise of the firetruck changes because the driver or truck intentionally changes the sound (Figure 21).

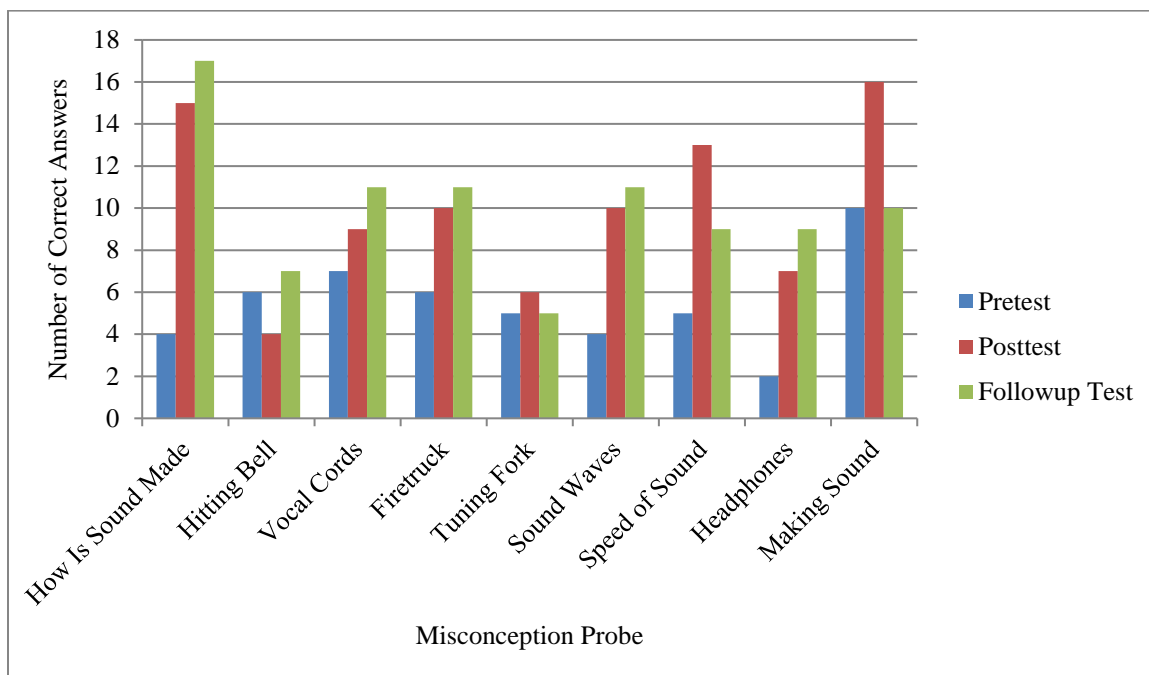


Figure 21. Comparison of sound misconception probe answers, ( $N=22$ ).

On the Tuning Fork Misconception Probe, administered during the open inquiry unit on sound, the incorrect answers on the Pretest were almost even. In the class discussion one student said, “(It) gets higher as the tuning fork speeds up because it starts low.” This student incorrectly answered with somewhat sure confidence ratings that the pitch depends on how hard you hit it on the Pretest, the pitch decreases as it slows down on the Posttest, and that the pitch increases as it speeds up on the Followup Test. Another four students agreed with this student that the pitch would get lower. The number of students who said that the pitch would get lower decreased from the Pretest to the Posttest, but then it increased to become the largest response on the Followup Test (Figure 22).

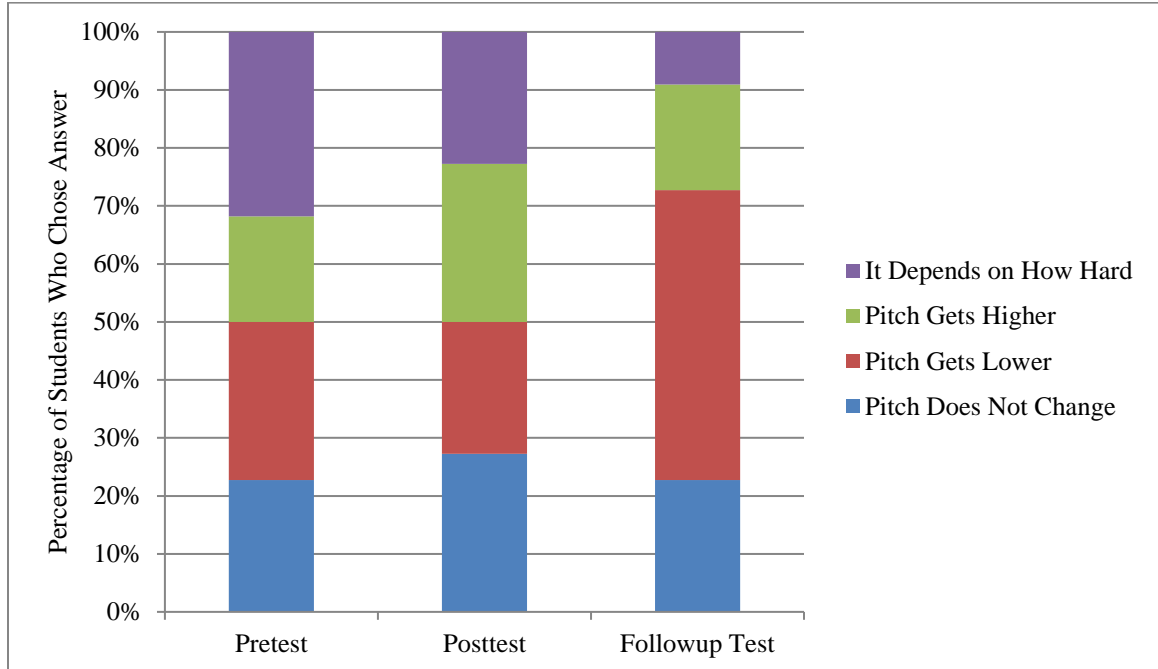


Figure 22. Comparison of answers on tuning fork, ( $N=22$ ).

On the Sound Waves Misconception Probe, administered during the open inquiry on sound, the number of students who correctly indicated that sound waves travel faster through solids than air increased slightly from the Pretest to the Posttest, then it decreased back to the same as the Pretest on the Posttest. The biggest misconception on the Pretest was that sound waves travel faster through air than solids or liquids. During the class discussion one student who incorrectly indicated that sound waves cannot travel through solids or liquids with a not sure confidence rating said, “Sound waves travel faster through air because waves are just liquid and cannot go through things.” She responded correctly on the Posttest with a little sure confidence rating on the Posttest, but she incorrectly responded that sound waves move faster through air on the Posttest with a somewhat sure confidence rating. Another student who incorrectly indicated on the Pretest that sound waves travel faster through air with a very sure confidence rating said,

“(Sound waves travel faster through) air but not solids or liquids, because I tried to talk underwater but people can’t hear me.” He responded correctly on the Posttest and the Followup Test (Figure 23).

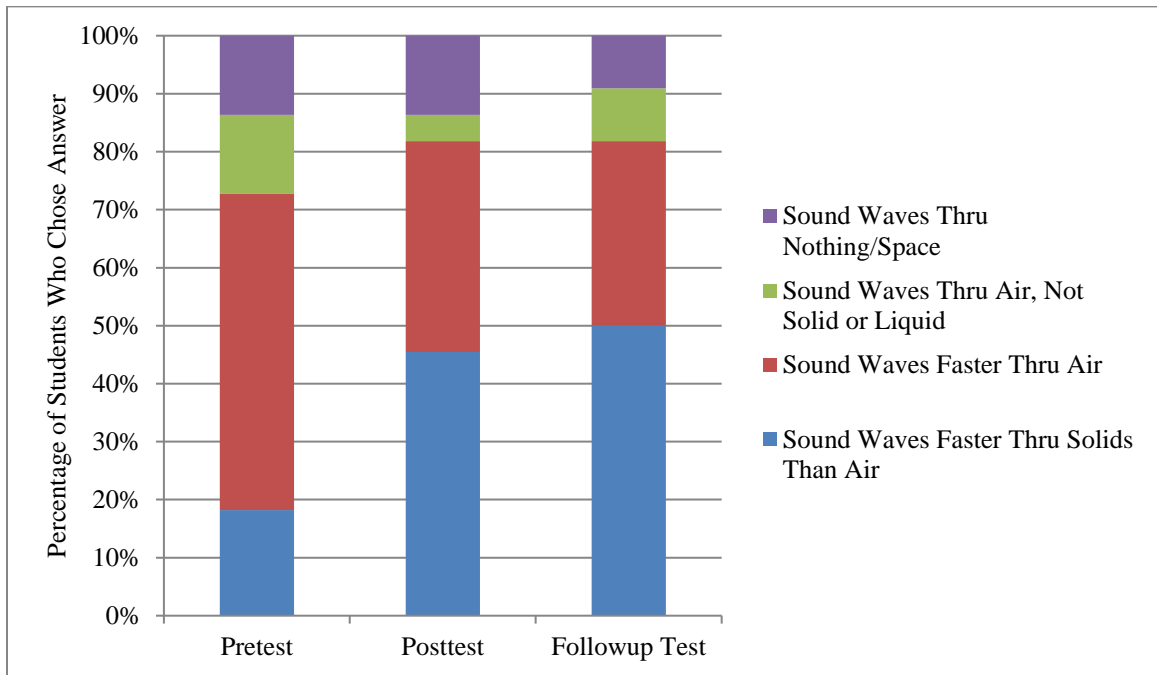


Figure 23. Comparison of answers on sound waves, ( $N=22$ ).

On the Making Sound Misconception Probe, administered during the open inquiry on sound, students were scored correct only if they indicated that every object was able to make sound. The number of students who correctly indicated that all of the objects were able to make sound increased from the Pretest to the Posttest, but went back to the Pretest number on the Followup Test (Figure 24).

