ABSTRACT

A.C.C.E.S.S.

Alternative Conceptions: a Comprehensive Examination of Space Science

by Adam Scott Hicks

This study was performed by giving an astronomy survey to fifth grade, eighth grade and introductory physics college students. A survey was developed with carefully selected “distracters,” common alternative conceptions that, combined with the phrasing of the question, are used to bring out the students’ actual conceptions of the topics being probed: phases of the Moon, the tilt of the Earth’s axis and the apparent movement of the sun and stars across the sky, and distances to various celestial objects in the solar system. Through the use of this survey, several alternate conceptions and the relative strength and resiliency of those alternative conceptions were discovered. Also, by examining the data, we determined which demographic factors affected susceptibility to these alternative conceptions. With the results from this study, new curricula and teaching strategies can be formed to address these alternative conceptions.
A.C.C.E.S.S.
Alternative Conceptions: a Comprehensive Examination of Space Science

A Thesis

Submitted to the
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in partial fulfillment of
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Department of Physics

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Dedication

To my mother Gail: for always pushing me to be my best.
To my sister Crystal: for always having confidence in me.
Hey. Thanks.
Acknowledgements

To my advisor Jennifer Blue: Thank you for all of your encouragement and understanding through my graduate journey.

To Jeff Winslow, the Talawanda school district’s science instructional leader: thank you for all the help with this project. Your help was monumental in both launching this study and keeping anonymity intact.

To Mr. Plank, Mrs. Dowd, Mrs. McQueen, and Mrs. Garver and the principals of those schools: thank you for the willingness you have shown to help facilitate the survey of the fifth and eighth grade students.

To all the faculty and staff in the Miami University’s Physics Department: Thank you for making my journey a memorable one.
Chapter 1

Introduction

This thesis is a study of astronomy alternative conceptions in a rural/suburban school district and a mid-sized Ohio university. In this study, we examined student conceptions by conducting an astronomy survey with fifth grade, eighth grade, and college students. This first chapter provides a purpose for pursuing this topic, a background of this study, and hypotheses predicting what the final data will suggest. This chapter concludes with an outline of this entire thesis.

Recently, student-centered learning has gained popularity in the education community. Knowing students’ conceptions is essential in order to cater prepare better instructional materials and methods. It is nearly impossible to teach to the students’ needs without knowing their current mindset in the topics being taught. Knowing the students’ current conceptions not only gives insight into what material to teach, but how to best accomplish overturning any incorrect conceptions currently held. With this in mind, the purpose of this study is to determine what astronomy (called space science in the Ohio K-12 schools) alternative conceptions, if any, are held by fifth grade, eighth grade, and college students. This project will help to determine which of the astronomy alternative conceptions held by students are the most resilient and, thus, help teachers eliminate those alternative conceptions.

This study will address astronomy alternative conceptions involving three specific phenomena: phases of the Moon, the tilt of the Earth’s axis and the apparent movement of the sun and stars across the sky, and distances to various celestial objects in the solar system. A pilot study was performed in August 2008 in order to choose the topics of this alternative conception research. This pilot study covered many fifth grade science topics, including basic circuits, light, sound, and astronomy. While examining the results of that
pilot study, it was found that the most interesting and some of the most prevalent alternative conceptions revealed themselves in the astronomy portions of the study. The results were found to be fascinating enough to become the main focus of this study. In designing this study, several research questions arose that required answers.

- What astronomy alternative conceptions, if any, exist in a fifth grade, eighth grade, and college classroom setting?
- Which of those space science alternative conceptions found is the strongest, and which is the most resilient?
- Do any demographic factors affect the susceptibility of students to the alternative conceptions that exist in the subject population?
- Does the highest education level of the fifth and eighth grade students’ immediate family affect those students’ alternative conceptions?
- Does the location of the elementary school, where the student was primarily exposed to this material, affect college students’ alternative conceptions?

Through a review of the current research on similar subjects, using similar instruments, hypotheses were formed.

- Due to the sizeable amount of literature on alternative conceptions involving the phases of the Moon, it was hypothesized that this topic would elicit the strongest and most resilient of the alternative conceptions. A strong alternative conception will be defined as an alternative conception that consistently draws a high percentage of students. A resilient alternative conception will be defined as an alternative conception which, although overturned for a time, reemerges later in the student’s life. Resilient alternative conceptions are denoted by a fall and rise pattern in the question that denotes the alternative conception. Along with this fall and rise pattern may be an anti-symmetric rise and fall in the correct answer if the other distracters do not illicit much attention by the students.
- It was predicted that male students would do better than female students. Also hypothesized was that White and Asian students would do notably better than
under-represented minorities (African Americans, Latinos, and Native American), also denoted URMs.

- It was finally hypothesized that as the education level of the students’ immediate family rose, so would the students’ overall test score.
- Due to the apparent wide spread nature of the alternative conception in question, it was hypothesized that the location of the college students’ elementary education would have little to no affect on the prevalence of these alternative conceptions for college students.

Throughout this study, support behind the rationale of these hypotheses is given. In chapter two, a literature review of relevant material is presented; first on astronomy alternative conceptions, then on the importance of parents education level on student achievement, and finally on the gender and racial gaps. In chapter three, the methods by which the survey was designed and data were taken are described. Also in chapter three, the fifth grade and eighth grade Ohio space science academic content standards are laid out. In chapter four, the results from the survey are displayed in graphical form and an overview and short discussion of those results is given. In chapter five, final conclusions are drawn from the results seen in chapter four, and some implications for instruction are examined.
Chapter 2

Literature Review

As early as the 1940’s, educators have realized the importance of recognizing science alternative conceptions. An article was published in 1940 in the journal *Science Education* entitled "An Evaluation of Certain Popular Science Misconceptions."¹ In this article, the author defined a "misconception" as

"...any unfounded belief that does not embody the element of fear, good luck, faith, or supernatural intervention." (208)

Since then, the term “misconception” has been reclassified, redefined, and finally replaced. There are some who feel that the term “misconception” is a misnomer. In the article “Research on Alternative Conceptions in Science,”² Wandersee poses the argument that the term “misconception” implies that the idea held by the students has a “negative value” and serves no productive purpose for the student. In the paper "Studying conceptual change in learning physics,"³ Dykstra claims that the term “misconception”

“...is inappropriate for referring to student’s alternative conceptions because it ignore(s) the rational basis of those conceptions; they are rationally based on the students’ experiences with the world and prove

---

adequate for the person-on-the-street to accomplish most everyday tasks.”  
(621)

With this in mind, the term alternative conception will replace the term “misconception” for the duration of this study.

Now that the terminology has been established, an exact definition of the phrase should be solidified. However, even today, there is only a fuzzy definition of what entitles an idea to be called an alternative conception. In the same article listed above, Dykstra gives several examples of what is often meant by the term “alternative conception.”

“1. The “mistaken” answers students give when confronted with a particular situation; e.g., “The sun goes around the Earth.” The focus is not why students might think this, that is, there is no attention to what the student believes about how the world works, which would make such statements seem reasonable.

2. The ideas about particular situations students have which evoke the “mistaken” answers…

3. The fundamental beliefs students have about how the world works, which they apply to a variety of different situations…” (621)

David Hammer, in his article "Misconceptions or P-Prims: How may alternative perspectives of cognitive structure influence instructional perceptions and intentions?"⁴, writes that alternative conceptions

“1. are strongly held, stable cognitive structures;

2. differ from expert conceptions;

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3. affect in a fundamental sense how students understand natural phenomena and scientific explanations.

4. must be overcome, avoided, or eliminated for students to achieve expert understanding.” (99)

For clarification, the David Hammer definition of alternative conception will be used in this survey.

The purpose of this study was to research alternative conceptions of astronomy and space science. Many of the alternative conceptions and alternative conception theories explored throughout this study were also examined in the article by Danaia and McKinnon, “Common Alternative Astronomical Conceptions Encountered in Junior Secondary Science Classes: Why Is This So?” The data reported in this article was collected by giving the Astronomy Diagnostic Test (ADT) to Australian students. The multiple choice questions used for this study, which are available in Appendix A-2 and A-3, were also taken from the ADT. The ADT will be discussed further in Chapter 3. Relevant results contained in this article are listed in Tables 2.1-4. (39, 40, 43, 44, 45, 46)

<table>
<thead>
<tr>
<th></th>
<th>Grade</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent Movement of the Sun across the Sky</td>
<td>4.90%</td>
<td>8.90%</td>
<td>10.60%</td>
<td></td>
</tr>
<tr>
<td>Phases of the Moon</td>
<td>31.50%</td>
<td>44.20%</td>
<td>41.40%</td>
<td></td>
</tr>
<tr>
<td>Causes of the Seasons</td>
<td>10.30%</td>
<td>18.50%</td>
<td>23.70%</td>
<td></td>
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</table>

Table 2.1: Percentage of All Students Who Chose Correct or Partially Correct Responses Containing No Alternative Conceptions

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The Sun always rises in the east and sets in the west.  