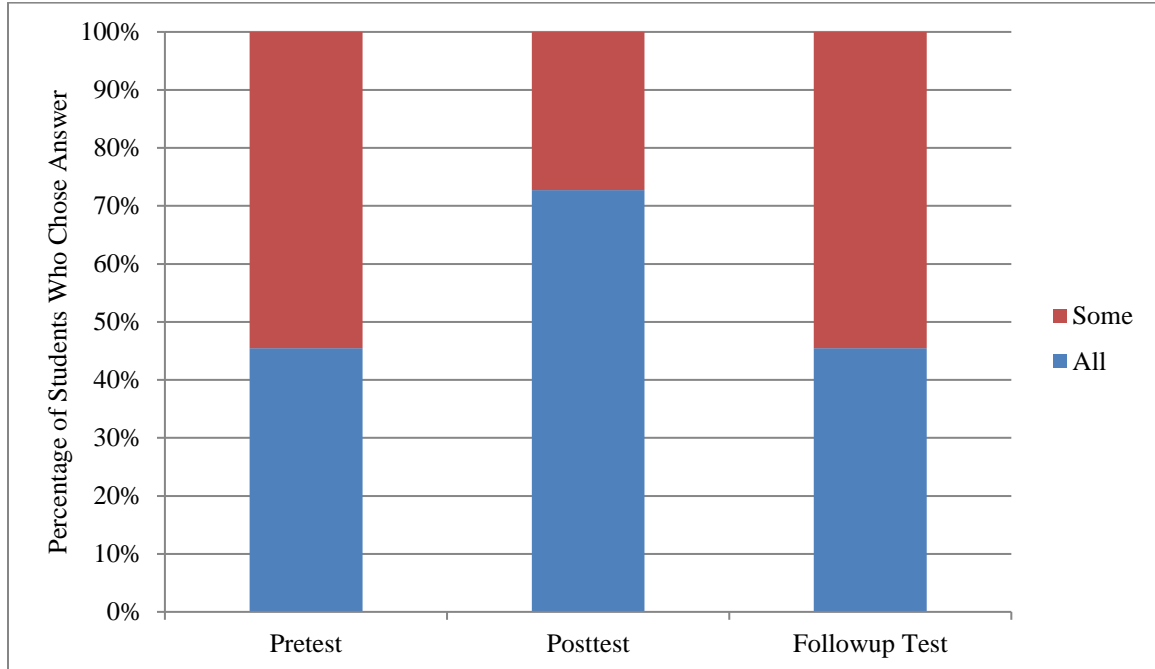


Figure 24. Comparison of answers on making sound, ( $N=22$ ).

Each student had a wide range of scores. I arranged students by their mean score on the misconception probes, in ascending order. Six students showed large amounts of growth in three of the units, defined as a growth of five or more points from the Pretest to the Posttest or Followup Test. No student made a growth of five points or greater in the Movement in the Sky unit, although it also had the highest Pretest scores. Two students, labeled as I and R, showed large growth over the Seasons unit, taught through demonstrated inquiry. One of the student's, labeled as I, score dropped to the Posttest, but it was still a difference of five. Two different students, labeled as Q and T, showed large growth in the light unit, taught through 5e guided inquiry. One of these students, labeled as Q, made as much growth from the Posttest to the Followup Test as she did from the Pretest to the Posttest. The other student, labeled as T, showed a growth of five from the Pretest to the Posttest, but he got one less correct on the Followup Test than the Posttest.

One student, labeled as L, showed a large growth in both the light unit taught through 5e guided inquiry and the sound unit taught through open inquiry. He made as much, or more, growth from the Posttests to the Followup Tests as he did from the Pretests to the Posttests. One student, labeled V, showed large gains in only the open inquiry unit on sound. Her score dropped one point from the Posttest to the Followup Test (Figure 25).

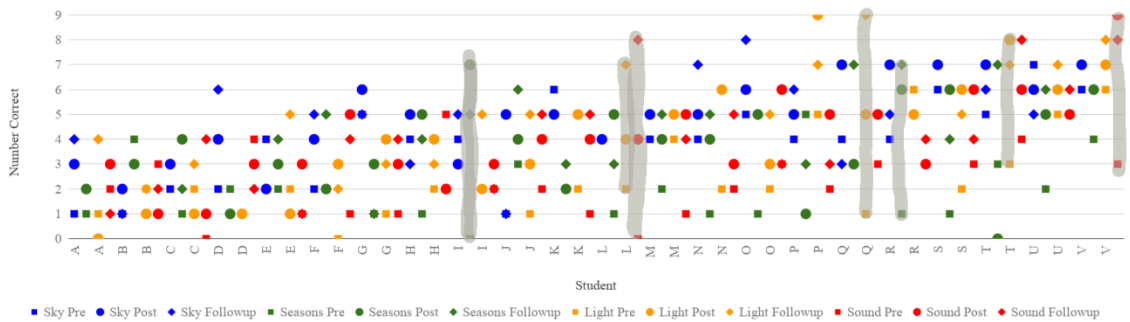


Figure 25. Comparison of student scores throughout units, ( $N=22$ ).

Engagement was measured by the Daily Survey on Fun and Control of Learning (Appendix J) administered at the end of the lessons ( $N=416$ ). The range between units for very fun was 16%. The range for kind of fun was 12%. The range for A Little Fun was six percent. The range for Not fun was ten percent. In general, the fourth unit taught through open inquiry had the highest rating of very fun, followed closely by the third unit which was taught through 5E guided inquiry. According to the survey, the most fun lessons were March 5<sup>th</sup> watching The Magic School Bus on Light, March 20<sup>th</sup> watching The Magic School Bus on Sound, and March 22<sup>nd</sup>, watching videos to demonstrate the difference between the speed of light and the speed of sound. The least fun lesson was February 13<sup>th</sup>, which included analyzing the bar graphs. On the Misconception Interviews, students named many different parts of the units, with no real theme. One student said that, “I liked all of it but I liked figuring out how the seasons worked best,”

then said, “(Analyzing graphs were) the hardest because we had to use our brains and all the knowledge we know,” (Figure 26).

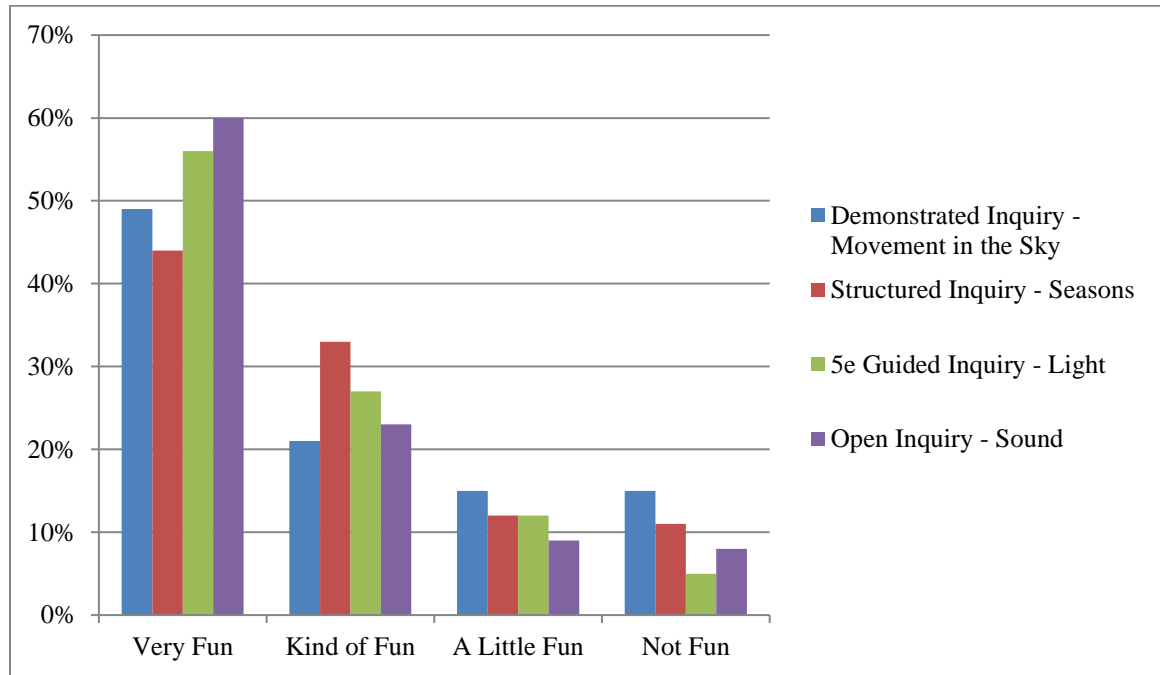


Figure 26. Comparison of answers indicating student perception of fun, ( $N=416$ ).

Control of learning was measured by the Daily Survey on Fun and Control of Learning (Appendix J) administered at the end of the lessons. The range between units for Students Controlled All was 9%. The range for Students Controlled Most was 11%. The range for Teacher Controlled Most was 24%. The range for Teacher Controlled All was 22%. In general, the first unit taught through demonstrated inquiry had the highest rating of Students Controlled All at 12%, and the fourth unit, taught through open inquiry had the lowest rating of Students Controlled All at three percent. In the first unit, taught through demonstrated inquiry, about half of responses indicated that students perceived the Teacher Controlled Most. In the other three units, about half of responses indicated that the Teacher Controlled All. The students indicated that they had the most control on

the first two lessons on January 16<sup>th</sup> and 18<sup>th</sup>, which were two of the lessons I felt that they had the least control over. The lesson with the next highest rating of student control was March 19<sup>th</sup>, inquiry-based stations based upon student questions. The students felt they had the least control on lessons that included watching *The Magic School Bus* and watching videos on the difference between the speed of light and the speed of sound (Figure 27).

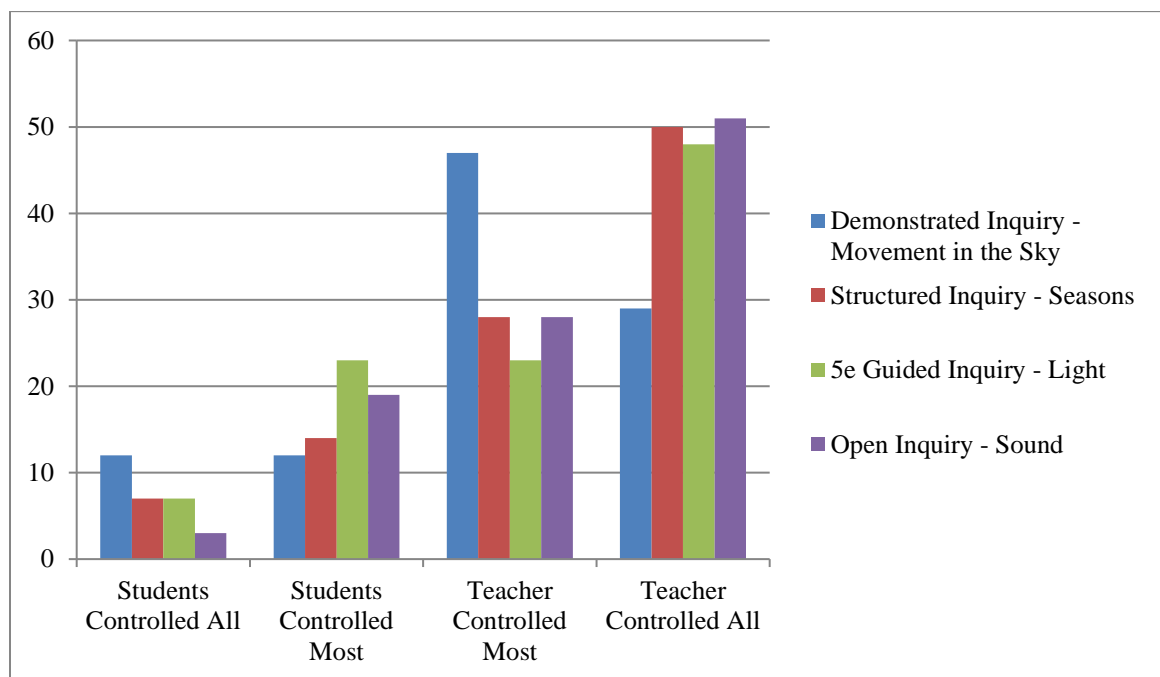


Figure 27. Comparison of answers indicating student perception of control of learning, (N=416).