<table>
<thead>
<tr>
<th>Grade</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Sun always rises in the east and sets in the west.</td>
<td>38.60%</td>
<td>40.80%</td>
<td>39.90%</td>
</tr>
<tr>
<td>The Sun is directly overhead at noon every day.</td>
<td>19.80%</td>
<td>35.20%</td>
<td>28.20%</td>
</tr>
<tr>
<td>The Sun is only directly overhead on one or two days per year.</td>
<td>24.70%</td>
<td>10.50%</td>
<td>19.20%</td>
</tr>
</tbody>
</table>

Table 2.2: A Breakdown by Conception of Those Students Who Displayed Alternate Conceptions Related to the Apparent Movement of the Sun Across the Sky

Seasons are caused by the Earth's distance from the Sun.  

<table>
<thead>
<tr>
<th>Grade</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasons are caused by the Earth's distance from the Sun.</td>
<td>85.40%</td>
<td>88.90%</td>
<td>91.70%</td>
</tr>
</tbody>
</table>

Table 2.3: A Breakdown by Conception of Those Students Who Displayed Alternate Conceptions Related to the Causes of the Seasons

<table>
<thead>
<tr>
<th>Grade</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phases of the Moon are caused by the shadow of the Earth.</td>
<td>27.70%</td>
<td>29.70%</td>
<td>51.20%</td>
</tr>
<tr>
<td>Phases of the Moon are caused by cloud blocking the light reaching the Moon.</td>
<td>23.60%</td>
<td>13.90%</td>
<td>14.00%</td>
</tr>
<tr>
<td>Phases of the Moon are caused by the Sun covering the Moon.</td>
<td>7.50%</td>
<td>6.90%</td>
<td>14.00%</td>
</tr>
</tbody>
</table>

Table 2.4: A Breakdown by Conception of Those Students Who Displayed Alternate Conceptions Related to the Phases of the Moon

Of the three relevant astronomical topics covered by this paper, students who took part in the survey were the most confident with phases of the Moon, with an average of 39% of the students giving, if not wholly correct, at least partially correct responses with no
apparent alternative conceptions. It is also noteworthy to see that one of the alternative conceptions about the sun’s path is

“The Sun is only directly overhead on one or two days per year.” (40)

This conception is false for the students reported in the paper because

“…none of (the sample population) lived with the tropical regions of Australia.” (39)

This alternative conception is not applicable for all locations, because there are places on the Earth where the sun does appear overhead. The consecutive nature of the subjects’ grade levels make it difficult to gauge whether the students that gave the correct answer will continue carrying the correct conception, or if they will fall back to one of the other, more popular, alternative conceptions.

Wilson Gonzalez-Espada had approximately 100 of his “PHSA 1013: Introduction to Physical Science” students pick their top 5 alternative conceptions from a comprehensive list. The selection criterion was that the students must have held one of these alternative conceptions until they read the list, which contained the alternative conceptions and the correct answers. Gonzalez-Espada then compiled a “top ten” of alternative conceptions as chosen by the students.

“… (in order of decreasing frequency)

• Seasons are caused by the Earth’s changing distance from the Sun.
• Meteors are falling stars.
• God and angels cause thunder and lightning.
• Batteries have “electricity” inside.

• The phases of the Moon are caused by the shadow of the Earth on the Moon.
• The pupil of the eye is a black object or spot on the surface of the eye.
• All metals are attracted to a magnet.
• All stars are the same size (or have the same brightness).
• Continents do not move.
• The Sun will never burn out.” (37)

The fact that an astronomy alternative conception is the most frequent alternative conception chosen by the students in the survey only serves to strengthen the argument that astronomy alternative conceptions are very prevalent. Also, five of these top ten alternative conceptions are astronomy related, which strengthens the argument that astronomy alternate conceptions are numerous. Two of these conception topics will be explored in this study: the Earth’s seasons and phases of the Moon.