A one way chi square test for independence was run on the daily averages for the Survey of Fun and Control of Learning to determine if there is a correlation between perceived fun and control of learning. Very Fun was coded as four, Kind of Fun was coded as three, A Little Fun was coded as two, and Not Fun was coded as one. Students Controlled All was coded as four, Students Controlled Most was coded as three, Teacher Controlled Most was coded as two, and Teacher Controlled All was coded as one. The

chi square, with 20 degrees of freedom, calculated a p value of 1, indicating no relationship between perceived fun and control of learning.

### INTERPRETATION AND CONCLUSION

The four inquiry-based units, which were created around the conceptual change process, were effective at repairing some, but not all of the misconceptions targeted misconceptions. Some students demonstrated through statements that they had serious misconceptions, even when the students had chosen the correct response on the misconception probes. As previously found with university students, the inquiry-based units reinforced some misconceptions and created or raised student confidence levels in other misconceptions (Adam, Self, Wildmann, Coburn, & Saoud, 2015). Identifying, challenging, and hopefully repairing misconceptions continues to be an important part of planning any science unit.

Some students reverted back to their misconceptions at the one month Followup Test. This is consistent with previous findings that many students retain or revert back to their previously held misconceptions (Eryilmaz, 2002; Stepans, 2006). Many other students solidified their understanding and chose correct answers on the one month Followup Test after choosing an incorrect answer on the Posttest. In the future, teachers may benefit from reassessing students after a unit has been completed to see what growth the students have made, and if there are misconceptions that need to be readdressed.

Each of the units showed growth for some students, with certain students making much more growth in a unit than in others. Overall student achievement and normalized gains indicated that the units were less effective than I had hoped. Some concepts showed

little or no improvement in understanding from the treatment. This is consistent with findings that inquiry is not effective with learners have less prior knowledge (Kirschner, Sweller, & Clark, 2006). It is difficult to determine how much of the ineffectiveness was due to inquiry not being suitable for young learners because there was no control group. The ineffectiveness could also be due to my unit plans. The first unit was originally planned around students creating and using sundials to tell the time. The lesson, which revolved around observing objects in the sky, was taught in January and every day was overcast. In the future, I will need to time lessons with their related natural phenomena.

Students reported that all types of inquiry-based instruction were considered fun, which means that they should have been engaged. This is consistent with what Blomquist (2013) found with her first grade class. Open inquiry was found to be more fun for the students than the other instructional methods, which would indicate that it is more engaging to students. Students reported the highest level of control of learning at the beginning of the first unit and again in fourth unit, which was taught through open inquiry. According to my analysis, perceived fun was not connected to perceived control over learning.

## VALUE

I will continue to research misconceptions before the start of each unit, including creating misconception probes if none exist, although the practice of identifying potential misconceptions from multiple sources can be quite exhausting. I also enjoyed creating all of the units for the classroom research project. This process of identifying misconceptions and weaving them into each unit helped me to understand what concepts

needed to be focused on. Encouraging students to contribute in group discussions about phenomena to identify misconceptions proved difficult, as only a small fraction of the class would answer for any one of the questions. I also found that once certain students gave an answer, every other answer agreed with them, no matter how correct they were.

The 5E guided inquiry unit was the easiest for me to teach. The lower levels of inquiry demanded that I perform more to maintain the students' attention. Open inquiry was difficult to pace, as I could not plan lessons and activities ahead of time without student questions. In the near future I will integrate student questioning into units that follow the 5Es: engage, explore, explain, elaborate, and evaluate.

Before conducting this classroom research project, I had never noticed growth from a Posttest to a Followup Test where the content was not addressed. This could be an area of new research as I was also not able to find this phenomena explained anywhere in current research.

My next step in science education is to create or compile first grade NGSS aligned units, using easily sourced materials. My grade level partner approached me to meet several times over summer vacation to develop our first unit. Our goal is to help drive elementary teachers to teach to the NGSS standards without access to updated curriculum.

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APPENDICES

APPENDIX A  
IRB APPROVAL



**INSTITUTIONAL REVIEW BOARD**  
**For the Protection of Human Subjects**  
**FWA 0000165**

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 Cheryl Johnson  
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**MEMORANDUM**  
 .....

**TO:** Cameron Jones and John Graves  
**FROM:** Mark Quinn *Mark Quinn Chg*  
 Chair, Institutional Review Board for the Protection of Human Subjects

**DATE:** November 27, 2017

**RE:** "The Effectiveness of Inquiry-based Teaching Methods at Repairing Misconceptions in a First Grade Class"  
 [CJ112717-EX]

The above research, described in your submission of November 27, 2017, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

MOVEMENT IN THE SKY UNIT PLAN

Movement in the Sky  
January 8<sup>th</sup>, 2018 to January 25<sup>th</sup>, 2018  
Path of the Sun, Moon, and Stars

Standard:

NGSS-1-ESS1-1. Use observations of the sun, moon, and stars to describe patterns that can be predicted.

Type of Inquiry:

Demonstrated Inquiry: The teacher predetermines all research questions and guides the students through the process.

Guiding Question:

How can our observations of objects' patterns in the sky help us to make predictions about what the objects will do in the future?

S & E Practices:

Planning and carrying out investigations: Students carry out investigations of the sun and moon.

Make observations: Students observe media and models to draw conclusions and facilitate discussion.

Crosscutting Concepts:

Patterns: Students observe patterns in the sky to understand their causes.

Systems and System Models: Students use models of the planetary system and solar system.

Misconceptions:

The sun revolves around the Earth.

The sun and moon's sizes are significantly smaller than reality.

The Earth is larger than the sun.

The sun disappears at night.

The sun is directly overhead at noon.

The Earth's revolution around the sun causes night and day.

The moon's phase is caused by clouds blocking the light.

The moon's phase is caused by shadows.

Different countries see different phases of the moon in the same day.

The stars go away during the day.

The moon is only out at night.

Misconception Probes:

- Objects in the Sky
- Darkness at Night

- Where Do Stars Go
- Me and my Shadow
- Gazing at the Moon
- Going Through A Phase

Materials:

\*This is modified from original due to cloudy weather. Ideally this unit would have centered around creating sundials.

Computer with web browser

Computer program Stellarium

Projector/smartboard

Class set of computers

Globe

Lamp

Model moon scaled to size of globe (I used crumpled paper on a popsicle stick)

Moon phase model (<http://www.scienceteachingjunkie.com/2013/03/clearest-way-to-teach-moon-phases-ever.html>)

- cardboard, black paper, ping pong balls, black marker, nails

Circles traced on blacktop/asphalt/grass

Scale model of the solar system

Date / Conceptual Change Phase	Questions	Activities / Notes
1-8 Commit to Outcome	<p>Pretest</p> <p>What will we learn?</p> <p>What words do you need help understanding?</p>	<p>Students completed the misconception probes while sitting at tables with privacy folders. Each question was read aloud twice.</p> <p>How can our observations of objects' patterns in the sky help us to make predictions about what the objects will do in the future?</p> <p>Observation Object Pattern Predictions</p>
1-9 Expose Beliefs	<p>Review Answers</p> <p>Students defend thinking "Why do you think...?"</p>	<p>Misconception probe answers were displayed as pie charts of student responses. Students were asked to explain their thinking on a voluntary basis.</p>

<p>1-12 Confront Beliefs</p>	<p>How does the sun light up the Earth?</p> <p>What happens to the stars at night?</p>	<p>Use Google Earth to investigate how the sun illuminates the Earth.</p> <p>As a Followup Test question, students were asked where do the stars go when one side is lit/day. *You can show sunlight by navigating to view &gt; sun or clicking the icon with a sun and mountains.</p>
<p>1-16 Confront Beliefs</p>	<p>What types of patterns can we see in the sky over the course of a day?</p> <p>Observe the path of the sun and moon across the sky.</p> <p>Do the stars have a similar pattern to the sun and moon?</p> <p>How does the path of the sun change the size and shape of shadows?</p> <p>How do shadows change throughout the day?</p>	<p>Original lesson plan was to track the sun across the sky with a sundial, but weeks cloudy weather ruined this.</p> <p>Use Stellarium or other planetarium program to view the sun's path</p> <ul style="list-style-type: none"> <li>- Path of sun (day/night) (rise/set)</li> <li>- Where is the sun at night?</li> </ul> <p>View Youtube video of path of the sun: <a href="https://www.youtube.com/watch?v=UN2RDobXhbg">https://www.youtube.com/watch?v=UN2RDobXhbg</a></p> <p>Use Stellarium or other planetarium program to view the moon's path.</p> <ul style="list-style-type: none"> <li>- Where is the moon?</li> <li>- Can we see it during the day?</li> <li>- Is its path similar to the sun's?</li> </ul> <p><a href="https://www.youtube.com/watch?v=iQtMTWakKCs">https://www.youtube.com/watch?v=iQtMTWakKCs</a></p> <p>Stars rotate: <a href="https://www.youtube.com/watch?v=pGJKjXYgjzg">https://www.youtube.com/watch?v=pGJKjXYgjzg</a></p> <p>With trails: <a href="https://www.youtube.com/watch?v=tp6UkqIwVfk">https://www.youtube.com/watch?v=tp6UkqIwVfk</a></p> <p>Stabilized Version: <a href="https://gfycat.com/GiganticPitifulAoudad">https://gfycat.com/GiganticPitifulAoudad</a></p> <p><a href="https://www.youtube.com/watch?v=3B7KLstUZbI">https://www.youtube.com/watch?v=3B7KLstUZbI</a></p> <p>Students can go up and measure shadow on screen.</p>



		Students use the moon phase model to view the position of the moon during each moon phase.
1-24 Make Connections	How do people keep track of the sun and moon?  How can we model this in the classroom?  Can you show how big the sun, moon, and Earth are?	Connect to the calendar: A week is 1 phase of the moon. A month is 1 cycle of the moon. A day is 1 rotation of the Earth. A year is 1 revolution of the Earth. Vocab: rotate, revolve  Act out a day/week/month/year kinesthetically in the classroom. Act it out outside using circles on the blacktop. Students take turns as the moon or the Earth. Students draw a picture of the objects' size.
1-26 Go Beyond	How do the other planets move in comparison to the sun?  How can we make a scale model of the solar system?  Posttest  Interviews	Watch simulation of solar system. <a href="https://www.solarsystemscope.com">https://www.solarsystemscope.com</a>  Watch Magic School Bus Gets Lost in Space  Build a scale model of the solar system starting at your classroom. I used: <a href="http://www.exploratorium.edu/ronh/solar_system/">http://www.exploratorium.edu/ronh/solar_system/</a> with the sun at 100mm diameter. I drew objects on paper and laminated. This made the Earth just at the edge of the classroom and Saturn at the edge of campus. We used Google Maps to see how far away Uranus and Neptune are.  Administer misconception probes.  Conducted interviews with students during computer lab time.
2-26 Reassess	Followup Test	Re-administered misconception probes.