Finally, in the article “Early Elementary Students’ Development of Astronomy Concepts in the Planetarium,” a study is discussed that deals with several key alternative conceptions. In this study, 42 English students in year 6 (10-11 year olds) were surveyed. 64% of those students didn’t believe the Moon appears to move across the sky and 86% of students didn’t believe the stars appear to move. It is also stated in this paper that

“A prevalent view among young children is that the Moon’s phases are caused by the movement of clouds while many older children and adults use the Earth’s shadow (the eclipse model) to explain the changing phases.”(193)

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This suggests an evolution of alternative conceptions; substituting one completely nonscientific explanation of a natural phenomenon for a slightly more scientific, albeit still flawed, explanation.

As well as exploring alternative conceptions and the strength of those alternative conceptions, it was also deemed to be beneficial to explore some of the factors that influence susceptibility of students to these alternative conceptions. The paper “Parents’ education, cognitive ability, educational expectations and educational attainment: Interactive effects” by Yoav Ganzach, states

“The education of the parents and the cognitive ability of the child are probably the most important determinants of educational attainment.”

Ganzach supports this claim with data on 8570 subjects.

“Thus the data do indeed justify the emphasis on parents’ education and cognitive ability in the study of the determinants of educational expectations and educational attainment.”

This article suggests that the higher the grade level completed by a member of a student’s immediate family, the less likely that student is to have any strong or resilient alternative conceptions.

There is much time spent researching “the gender gap” in a variety of subjects and occupations. “The gender gap” refers to the difference in test scores between men and women. The paper entitled “Trends in gender differences in mathematics and science (TIMSS 1995–2003),” 16 countries participated in an international survey designed to test for gender differences in 7 subject areas; geometry, algebra, measurement, Earth science,

8 Ganzach, Yoav “Parents’ education, cognitive ability, educational expectations and educational attainment: Interactive effects” British Journal of Educational Psychology 70. 419- 441(2000)
life science, physics, and chemistry. This was an eight year study, giving a test in 1995, 1999, and again in 2003. The results were promising for the females in the sciences, in that

“Our most interesting results were those for the previously male-dominated content areas of chemistry and physics, where, on average, the gender gap closed by about 15 points between 1995 and 2003” (72)

This would still represent a slight advantage to males in the sciences, though the advantage seems to be narrowing.

In an article by Wei-Jun Jean Yeung entitled “The black–white test score gap and early home environment,” studies based on several national datasets were discussed. It was found that

“…racial achievement differences appeared in all of them, although the size of the difference varied by study and measure of achievement. The differences range from half a standard deviation to more than a full standard deviation. The magnitude of these gaps is found to vary across child’s age, exist before children enter kindergarten, widen as they move through elementary and middle schools, and persist into adulthood” (412)

Harold Berlak, in his paper “Race and the Achievement Gap,” discusses the racial gap in terms of standardized test scores. He asserts a 10 percent gap in standardized test scores between white and nonwhite students. The 2008 Ohio

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S.A.T. scores\textsuperscript{12} dictate a higher gap than even Berlak claims. These results can be seen in Table 2.5.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|}
\hline
Ethnicity & Number of Test-Takers & Mean Math Score & Percentage (out of 800) \\
\hline
White & 25639 & 554 & 69.25% \\
Asian, Asian American, or Pacific Islander & 1390 & 612 & 76.50% \\
Under Represented Minorities & 3845 & 452 & 56.55% \\
\hline
\end{tabular}
\caption{2008 S.A.T. Math Scores}
\end{table}

The results of these papers and test scores suggest that White and Asian students could be less susceptible to alternative conceptions than under-represented minorities.

Chapter 3

Methods

The first step that must be taken before testing any student body is, of course, creating the test. Two separate versions of this test were used; one version for the fifth and eighth grade students, which is located in Appendix A-2, and one version for the college students, which is located in Appendix A-3. The questions that probed physical knowledge were identically worded and appeared in the same order in both versions of the test. However, the questions probing demographic data varied between populations.

The fifth and eighth grade tests contained questions asking for the students’ ID numbers (to ensure anonymity), gender, and ethnic background. Because fifth and eighth grade students are under the age of 18, a consent letter was sent home with the students to gain permission from a parent or guardian. On the letter, a question was included asking for the highest education level of the child’s immediate family. This information was sought because a link has been found in previous studies between the education of a child’s family and that child’s test scores. This link is demonstrated in the paper “Parents’ education, cognitive ability, educational expectations and educational attainment: Interactive effects” by Yoav Ganzach\textsuperscript{13}, which was discussed previously.

The college students’ tests not only contained questions asking for the students’ genders and ethnic backgrounds, but also contained several questions not included in the fifth and eighth grade version. Due to the expected ages of the subjects, the test includes questions asking if the subject is over the age of 18 and if we had permission to use their test in this study. Only subjects 18 years or older had their tests evaluated. By excluding minors in college from this study, parental permission did not need to be sought for this

\textsuperscript{13} Ganzach, Yoav “Parents’ education, cognitive ability, educational expectations and educational attainment: Interactive effects” British Journal of Educational Psychology 70. 419- 441(2000)
population. This question probing age was not necessary for the fifth and eighth grade tests because parent permission slips were sent home and collected prior to the testing day.

The content questions were chosen so that the test would contain material covered by the space science portion of the Ohio Academic Content Standards. The Academic Content Standards (ACS) \(^{14}\), which are guidelines that lay out what subject knowledge a student should have at specific grade levels, differ from state to state. Due to these possible ACS differences, a question probing the state in which the subject attended was added to the college test. In the state of Ohio, the fifth grade “space science” ACS state that by the end of fifth grade, the students should be able to

“1. Describe how night and day are caused by Earth's rotation.
2. Explain that Earth is one of several planets to orbit the sun, and that the Moon orbits Earth.
3. Describe the characteristics of Earth and its orbit about the sun (e.g., three-fourths of Earth's surface is covered by a layer of water [some of it frozen], the entire planet surrounded by a thin blanket of air, elliptical orbit, tilted axis and spherical planet).
4. Explain that stars are like the sun, some being smaller and some larger, but so far away that they look like points of light.” (48)

The eighth grade Ohio “space science” ACS state that by the end of eighth grade, the students should be able to

“1. Describe how objects in the solar system are in regular and predictable motions that explain such phenomena as days, years, seasons, eclipses, tides and Moon cycles.

2. Explain that gravitational force is the dominant force determining motions in the solar system and in particular keeps the planets in orbit around the sun.
3. Compare the orbits and composition of comets and asteroids with that of Earth.
4. Describe the effect that asteroids or meteoroids have when moving through space and sometimes entering planetary atmospheres (e.g., meteor-"shooting star" and meteorite).
5. Explain that the universe consists of billions of galaxies that are classified by shape.
6. Explain interstellar distances are measured in light years (e.g., the nearest star beyond the sun is 4.3 light years away).
7. Examine the life cycle of a star and predict the next likely stage of a star.
8. Name and describe tools used to study the universe (e.g., telescopes, probes, satellites and spacecraft)." (50)

By the time fifth grade Ohio students cover the space science portion of their curriculum, those students should have covered most (if not all) of the material asked of them in the test. Ohio students should cover all of the test material by the end of their eighth grade.

The questions on the survey that covered the ACS were selected from The Astronomy Diagnostic Test (ADT) Version 2.0. This test was developed by the Consortium for Astronomy Education Research (CAER)\textsuperscript{15}, which consists of faculty from four universities: Montana State, University of Maryland, University of Nebraska, and the University of New Mexico. The ADT was designed as a diagnostic tool to determine the effectiveness of different styles of teaching astronomy. The ADT Version 1.0 drew from two preceding surveys. The first was a 47-item multiple-choice survey

\textsuperscript{15} Collaboration for Astronomy Education Research (CAER) “Astronomy Diagnostic Test (ADT) Version 2.0” 1999 <http://solar.physics.montana.edu/aae/adt/ADTv2.0.PDF>
called the “Project STAR Astronomy Concept Inventory.” The second predecessor was the Misconceptions Measure, which was developed by Michael Zeilik. The ADT Version 1.0 was then rewritten into version 2.0 using standard psychometric rules along with student responses to open ended questions. The ADT Version 2.0 was developed with carefully selected “distracters.” A “distracter” is a common alternative conception that, combined with the phrasing of the question, is used to bring out the students’ sincere ideas of the information being probed. Questions were chosen from the ADT that covered several subjects for use in this study; phases of the Moon, the tilt of the Earth axis and the apparent movement of the sun and stars across the sky, and distances to various celestial objects in the solar system. These questions appeared with identical wording and in the same order in both tests to ensure standardized results among the different grade levels. These questions can be viewed in Appendix A-2 and Appendix A-3.