APPENDIX C

MOVEMENT IN THE SKY MISCONCEPTION PROBES

## Objects in the Sky

Different things can be seen in the sky.

Put a D next to the things that are seen *only* in the daylight.

Put an N next to the things that can be seen *only* at night.

Put a B next to the things that can be seen in both day and night.

\_\_\_ the Sun

\_\_\_ the Moon

\_\_\_ the next-nearest star to our Sun

\_\_\_ constellations



Explain your thinking. How did you decide when you could see different things in the sky?

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How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Darkness at Night

Six friends were wondering why the sky is dark at night. This is what they said:

Jeb: "The clouds come in at night and cover the Sun."

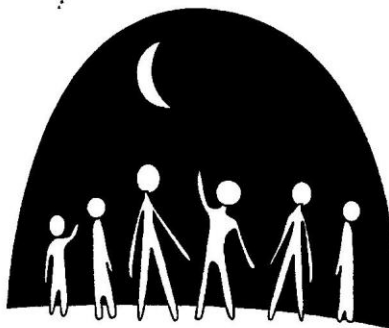
Talia: "The Earth spins completely around once a day."

Nick: "The Sun moves around the Earth once a day."

Becca: "The Earth moves around the Sun once a day."

Latisha: "The Sun moves underneath the Earth at night."

Yolanda: "The Sun stops shining."



Which friend do you think has the best reason for why the sky is dark at night? Describe your ideas about why the Earth is dark at night and light during the day.

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How strongly do you believe your answer?



Not Sure



A Little Sure



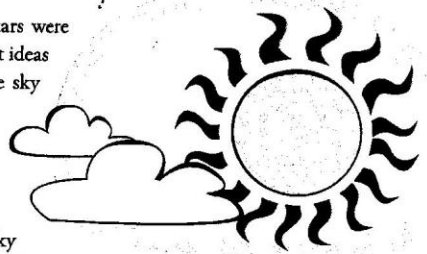
Somewhat Sure



Very Sure

# Where Do Stars Go?

Five friends were wondering where stars were in the daytime. They each had different ideas about why we do not see stars in the sky during the day. This is what they said:



Jack: "The stars stop shining when the Sun comes out."

Shelley: "The stars are still in the sky above us, but we can't see them."

Nancy: "The stars go underneath Earth during the daytime."

Emma: "The stars cool down during the day and the Sun gets hotter."

Flavio: "The stars are on the other side of Earth where it's nighttime."

Which friend do you most agree with? \_\_\_\_\_

Describe your thinking about why you do not see stars during the daytime. Provide an explanation for your answer.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

# Me and My Shadow

Five friends were looking at their shadows early one morning. They wondered what their shadows would look like by the end of the day. This is what they said:

Jamal: "My shadow will keep getting longer throughout the day."

Morrie: "My shadow will keep getting shorter throughout the day."

Amy: "My shadow will keep getting longer until it reaches its longest point and then it will start getting shorter."

Fabian: "My shadow will keep getting shorter until noon and then it will start getting longer."

Penelope: "My shadow will stay about the same from morning to day's end."



Which friend do you most agree with? \_\_\_\_\_

Describe your thinking. Explain the reason for your answer.

\_\_\_\_\_  
\_\_\_\_\_

How strongly do you believe your answer?



Not Sure



A Little Sure

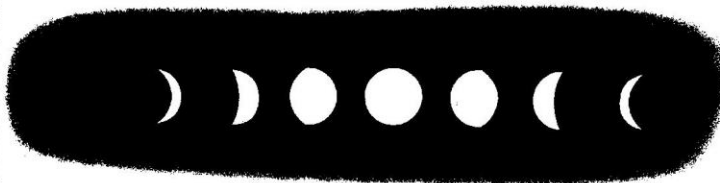


Somewhat Sure



Very Sure

## Going Through a Phase



Mrs. Timmons asked her class to share their ideas about what causes the different phases of the Moon. This is what some of her students said:

Mona: The Moon lights up in different parts at different times of the month.

Jared: The phases of the Moon change according to the season of the year.

Sofia: Parts of the Moon reflect light depending on the position of the Earth in relation to the Sun and Moon.

Drew: The Earth casts a shadow that causes a monthly pattern in how much of the Moon we can see from Earth.

Trey: Different planets cast a shadow on the Moon as they revolve around the Sun.

Oofra: The shadow of the Sun blocks part of the Moon each night causing a pattern of different Moon phases.

Natasha: The clouds cover the parts of the Moon that we can't see.

Raj: The Moon grows a little bit bigger each day until it is full and then it gets smaller again. It repeats this cycle every month.

Which student do you agree with and why? Explain your thinking.

How strongly do you believe your answer?



Not Sure



A Little Sure



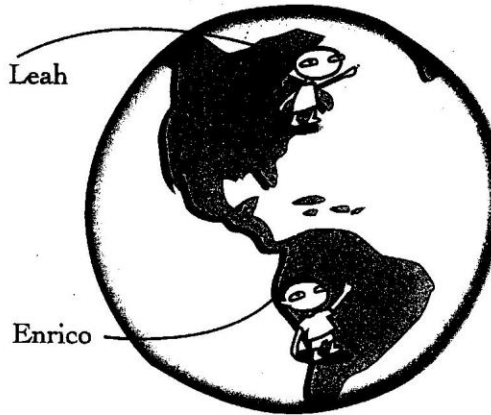
Somewhat Sure



Very Sure

## Gazing at the Moon

Enrico and Leah live in opposite hemispheres. Enrico lives in Santiago, Chile, which is in the Southern Hemisphere. Leah lives in Boston, Massachusetts, which is in the Northern Hemisphere. They both gazed at the Moon on the same evening. Enrico noticed there was a full Moon when he looked up at the sky from his location (the Southern Hemisphere). What do you predict Leah saw when she looked up in the sky from her location (the Northern Hemisphere)?



- A** New Moon (no part of the Moon is visible)
- B** Crescent Moon (a quarter of the face of the Moon is visible)
- C** Half Moon (half of the face of the Moon is visible)
- D** Gibbous Moon (three-quarters of the face of the Moon is visible)
- E** Full Moon (the entire face of the Moon is visible)

Provide an explanation for your answer. How did you decide what the Moon would look like in the opposite hemisphere?

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

APPENDIX D  
SEASONS UNIT PLAN

Seasons  
February 2<sup>nd</sup>, 2018 to February 22<sup>nd</sup>, 2018  
The Cause of the Seasons

**Standard:**

NGSS-1-ESS1-2. Make observations at different times of year to relate the amount of daylight to the time of year.

**Type of Inquiry:**

Structured inquiry: Teacher gives the students questions and a procedure to follow.

**Guiding Question:**

Why do we have different seasons?

**3D:****S & E Practices:**

Planning and carrying out investigations: Students carry out investigations of the seasons.

Make observations: Students observe media and models to draw conclusions and facilitate discussion.

Analyzing and interpreting data: Students analyze graphs of daylight to determine patterns

**Crosscutting Concepts:**

Patterns: Students observe patterns of the path of the sun and amount of daylight.

Systems and System Models: Students use models of the Earth and the sun.

**Misconceptions:**

The seasons are caused by the Earth getting closer or farther from the sun.

The seasons caused by one hemisphere being closer during summer.

The amount of daylight increases each day of summer.

The whole planet experiences the same season simultaneously.

Winter clouds block heat from the sun to create seasons.

The sun gives off more heat in the summer than in winter.

Seasons caused because one side of the Earth faces the sun in the summer.

The sun rises due East and sets in due West.

The coldest time of night is midnight.

The sun is directly overhead at noon.

**Misconception Probes:**

- Sunrise Direction
- Earth's Tilt
- Length of Day
- Temperature in Day
- The Sun's Angle

- Different Seasons
- Timing of the Seasons
- Cause of the Seasons
- Temperature in Seasons

**Materials:**

Several globes, preferably with a tilted axis or axis that can be changed.

Lamp

Bill Nye the Science Guy – Seasons

Projector/Smartboard

Solar oven

S'mores ingredients: graham crackers, marshmallows, chocolate

Graphs with amount of daylight by month

Calendars with time of sunrise, sunset, and length of day

Date / Conceptual Change Phase	Questions	Activities / Notes
2-2 Commit to an outcome	<p>Pretest</p> <p>What will we learn?</p> <p>What words do we need help understanding?</p>	<p>Students completed the misconception probes while sitting at tables with privacy folders. The misconceptions probes were read aloud twice.</p> <p>Why do we have different seasons?</p> <p>Summer, Winter, Fall, Spring  <a href="https://www.youtube.com/watch?v=8ZjpI6fgYSY">https://www.youtube.com/watch?v=8ZjpI6fgYSY</a></p>
2-5 Expose Beliefs	<p>Review Answers</p> <p>Students defend thinking “Why do you think...?”</p>	<p>Misconception probe answers were displayed as pie charts of student responses. Students were asked to explain their thinking on a voluntary basis.</p>
2-6 Confront Beliefs	<p>How does the Earth revolve around the sun?</p> <p>What causes the seasons?</p>	<p>Model Earth around the sun for whole class. Then move to stations. One model on each table. One Globe axis tilted 0 degrees, one globe fixed at 23.5 degrees, third globe also at 23.5. Students look at each globe. How are they similar and different?</p> <p>Tilt of Earth gives us more direct sunlight. Demonstrate how tilted globe is better illuminated.</p>

	When is the Earth closest to the sun? What is the weather like?	<p><a href="https://www.youtube.com/watch?v=drujIxWmxyc&amp;t=1s">https://www.youtube.com/watch?v=drujIxWmxyc&amp;t=1s</a></p> <p>How can it be summer in July when we are farthest from the sun? How could an area get warmer until it received direct sunlight? Student asked (sic): "How does the other side of the Earth night shorter than day?"</p>
2-8 Confront Beliefs	What causes the seasons?	<p>Bill Nye Seasons</p> <p>The seasons are caused by more direct sunlight in the summer. Drills in the concept of TILT!</p> <p>Covers basics of the seasons.</p>
2-13 Accommodate Concept	<p>When and where will the sun rise and set today?</p> <p>How does the length of day and night change throughout the year?</p> <p>How does the amount of sunlight change throughout the year?</p>	<p>Ancient Calendars Thirteen towers, Brian Cox: <a href="https://www.youtube.com/watch?v=DQnSqJ7jGmI&amp;disable_polymer=true">https://www.youtube.com/watch?v=DQnSqJ7jGmI&amp;disable_polymer=true</a> STOP: 2:45</p> <p>Stonehenge Predict it is calendar. Sunrise. Where sun will be. <a href="https://www.youtube.com/watch?v=Fx-KrvuiafE">https://www.youtube.com/watch?v=Fx-KrvuiafE</a> Start: 3:30, Stop: 5:37</p> <p>Look at bar graph of hours of day/night per month. Look at calendar with sunrise, sunset, length of day for longest day, shortest day, earliest sunrise, earliest sunset. When are day and night almost the same? Data from: <a href="http://sunrisesunset.com">sunrisesunset.com</a></p>
2-14 Accommodate Concept	Is day and night the same in every place on Earth?	<p>Look at graphs again. Why is day longer and shorter?</p> <p>Use Stellarium to model sun at different times of the day.</p>