Finally, a single probe question is used to gain a further understanding on students’ ideas about the phases of the Moon. A “probe” is an open-ended question designed to allow a students’ true perceptions on a topic to be revealed and allows the student an opportunity to write about those perceptions. The probe used in this study, which is shown below, was taken from Uncovering Student Ideas in Science: 25 formative assessment probes. Using this probe, the students can agree with a faceless student (Sophia, Drew, etc.) instead of simply stating their beliefs about what causes the phases of the Moon. This technique of passive agreement is more likely to get students to state their actual beliefs, instead of simply stating what they think the teacher wants to hear. Also, the probe itself is designed to get the students thinking about science.

“The assessment probes included in (Uncovering Student Ideas in Science: 25 formative assessment probes) were purposely developed to elicit students’ thinking about specific ideas in science. Several of these ideas have been identified as difficult for student to learn due to their abstract or counterintuitive nature.” (ix-x)

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Because “phases of the Moon” is such a confusing and perhaps counterintuitive subject, a probe was created Keeley et al. covering many possible alternative conceptions.

In order to put the results in a context, demographics of the subject populations were researched. For the fifth and eighth grade demographics, we turned to the Ohio Department of Education’s District report card\(^\text{18}\). The results of this report card can be seen in Table 3.1.

<table>
<thead>
<tr>
<th>Under Represented Minorities</th>
<th>Asian or Pacific Islander</th>
<th>White, non-Hispanic</th>
<th>Economically Disadvantaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.30%</td>
<td>1.70%</td>
<td>92.90%</td>
<td>30.80%</td>
</tr>
</tbody>
</table>

Table 3.1: Talawanda Students’ Demographics

The Talawanda school district is an interesting cross section of socioeconomic statuses. Because Talawanda lies in a semi-rural area, there are many students from a lower economic background, as shown by the 30.8% percent of economically disadvantaged students. However, the Talawanda school district also contains Oxford, Ohio, which houses many of the faculty and staff of Miami University. Since many of the children of these Miami employees go to Talawanda, the district, therefore, also holds a sizable number of children that lie in the middle to upper socioeconomic bracket. This duality makes the Talawanda school district a better representation of Ohio schools than other individual districts.

For the college data, we turned to Miami University’s institutional research department\(^\text{19}\). Its website contains demographic data from the past ten years of Miami’s history, all in Excel format. Table 3.2, which can be seen below, contains the demographic data from degree seeking students from the 2008-2009 school year.

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\(^{18}\) Ohio Department of Education “District Report for ‘Talawanda City’ ” 2008
<http://ilrc.ode.state.oh.us/districts/District_Questions.asp?sel=046151,Talawanda%20City,Butler %20County>

\(^{19}\) Miami University: Office of Institutional Research “CDS (Common Data Set) 2008-2009” 2008
http://www.units.muohio.edu/oir/CommonDataSet/CDSMain.htm
<table>
<thead>
<tr>
<th>Under Represented Minorities</th>
<th>Asian or Pacific Islander</th>
<th>White, non-Hispanic</th>
<th>Have Financial Need</th>
<th>Ohio Natives</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.19%</td>
<td>2.75%</td>
<td>85.05%</td>
<td>39.13%</td>
<td>63.50%</td>
</tr>
</tbody>
</table>

**Table 3.2: Miami University Students' Demographics**

When discussing the importance of demographics in science education, ethnicity is usually divided into two groups. Non-Hispanic Whites and Asians and grouped into one group, where the rest fall into the second group. This second group is commonly referred to as “under represented minorities.” By comparing the two demographics, it can be observed that Miami University contains more underrepresented minorities, with 12.19%, than the Talawanda school district, with 5.3%.