	<p>Where is the sun in the sky at different time of the day?</p> <p>How can the movement of the Earth help us understand where the sun will be?</p> <p>What should the axis of the Earth look like in summer and winter?</p> <p>How can we use the sun's energy?</p>	<p>Discuss why the sun is higher or lower.  * most said closer or farther, still!  *Only one student mentioned tilt.</p> <p>Used globes and a lamp to show summer/winter.  Look at direct sunlight in tropics.</p> <p>Shorter and longer days  <a href="https://www.youtube.com/watch?v=drujIxWmxyc">https://www.youtube.com/watch?v=drujIxWmxyc</a></p> <p>Draw tilt of axis in the summer and the winter.</p> <p>Make s'mores in solar oven.</p>
2-20 Make Connections	<p>Why do we have the seasons?</p> <p>How is the sun directly overhead in the tropics?</p> <p>How does the sun stay up all day in the Arctic?</p>	<p>Model direct sunlight and the tilted Earth.</p> <p>Some places are not very affected by the tilt. These places are tropical.  Picture of no shadows  <a href="https://www.youtube.com/watch?v=7J3E4wNDNZo">https://www.youtube.com/watch?v=7J3E4wNDNZo</a>  Watch video of Lahaina Noon.  <a href="https://www.youtube.com/watch?v=qFOX3AO2FjE">https://www.youtube.com/watch?v=qFOX3AO2FjE</a>  DISCUSS – why are there no shadows?  -too much light  - light doesn't bounce  - sun directly above  <a href="https://www.youtube.com/watch?v=JCjEyITpRAI">https://www.youtube.com/watch?v=JCjEyITpRAI</a></p> <p>Google Earth, view the Earth and the sun.</p> <p>Video of sun going around in a day</p>

		<p>Summer:  <a href="https://www.youtube.com/watch?v=ZZcaf-g-meJA">https://www.youtube.com/watch?v=ZZcaf-g-meJA</a>  Winter:  <a href="https://www.youtube.com/watch?v=MXxRcXHI_tI">https://www.youtube.com/watch?v=MXxRcXHI_tI</a></p> <p>Will the sun rise earlier or later tomorrow?</p>
2-22 Go Beyond	<p>What are seasons like on other planets?</p> <p>Posttest</p>	<p>Compare the seasons on other planets. Start with chart that includes the axial tilt of each of the 8 planets. What planets would have similar seasons? How do we know?  Watch video on extraterrestrial seasons.</p> <p>Administer misconception probes.</p> <p>Interviews During Computer Lab</p>
3-22 Reassess	Followup Test	Readminister misconception probes.

APPENDIX E  
SEASONS MISCONCPETION PROBES

## Earth's Tilt Misconception Probe

Name: \_\_\_\_\_

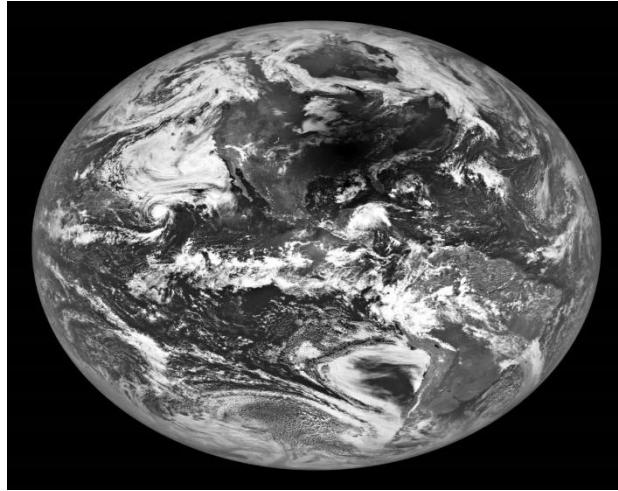


Image from: <https://www.nasa.gov/feature/goddard/2017/LRO-captures-eclipse-from-the-moon>

In what position does the Earth rotate or spin?

- A) The is straight up and down as it rotates, which is what makes the seasons.
- B) The Earth wobbles like a top as it rotates, which is what makes the seasons.
- C) The Earth is tilted a small amount (23.5 degrees) as it rotates, which is what makes the seasons.
- D) The Earth rotates on its side (90 degrees), which is what makes the seasons.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Different Seasons Misconception Probe

Name: \_\_\_\_\_



Image from: [https://c1.staticflickr.com/6/5589/14647751643\\_73c6f73d85\\_b.jpg](https://c1.staticflickr.com/6/5589/14647751643_73c6f73d85_b.jpg)

What seasons are there on Earth?

- A) Every place on Earth has the same seasons: summer, fall, winter, and spring.
- B) Tropical places have wet and dry seasons, while places outside the tropics have summer, fall, winter, and spring.
- C) It is always winter in Antarctica and in the Arctic, but other places have summer, fall, winter, and spring.
- D) Most places have summer, fall, winter, and spring, but other places only have summer and winter.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Timing of the Seasons Misconception Probe

Name: \_\_\_\_\_

2018

JANUARY							FEBRUARY							MARCH							APRIL								
1	2	3	4	5	6		1	2	3							1	2	3	4	5	6	7	1	2	3	4	5	6	7
7	8	9	10	11	12	13	4	5	6	7	8	9	10			4	5	6	7	8	9	10	8	9	10	11	12	13	14
14	15	16	17	18	19	20	11	12	13	14	15	16	17			11	12	13	14	15	16	17	15	16	17	18	19	20	21
21	22	23	24	25	26	27	18	19	20	21	22	23	24			18	19	20	21	22	23	24	22	23	24	25	26	27	28
28	29	30	31				25	26	27	28						25	26	27	28	29	30	31	29	30					

MAY							JUNE							JULY							AUGUST						
1	2	3	4	5			1	2						1	2	3	4	5	6	7	1	2	3	4			
6	7	8	9	10	11	12	3	4	5	6	7	8	9	8	9	10	11	12	13	14	5	6	7	8	9	10	11
13	14	15	16	17	18	19	10	11	12	13	14	15	16	15	16	17	18	19	20	21	12	13	14	15	16	17	18
20	21	22	23	24	25	26	17	18	19	20	21	22	23	22	23	24	25	26	27	28	19	20	21	22	23	24	25
27	28	29	30	31			24	25	26	27	28	29	30	29	30	31					26	27	28	29	30	31	

SEPTEMBER							OCTOBER							NOVEMBER							DECEMBER						
						1	1	2	3	4	5	6					1	2	3							1	
2	3	4	5	6	7	8	7	8	9	10	11	12	13	4	5	6	7	8	9	10	2	3	4	5	6	7	8
9	10	11	12	13	14	15	14	15	16	17	18	19	20	11	12	13	14	15	16	17	9	10	11	12	13	14	15
16	17	18	19	20	21	22	21	22	23	24	25	26	27	18	19	20	21	22	23	24	16	17	18	19	20	21	22
23	24	25	26	27	28	29	28	29	30	31				25	26	27	28	29	30	23	24	25	26	27	28	29	
																					30	31					

Image from: [https://pixabay.com/p-2952462/?no\\_redirect](https://pixabay.com/p-2952462/?no_redirect)

When do the seasons happen in relation to one another?

- A) It is always the same season for the whole planet.
- B) When it is summer in the eastern hemisphere it is winter in the western hemisphere.
- C) When it is summer in the northern hemisphere it is winter in the southern hemisphere.
- D) The seasons change on their own and it can sometimes be the same, sometimes be different.

How strongly do you believe your answer?



Not Sure



A Little Sure



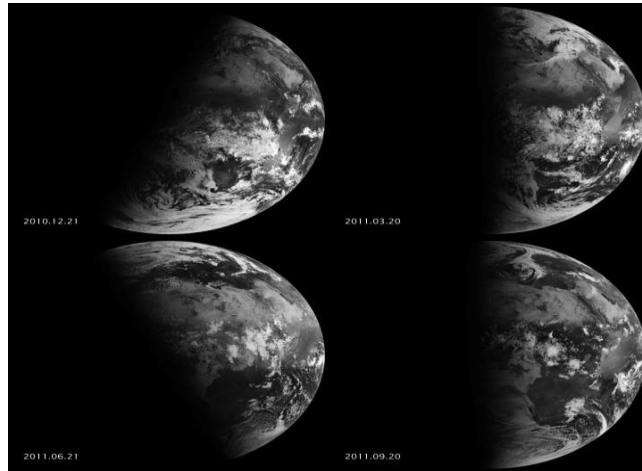
Somewhat Sure



Very Sure

## Cause of the Seasons Misconception Probe

Name: \_\_\_\_\_

Image from: [https://c1.staticflickr.com/7/6162/6174784751\\_be548e5be4\\_b.jpg](https://c1.staticflickr.com/7/6162/6174784751_be548e5be4_b.jpg)

What causes the seasons: summer, winter, fall, and spring?

- A) The Earth's tilt makes one hemisphere get more direct light in the summer and less in the winter.
- B) The Earth's orbit is closer to the sun in the summer and farther in the winter.
- C) The Earth's tilt makes one hemisphere closer in the summer and farther in the winter.
- D) The moon's gravity makes seasons with the ocean's tides.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Sunrise Direction Misconception Probe

Name: \_\_\_\_\_

Image from: [https://upload.wikimedia.org/wikipedia/commons/8/80/Sunrise\\_in\\_Vengedalen.jpg](https://upload.wikimedia.org/wikipedia/commons/8/80/Sunrise_in_Vengedalen.jpg)

How does the sun move across the sky throughout a day?

- A) The sun always rises in the east and sets in the west.
- B) The sun only rises in the east and sets in the west on the equinoxes. It rises in the northeast in the spring and summer, and the southeast in fall and winter.
- C) Sunrise changes depending on the phase of the moon.
- D) The sun always rises in the west and sets in the east.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## The Sun's Angle Misconception Probe

Name: \_\_\_\_\_

Image from: <https://pxhere.com/en/photo/423379>

When can we find the sun directly overhead?

- A) The sun is directly overhead at noon in every season.
- B) The sun is only directly overhead at noon in the summer.
- C) The sun is only directly overhead in the Arctic and Antarctic.
- D) The sun can only be directly overhead in the tropics.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

### Temperature in Day Misconception Probe

Name: \_\_\_\_\_



Image from: <http://www.buffertanks.co.uk/wp-content/uploads/2012/10/Rigid-Stem-Termometer.jpg>

What time of day is generally the coldest?

- A) The coldest time is at midnight.
- B) The coldest time is in the evening, right before sunset.
- C) The coldest time is in the early morning, right before sunrise.
- D) The coldest time is in the middle of the day.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Temperature in Seasons Misconception Probe

Name: \_\_\_\_\_



Images from: <https://pxhere.com/en/photo/794846> and [https://upload.wikimedia.org/wikipedia/commons/4/40/Children.\\_North\\_Branch\\_Y.M.C.A.\\_Summer\\_Camp\\_Picnic.\\_Ville\\_Lasalle\\_BAnQ\\_P48S1P08724.jpg](https://upload.wikimedia.org/wikipedia/commons/4/40/Children._North_Branch_Y.M.C.A._Summer_Camp_Picnic._Ville_Lasalle_BAnQ_P48S1P08724.jpg)

Why is it warmer in the summer and colder in the winter?

- A) It is winter because of the cold and summer because of the heat.
- B) Winter clouds block the heat from the sun.
- C) The sun gives off more heat in the summer and less heat in the winter.
- D) There is more direct sunlight in the summer than in the winter.

How strongly do you believe your answer?



Not Sure



A Little Sure



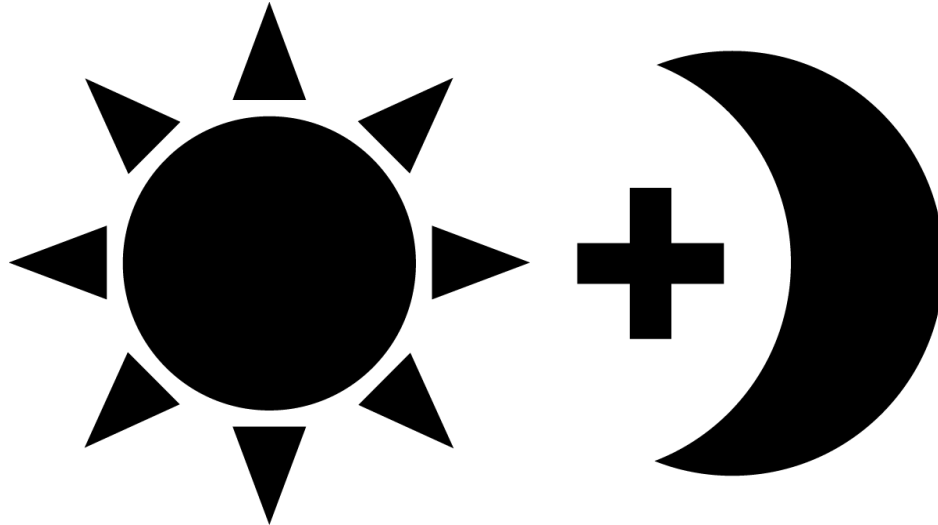
Somewhat Sure



Very Sure

## Length of Day Misconception Probe

Name: \_\_\_\_\_

Image from: [https://upload.wikimedia.org/wikipedia/commons/4/42/Day\\_and\\_night\\_icon.png](https://upload.wikimedia.org/wikipedia/commons/4/42/Day_and_night_icon.png)

How long is day and night?

- A) Days and nights are always the same length.
- B) Each day gets shorter through summer and fall and then longer in winter and spring.
- C) Day is always longer than night.
- D) Each day gets longer through summer and fall and then shorter in winter and spring.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

APPENDIX F  
LIGHT UNIT PLAN

## Light

February 26<sup>th</sup>, 2018 to March 9<sup>th</sup>, 2018

## Light and Color

## Standard:

NGSS-1-PS4-2. Make observations to construct an evidence-based account that objects can be seen only when illuminated.

NGSS-1-PS4-3. Plan and conduct an investigation to determine the effect of placing objects made with different materials in the path of a beam of light.

## Type of Inquiry:

5E Guided Inquiry: Teacher develops questions and guides students through a process. Students develop some activities, but the process is outlined by the teacher.

## Guiding Question:

Why do we see objects, shadows, and colors?

## 3D:

## S &amp; E Practices:

Plan and conduct investigations collaboratively: students gather materials, help plan, and conduct investigations into light.

Make observations: students observe phenomena related to light.

## Crosscutting Concepts:

Cause and effect: Students observe how light causes us to be able to see, the effects of bodies on shadows, the effects of bending light.

## Misconceptions:

Shadows are independent of the objects causing them.

Shadows are emitted from our bodies.

Shadows are alive and follow us.

Light “bounces off” of our bodies to create shadows.

A light source and its effects are not separate.

White light is colorless and pure.

A color filter adds color to a beam of light.

Light is reflected from mirrors, but remains in other objects.

Mirrors reverse light so we see the reflection backwards.

Light doesn't travel.

Light helps us see by illuminating objects and making them visible.

Magnifying glasses make the light bigger.

The moon creates its own light.

Light can bend independently; it doesn't travel in a straight line.

Transparent, translucent, and opaque materials interact similarly.

Misconception Probes:

- Birthday Candles
- Shadows
- Apple in the Dark
- Light's Color
- Paper Window
- Magnifying Glass
- Moonlight
- Mirrors
- Can it Reflect Light?

Materials:

Computer

Projector/Smartboard

Lamp

Prism

Opaque, translucent, transparent objects

Colored paper: red, orange, yellow, green, blue, violet

Cardboard box

Flashlight

Objects from does it reflect light: water and cup, grey rock, leaf, mirror, glass, sand, potato, wax paper, tomato soup, white paper, shiny metal, dull metal, red apple, cardboard, rusty nail, soil, wood, milk, bedsheet, new penny, old penny, aluminum foil, and pictures of the moon and a cloud.

Colored light filters

CD

Garden hose

Mirror

Magnifying Glass

Reading glasses

Date / Conceptual Change Phase	Questions / Activities	Notes
2-26 Commit to an Outcome	Pretest	Students completed the misconception probes while sitting at tables with privacy folders. The misconceptions probes were read aloud twice.
2-27 Expose Beliefs	Review Answers Students defend thinking	Misconception probe answers were displayed as pie charts of student

	“Why do you think...?”	responses. Students were asked to explain their thinking on a voluntary basis.
3-1 Confront Beliefs	<p><b>Engage:</b> How can we make shadows? What happens when we put other objects?</p> <p>Can we see something without light?</p>	<p>Shine lamp on wall. What would happen if put body between light and screen.</p> <p>Put colored paper. Prism? Filter. Mirror? Paper? Students get objects to put in path. Analyze if transparent, opaque, translucent etc.</p> <p>Seeing in the dark. Put a small hole in a box and put an object in it. Students take turns trying to see the object without any light. Shine a flashlight into the box, can they see the object now.</p>
3-2 Confront Beliefs	<p><b>Explore:</b> What reflects light?</p> <p>How do we see?</p>	<p>What reflects light misconception probe. Students go through stations with several of the objects from the misconception probe. Which ones reflect light?</p> <p><a href="https://www.youtube.com/watch?v=syaQgmx5i0&amp;t=127s">https://www.youtube.com/watch?v=syaQgmx5i0&amp;t=127s</a> Full class discussion on how light needs to enter our eye in order for us to see. If we can see the object then light is being reflected.</p>
3-5 Accommodate Concept	<p><b>Explain:</b> Why do we see certain colors?</p> <p>What words do we need to know?</p>	<p>Watch The Magic School Bus light. Describes that we see things because light reflects off of them and enters our eyes. An object appears to be a color because it absorbs all colors except what we see.</p> <p>Transparent. Translucent. Opaque. Reflect. Refract. Demonstrate each concept.</p>

	What happens when we put a filter over a flashlight?	Use different colored filters over the flashlight. How does the light change? Will objects appear different when illuminated by colored light?
3-6 Accommodate Concept	<b>Explain:</b> How can we make rainbows?  What color light will reflect off of things?	Different ways to make a rainbow: Shine a light through a prism Use a CD. Use a garden hose outside. Use light going through a slip of paper and a cup of water.  Shine flashlight on paper and view reflected light. Will the color of light shone on an object, change the color that it appears?
3-8 Make Connections	<b>Elaborate:</b> How do mirrors work?  How can we bend light? Why do we bend light?  What questions do you have about light?	Mirrors. Use mirrors to look at self. <a href="https://www.youtube.com/watch?v=5j7wJWhxuwU">https://www.youtube.com/watch?v=5j7wJWhxuwU</a>  Magnifying glass. Will use in next lesson. <a href="https://www.youtube.com/watch?v=zYN-QkUn1A8">https://www.youtube.com/watch?v=zYN-QkUn1A8</a>  Camera obscura. Unsuccessfully tried to make a pinhole camera. <a href="https://www.exploratorium.edu/video/camera-obscura">https://www.exploratorium.edu/video/camera-obscura</a>  How is light made? What would happen if there's no light? How does light reflect? Does air have light? Why do we block light?
3-9 Go Beyond	<b>Elaborate:</b> How can we bend light?  How can light reflect?  Why do we block light?	Light stations based upon student questions: 1. Lenses: Refracting Light in Water, Magnifying Glass and Reading glasses to make things appear larger 2. Reflection: student reflect light using a mirror, colored paper, and a flashlight. If students can see something, then it is reflecting light.

	<p><b>Evaluate:</b> Misconception Probes</p> <p>Interviews</p>	<p>3. Shadows: Students make shadows with transparent, translucent, opaque materials.</p> <p>Administer misconception probes.</p> <p>Interviews during computer lab.</p>
4-9 Misconception Probes	Followup Test	Readminister the assessment probes

APPENDIX G  
LIGHT MISCONCEPTION PROBES

Physical Science Assessment Probes

# Birthday Candles

Imagine you are at a birthday party. A birthday cake with candles is put on a table in the middle of a room. The room is very large. You are standing at the end of the room, 10 meters away from the cake. You can see the candles. Circle the response that best describes how far the light from the candles traveled in order for you to see the flames.

- A The light stays on the candle flames.
- B The light travels a few centimeters from the candle flames.
- C The light travels about 1 meter.
- D The light travels about halfway to where you are standing.
- E The light travels all the way to where you are standing.



Describe your thinking. Provide an explanation for your answer.

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How strongly do you believe your answer?

			
Not Sure	A Little Sure	Somewhat Sure	Very Sure

Keeley, P., Eberle, F., Farrin, L., (2005). Uncovering student ideas in science: 25 formative assessment probes. Arlington, Virginia: NSTA Press. Page 37.

## Misconception Probe: Shadows



(image from: <https://www.learner.org/jnorth/mclass/spring2017/update012717.html>)

Imagine that you and your class are on the playground looking at your shadows. You notice that each student has a shadow on the blacktop. What causes the students to have a shadow?

- A. The shadows come from the students' bodies because everybody gives out a shadow.
- B. The students' bodies block the light from the sun from hitting the blacktop.
- C. The students' shadows are alive and follow them everywhere.
- D. Light from the sun bounces off students to make the shadow.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



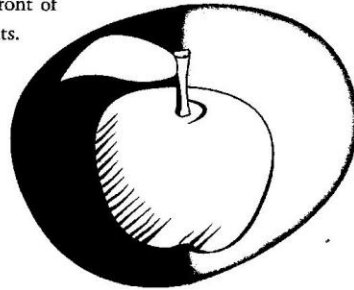
Very Sure

## Apple in the Dark

Imagine you are sitting at a table with a red apple in front of you. Your friend closes the door and turns off all the lights. It is totally dark in the room. There are no windows in the room or cracks around the door. No light can enter the room.