After creating, but before administering, the survey, permission had to be sought by submitting an application to Miami University’s Internal Review Board (IRB). Completion of the Collaborative Institutional Training Initiative (CITI) online course involving the study of human subjects is one of the first IRB requirements that must be completed in order to do research involving human subjects. In preparation of this study, the CITI course was completed on March 23, 2008. Also, the application required a statement of the study’s purpose, which as stated in Chapter 1, is

“…to determine what Astronomy (Space Science) alternative conceptions, if any, are presented by fifth grade, eighth grade, and college students. This project will help to determine which of the space science alternative conceptions held by students are the most resilient and, thus, help teachers eliminate these alternative conceptions.”

In the IRB application, Jennifer Blue, my advisor, was listed as the principal investigator of the study. It was then required to state the approximate size, grade levels, and some demographic data of the subject population. It was stated in the application that for fifth graders, three schools would be surveyed, each with two classes of
approximately 25 students. Also, 12 classes from two separate teachers would be
surveyed from Talawanda Middle School. Finally, we estimated that 200 college students
from two sections of PHY 172 would be surveyed. These were over approximations due
to the availability of the students and parents to refuse participation. The IRB application
also asked about risks, which we deemed negligible, and the benefits, which were stated
in the purpose of the study.

The IRB application also asked about the method by which anonymity or
confidentiality would be maintained. “Confidential” describes a study in which the
researcher is allowed access to the names of the subjects being studied, with the explicit
intent of not revealing those names to anyone. “Anonymous” describes a study in which
measures are taken to keep even the researcher ignorant of the names of the subjects
involved. Sometimes no names are collected in an anonymous study. It was decided that
this study should be kept anonymous. In order to keep anonymity intact, the students’
school IDs were collected and used to match the students’ tests to their corresponding
permission letters. This was done to gather the educational level data contained on the
permission slips while keeping the names separate from the data. This matching was done
by Jeff Winslow, the Talawanda school district’s science instructional leader. The Miami
University students were also not required to give any names to ensure anonymity.

Finally, the IRB required that the permission letters from all the principals, the
consent letters for the fifth, eighth, and college students, the permission letter sent home
with the fifth and eighth grade students, the letters sent to the teachers of the potential
subjects, and a copy of both tests be attached at the end of the application. The IRB in its
entirety can be seen in Appendix A. All documentation except for the tests can be seen in
Appendix A-1, where the tests can be found in Appendix A-2 and A-3. After fulfilling all
of the IRB applications requirements and completing the application, permission was
sought by sending the application to the IRB. Finally, after the IRB approved the
application, human subject testing could occur.

For all subjects, testing took no more than one class period (50 minutes) and the
informed consent sheet was read aloud to the entire class before testing occurred. The
data from the college students was received first. The surveys were given in two separate
sections; in one section the surveys were distributed by me, Adam Hicks, and the other
section’s surveys were distributed by Jennifer Blue. We used Scantron sheets to expedite the grading and the entry of data of this large subject population. The data was taken in the first week of class before a sizable amount of material could be covered. The Ohio high school ACS does not specifically require knowledge of the content contained on this survey. With astronomy not required in high school, in favor of classes such as biology, chemistry, geology, and non-astronomy physics, we assumed the vast majority of the college subjects had not had any major classroom astronomy coverage since the eighth grade. With this assumption, the college surveys can be used as a post-test to the eighth grade surveys.

After conversing with two of the eighth grade teachers, dates were scheduled to gather data in their classrooms. Mr. Plank, an eighth grade teacher at Talawanda Middle School, was the first eighth grade teacher to have his classes surveyed. This survey was distributed immediately before winter break in early December. Mrs. Dowd, the second eighth grade teacher, allowed her classes to be surveyed immediately after winter break. Although Mr. Plank’s classes were surveyed first, the college data was entered and analyzed first due to the extra steps needed to ensure the anonymity of the fifth and eighth grade students.

Finally, it was time for the fifth grade data to be taken. Due to the hectic nature of the fifth grade curricula, by which I mean the fifth grade achievement test which is given near the end of the second semester, the data from fifth grade was not collected until the beginning of May. Four classes were surveyed, three of which were from Mrs. McQueen’s classes at Marshall Elementary School. The other was from Mrs. Garver’s class at Bogan Elementary School. Both of these schools are part of the Talawanda School District. All of the fifth grade data was taken in one week, so all of the students had similar content knowledge.