Circle the statement you believe best describes how you would see the apple in the dark:

- A** You will not see the red apple, regardless of how long you are in the room.
- B** You will see the red apple after your eyes have had time to adjust to the darkness.
- C** You will see the apple after your eyes have had time to adjust to the darkness, but you will not see the red color.
- D** You will see only the shadow of the apple after your eyes have had time to adjust to the darkness.
- E** You will see only a faint outline of the apple after your eyes have had time to adjust to the darkness.



Describe your thinking. Provide an explanation for your answer.

How strongly do you believe your answer?



Not Sure



A Little Sure

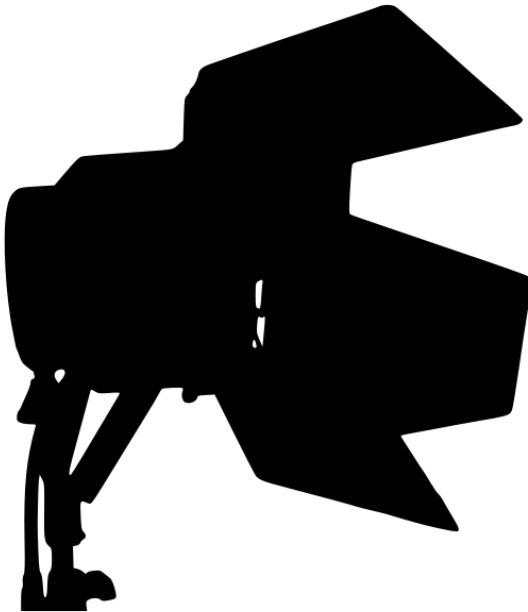


Somewhat Sure



Very Sure

## Misconception Probe: Light's Color



(image from: [https://commons.wikimedia.org/wiki/File:Movie\\_lighting.svg](https://commons.wikimedia.org/wiki/File:Movie_lighting.svg))

Why does putting a red filter over a light make the light red?

- A. The red filter adds red light to the white light.
- B. The red filter takes out all colors of light except red from the white light.
- C. The filter bends the light to make it look red.
- D. White light is pure and has no red color unless there is a filter.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Misconception Probe: Magnifying Glass



(image from: [http://www.publicdomainfiles.com/show\\_file.php?id=13533946212176](http://www.publicdomainfiles.com/show_file.php?id=13533946212176))

How do magnifying glasses make things look bigger?

- A. The magnifying glass's curved lens bends the rays to make it look bigger.
- B. The magnifying glass.
- C. The magnifying glass make the light bigger.
- D. The magnifying glass breaks the light into different colors.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Misconception Probe: Paper Window



(image from: <http://maxpixel.freegreatpicture.com/Empty-Crumpled-Background-Paper-Antique-Abstract-2537807>)

Abraham is building a fort to play in with his friends. He wants to have a window so that they have light in the fort, but he does not want the people to see through the window. Why is white paper a good choice of material?

- A. White paper is transparent and he can see what is on the other side.
- B. White paper is translucent, he will see light through it, but not details.
- C. White paper is opaque and no light will go through it.
- D. White paper is secret and it cannot make shadows.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

# Moonlight

Five friends noticed they could see better at night when there was a full Moon. They wondered where the moonlight came from. This is what they said:



Curtis: "The Moon reflects the light from the Earth."

Chet: "The light from the Sun bounces off the Moon."

Clarence: "The Moon gets its light from distant stars."

Fallon: "The Moon absorbs light from the Sun during the day."

Deirdre: "There is light inside of the Moon that makes it shine."

Which person do you most agree with? Explain your thinking about moonlight.

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How strongly do you believe your answer?

Not Sure

A Little Sure

Somewhat Sure

Very Sure

## Misconception Probe: Mirrors



(image from: <https://www.publicdomainpictures.net/view-image.php?image=198428&picture=white-tiles>)

John can see himself combing his hair in front of a mirror before he goes to school. How does John see himself in the mirror?

- A. John sees himself, but backwards because the mirror reversed the light from left to right.
- B. John needs to stand directly in front of the mirror to see himself.
- C. John sees light that reflects off the mirror and goes into his eyes.
- D. John's reflection is on the mirror and that's why it looks like a picture.

How strongly do you believe your answer?



Not Sure



A Little Sure



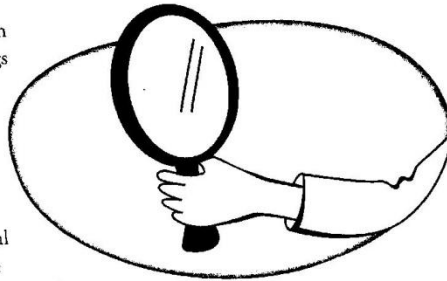
Somewhat Sure



Very Sure

# Can It Reflect Light?

What types of objects or materials can reflect light? Put an X next to the things you think can reflect light.







- |   |  |  |
|---|--|--|
| <input type="checkbox"/> water          | <input type="checkbox"/> dull metal      | <input type="checkbox"/> milk                          |
| <input type="checkbox"/> gray rock      | <input type="checkbox"/> red apple       | <input type="checkbox"/> bedsheet                      |
| <input type="checkbox"/> leaf           | <input type="checkbox"/> rough cardboard | <input type="checkbox"/> brand new penny               |
| <input type="checkbox"/> mirror         | <input type="checkbox"/> the Moon        | <input type="checkbox"/> old tarnished penny           |
| <input type="checkbox"/> glass          | <input type="checkbox"/> rusty nail      | <input type="checkbox"/> smooth sheet of aluminum foil |
| <input type="checkbox"/> sand           | <input type="checkbox"/> clouds          |  |
| <input type="checkbox"/> potato skin    | <input type="checkbox"/> soil            |  |
| <input type="checkbox"/> wax paper      | <input type="checkbox"/> wood            |  |
| <input type="checkbox"/> tomato soup    |  |  |
| <input type="checkbox"/> crumpled paper |  |  |
| <input type="checkbox"/> shiny metal    |  |  |

Explain your thinking. Describe the "rule" or the reasoning you used to decide if something can reflect light.

---

How strongly do you believe your answer?

			
Not Sure	A Little Sure	Somewhat Sure	Very Sure

Keeley, P., Eberle, F., Farrin, L., (2005). Uncovering student ideas in science: 25 formative assessment probes. Arlington, Virginia: NSTA Press. Page 25.

APPENDIX H  
SOUND UNIT PLAN

Sound

March 12<sup>th</sup>, 2018 to March 23<sup>rd</sup>, 2018  
Sound and Sound Waves

Standard:

NGSS-1-PS4-1 Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.

Type of Inquiry:

Open Inquiry: The students ask the questions and design the methods of research with support if needed.

Guiding Question:

Student question: How do things (objects) make sound?

3D:

S&E Practices:

Plan and carry out investigations: Students investigate what objects can make sound, how size can affect pitch, and how sound travels.

Produce data: Students use their investigations to answer questions.

Crosscutting Concepts:

Cause and effect: Students investigate how sound is a vibration and that vibrating materials make sound.

Misconceptions:

Sound cannot travel through solids or liquids.

Sound travels the same speed through all materials.

Sound travels fastest through air.

Sound can travel in space.

Sound can be produced without using any materials.

Hitting tuning fork harder/softer changes the pitch of a sound.

Pitch changes with the amount of energy put into a vibration.

Only certain materials, such as musical instruments, can make sound.

Humans have more than one pair of vocal cords.

Tuning forks change pitch a few seconds after they are hit.

Sound turns into waves.

Sound travels as fast as or faster than light.

Sound travels through wires as a sound wave.

Fire trucks/trains change the sound of the siren on purpose as they come/leave.

Misconception Probes:

- How Sound is Made

- Hitting Bell
- Vocal Cords
- Tuning Fork
- Sound Waves
- Speed of Sound
- Headphones
- Firetruck
- Making Sound

Materials:

Instruments: autoharp, small guitar, 12 inch djembe drum, small steel bell, large steel bell, bowl bell on cushion, tuning forks, and xylophone

Cup with water

Slinkys

Computer speakers with wires.

Computer and projector

Magic School Bus Haunted House

Phonograph with records and extra needle.

Paper

Date / Conceptual Change Phase	Questions	Activities / Notes
3-12 Commit to an outcome	Pretest  What we know about sound?	Students completed the misconception probes while sitting at tables with privacy folders. The misconception probes were read aloud twice.  Fill out K, of KWL chart with what students know about sound.
3-13 Expose Beliefs	Review Answers Students defend thinking “Why do you think...?”  What do you want to learn about sound?	Misconception probe answers were displayed as pie charts of student responses. Students were asked to explain their thinking on a voluntary basis.  Add more items to the K section of KWL chart. Complete W section with what students want to learn: How is sound made? How do things make sound? What makes sound? Where does sound come from? What is a sound wave? How does sound get

		into waves? How do headphones work? Why is there sound? How do bells get lower or higher?
3-15 Confront	How is sound made?  Where does sound come from?	Musical instruments. Students are given string (autoharp, guitar) instruments, bells, a xylophone, and a drum. All of these vibrate!  The vibrating part of the instrument makes sound. The sound can be stopped by holding the vibrating part of the instrument. Students hold pieces of paper in front of a speaker to feel the sound vibrations. Students put hands on throat to feel vibrations of vocal cords while speaking. *Lesson ran late and KWL chart was updated the morning of 3/16
3-19 Confront	What is a sound wave?  How does sound travel to headphones?  What length and sized string will make the highest sound?  What part of the instrument is vibrating? How can we stop the sound?	Whole class intro sound waves: Stations: Make waves with a slinky  How is sound getting to the speakers from the computer? Students feel the vibrations of different tones on a speaker. Then they feel if the speaker wire is vibrating.  Length of strings on autoharp and guitar. Length of bars on a xylophone.  Drum/bell/tuning fork. Feel vibrations and stop vibrations. *students made the connection of sound waves bouncing back as an echo without teacher involvement after playing with the slinky.
3-20 Accommodate	What is sound?	Watch the Magic School Bus Haunted House  Sound is vibrations

	<p>Why are sounds high or low?</p> <p>Why are sounds loud or quiet?</p> <p>How do sound waves travel?</p>	<p>High sounds are fast, low sounds are slow</p> <p>Sound travels in waves in all directions</p> <p>Loud sounds are strong vibrations, soft sounds are weaker vibrations</p>
<p>3-21 Accommodate</p>	<p>Watch clip after credits from magic school bus. Ask questions:</p> <p>What do waves look like?</p> <p>How do a paper and needle make sound on a Phonograph?</p> <p>What can sound travel through?</p>	<p>See sound waves  <a href="https://ca.pbslearningmedia.org/resource/phy03.sci.phys.mfe.ztunefork/sound-and-solids-visualizing-vibrations/#.WrKFakjwbc">https://ca.pbslearningmedia.org/resource/phy03.sci.phys.mfe.ztunefork/sound-and-solids-visualizing-vibrations/#.WrKFakjwbc</a>                      Vizualize vibrations  <a href="https://ca.pbslearningmedia.org/resource/phy03.sci.phys.mfe.ztunefork/sound-and-solids-visualizing-vibrations/#.WrKFakjwbc">https://ca.pbslearningmedia.org/resource/phy03.sci.phys.mfe.ztunefork/sound-and-solids-visualizing-vibrations/#.WrKFakjwbc</a>                      What can sound travel through                      Vacuum/space  <a href="https://www.youtube.com/watch?v=LbprvWGIaj8">https://www.youtube.com/watch?v=LbprvWGIaj8</a></p> <p>Introduce phenomena: play phonograph. Then use a paper cone and needle to hear the same music. The sound is created by the needle vibrating as it moves along the groove in the record.</p> <p>Sound in a vacuum:  <a href="https://www.youtube.com/watch?v=LbprvWGIaj8">https://www.youtube.com/watch?v=LbprvWGIaj8</a>                      Knocking on tables and listening on the other end.                      blue whales  <a href="https://www.youtube.com/watch?v=8Wt4pomro6M">https://www.youtube.com/watch?v=8Wt4pomro6M</a></p>
<p>3-22</p>	<p>How fast is sound?</p>	<p>Space shuttle</p>

Make Connections	Speed of sound	<a href="https://www.youtube.com/watch?v=NGJV0P_r1Rs">https://www.youtube.com/watch?v=NGJV0P_r1Rs</a> Firework <a href="https://www.youtube.com/watch?v=iail1vqS4MM">https://www.youtube.com/watch?v=iail1vqS4MM</a> Thunder <a href="https://www.youtube.com/watch?v=_PqOi1C6a6Y">https://www.youtube.com/watch?v=_PqOi1C6a6Y</a>
3-23 Go Beyond	<p>How can someone make different sounds?</p> <p>How does a moving object sound when coming closer or going farther away?</p> <p>How can we see the difference between the speed of light and the speed of sound?</p> <p>How does a trumpet make sound if it does not vibrate?</p> <p>How do wireless headphones work?</p> <p>How can we see sound waves like in Magic School Bus?</p>	<p>Fun Foley Artist  <a href="https://www.youtube.com/watch?v=E0pOLukIB4s">https://www.youtube.com/watch?v=E0pOLukIB4s</a></p> <p>Fire Engine:  <a href="https://www.youtube.com/watch?v=imoxDcn2Sgo">https://www.youtube.com/watch?v=imoxDcn2Sgo</a></p> <p>Train:  <a href="https://www.youtube.com/watch?v=wrzWAox8NCM">https://www.youtube.com/watch?v=wrzWAox8NCM</a></p> <p>Jet:  <a href="https://www.youtube.com/watch?v=RMrXAZJDmM">https://www.youtube.com/watch?v=RMrXAZJDmM</a></p> <p>Stations:          1. Go to one end of the field with a pair of large wooden blocks. Half the group is with teacher and blocks, the other half is</p> <p>Play with a large drum. The drum skin vibrates the air which travels to our ears. Sound from vibrating lips travel through trumpet as vibrating air.</p> <p>Transfer a signal, like speaker wire does. Feel speakers vibrate fast and slow. Students feel wire for vibrations. Listen to and feel increasing frequencies up to 1800Hz and William Tell Overture</p> <p>Tuning fork dipped in water to watch the waves.          Creating waves with a slinky.</p>

	Posttest	Administer misconception probes. Interviews during computer lab time.
4-23	Followup Test	Readminister misconception probes

APPENDIX I  
SOUND MISCONCEPTION PROBES

## Misconception Probe: How is Sound Made



(image from: <https://pixabay.com/en/photos/speaker/>)

How is sound made?

- A. Sound is made when our ears sense the air.
- B. Sound is made when a material vibrates.
- C. Sound is made only by musical instruments.
- D. Sound is made when a material has more energy.

How strongly do you believe your answer?



Not Sure



A Little Sure

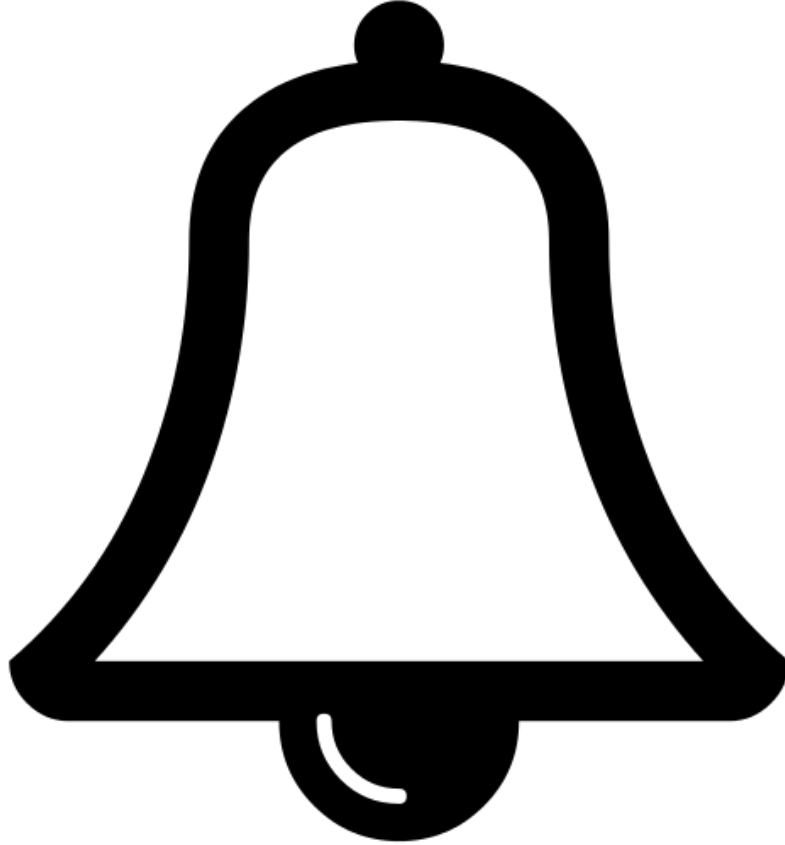


Somewhat Sure



Very Sure

## Misconception Probe: Hitting Bell



(image from: [https://commons.wikimedia.org/wiki/File:Bell\\_font\\_awesome.svg](https://commons.wikimedia.org/wiki/File:Bell_font_awesome.svg))

Your friend asked you to hit a bell. You hit the tuning bell once and he tells you to hit it harder the second time. How is the second sound different from the first?

- A. The second sound is a higher pitch because you hit it harder.
- B. The second sound is a lower pitch because you hit it harder.
- C. The second sound is quieter because you hit it harder.
- D. The second sound is louder because you hit it harder.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Misconception Probe: Vocal Cords



(image from: [https://commons.wikimedia.org/wiki/File:Darya\\_Antonyuk\\_01.jpg](https://commons.wikimedia.org/wiki/File:Darya_Antonyuk_01.jpg))

Where does sound come from when we talk or sing?

- A. The sound is made by five sets of vocal cords.
- B. The sound is made by one set of vocal cords.
- C. The sound is made by our mouth.
- D. The sound is made by our chest as we squeeze air out of our lungs.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Misconception Probe: Firetruck



(image from: <https://www.flickr.com/photos/rvp-cw/8365920943/>)

You notice that the sound changes as a fire truck drives past your house. How does the ?

- A. The sirens automatically change the sound as it gets closer to let you know it's coming.
- B. The driver of the fire truck changes the sound with a button.
- C. The pitch increases as the fire truck comes and decreases as it moves away from you.
- D. The pitch decreases as the fire truck comes and increases as it moves away from you.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Misconception Probe: Tuning Fork



(image from: <https://www.medipreventie.nl/stemvork-saehan-128-cps>)

Your friend asked you to hit a tuning fork to help him tune his guitar. After you hit the tuning fork and it makes sound for six seconds. How does the pitch of the tuning fork change?

- A. The pitch of the tuning fork does not change.
- B. The pitch decreases, or gets lower, as the tuning fork slows down.
- C. The pitch increases, or gets faster, as the tuning fork speeds up.
- D. The pitch of the tuning fork depends on how hard you hit it.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Misconception Probe: Sound Waves



(image from: <https://pixabay.com/en/audio-music-sfa-jazz-sound-wave-1293262/>)

Which sentences best describes how sound waves travel.

- A. Sound waves can move through nothing, such as in space.
- B. Sound waves move through air but not solids or liquids.
- C. Sound waves move faster through air because it is open space.
- D. Sound waves move through solids faster than through air.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Misconception Probe: Speed of Sound



(image from: [https://commons.wikimedia.org/wiki/File:Airplane\\_silhouette.svg](https://commons.wikimedia.org/wiki/File:Airplane_silhouette.svg))

You are one mile from the airport watching jet airplanes land and takeoff. Your friend asks if you will see or hear the plane first.

- A. We may see it first or may hear it first depending on the weather.
- B. We can see it and hear it at the same time.
- C. We can hear it first because sound travels faster than light.
- D. We can see it first because light travels faster than sound.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

## Misconception Probe: Headphones



(image from: [https://commons.wikimedia.org/wiki/File:Airplane\\_silhouette.svg](https://commons.wikimedia.org/wiki/File:Airplane_silhouette.svg))

You are listening to music on your headphones. How does the sound travel to the headphones?

- A. The sound travels through the wire as a sound wave.
- B. The sound travels through wires as a sound wave but faster because of electricity.
- C. The sound can travel in waves with wired headphones but not with wireless headphones.
- D. The sound travels as a signal that the headphone's speakers turn into sound.

How strongly do you believe your answer?



Not Sure



A Little Sure



Somewhat Sure



Very Sure

# Making Sound

All of the objects listed below make sounds. Put an X next to the objects you think involve vibrations in producing sound.

- guitar strings
- drum
- dripping faucet
- barking dog
- piano
- screeching brakes
- radio speaker
- crumpled paper
- car engine
- chirping cricket
- singer
- popped balloon
- drum
- wind
- wood saw
- clapped hands
- bubbling water
- rustling leaves
- hammer
- flute
- thunderstorm
- two stones rubbed together
- snapped fingers



Explain your thinking. What "rule" or reasoning did you use to decide which objects involve vibrations in producing sound?

How strongly do you believe your answer?

Not Sure     
  A Little Sure     
  Somewhat Sure     
  Very Sure

APPENDIX J

DAILY LIKERT ITEM SURVEY OF FUN AND CONTROL OF LEARNING

This survey is voluntary and anonymous. You can choose to answer as few or many questions as you would like.

1. How fun was today's lesson?

Not Fun ----- A Little Fun ----- Kind of Fun ----- Very Fun

2. Who controlled the learning in today's lesson?

- a. teacher controlled all
- b. teacher controlled most
- c. students controlled most
- d. students controlled all

APPENDIX K  
MISCONCEPTION INTERVIEW QUESTIONS

You can choose to answer these questions and say “pass” for any questions that you do not want to answer.

1. Ask the same question as on the misconception probe such as, “What causes students to have a shadow?”
2. Where did you learn that?
3. Was learning about \_\_\_\_\_ fun? What part made it fun?
4. Who do you think controlled most of the learning when we learned about \_\_\_\_\_