After collecting the data from all three subject sets, it was entered into Microsoft Excel. Excel was used to sort the data and create all graphs used. Finally, it was time to analyze the data and search for astronomy alternative conceptions.
Chapter 4

Survey Results and Alternative Conception Evaluation

After collection and data entry, it was tallied that there were 197 college student surveys, 134 eighth grade student surveys, and 35 fifth grade student surveys. Excel was used to create graphs so that the results of the tests could be more easily seen and compared. Since there are two different versions of the test, there are also two different numbers that correspond to each question. For the sake of simplicity and clarity, the graphs below will be denoted by the question number from the Miami University student test. The light yellow data set represents the fifth grade data, the pink data set represents the eighth grade data, and the light blue data set represents the college data. The correct answer in every graph is denoted by a darker bar in the grade’s respective color. Using this method of depicting the data, patterns begin to emerge and alternative conceptions revealed.

The first few questions asked about the subjects, either on the instrument itself or on the permission letter sent home with the fifth and eighth grade subjects, probed demographic data. The following figures depict the results of those questions.
Figure 4.1: Results of Question 3 - Where did you go to elementary school? (College Students Only)

The 67.01% of Ohio educated students that took this survey is consistent with the 63.5% of Ohio natives that attend Miami University, as stated by Miami’s institutional research department.²⁰

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²⁰ Miami University: Office of Institutional Research “CDS (Common Data Set) 2008-2009” 2008
<http://www.units.muohio.edu/oir/CommonDataSet/CDSMain.htm>
Figure 4.2: Results of Question 4 - Are you male/a boy or female/a girl?

There are no gender statistics given either by the Talawanda Report Card\textsuperscript{21}. Due to this lack of overall statistics for the Talawanda school district, there is no way of knowing how comparable our subject population is to that of Talawanda. However, the office of institutional research\textsuperscript{22} states that Miami University has 46.5\% men and 53.6\% women enrolled. Although the reported statistics for Miami show a higher female than male population, it is possible that because the data was taken in a science class the male/female ratio evened out. Regardless, it seems that our college student population is comparable to that of Miami as a whole. It is interesting to note that the older the population, the more even the male to female ratio. Because the data from the fifth and eighth grade students is a representation of only those who submitted the permission

\textsuperscript{21} Ohio Department of Education “District Report for ‘Talawanda City’ ” 2008 <http://lrc.ode.state.oh.us/districts/District_Questions.asp?sel=046151,Talawanda%20City,Butler%20County>

\textsuperscript{22} Miami University: Office of Institutional Research “CDS (Common Data Set) 2008-2009” 2008 http://www.units.muohio.edu/oir/CommonDataSet/CDSMain.htm
slips, it is possible that the fifth and eighth grade girls were simply more diligent at returning those slips.

![Figure 4.3: Results of Question 5 - What is your ethnic background?](image)

The statistics collected from the subject population are very similar in both the Talawanda school district and Miami University. The Talawanda population for this study is slightly less White (by 2%-4%) and the Miami subject population is slightly more white (5%) than the respective overall populations. The under-represented minority population for this study is within 1% of the demographics given by office of institutional research\(^{23}\) and the Talawanda Report Card\(^{24}\). There were a higher percentage of Asian/Pacific Islander students in this study than reported. All of the discrepancies reported are minor and support that the population surveyed is a good general representation of the Talawanda School District and Miami University.

Figure 4.4: Results of the Permission Slip Question - The highest grade level completed of my child’s immediate family is:

The percentage data displayed in Figure 4.4 represents the percentage of students whose family answered the question on the parental permission slip sent home with the students. It is with these statistics that we will be examining the relevant alternative conception susceptibility. With no predicted statistics about the highest grade level of the students’ immediate family, there is, again, no way to see if this data is an accurate representation of the Talawanda school district as a whole. The two grades are roughly comparable to each other. Even though the eighth grade has fewer families with bachelor’s degrees, they have a greater number of families with graduate degrees.

Now that the demographic / socioeconomic data has been presented, the focus can shift to the content based questions, which were next on the test and are depicted in Figures 4.5 – 4.21.
Figure 4.5: Results of Question 6 - As seen from your current location, when will an upright flagpole cast no shadow because the Sun is directly above the flagpole?

From the very first question, an alternative conception is revealed in the obvious popularity of one of the incorrect answers. The correct answer is that, from Oxford, Ohio, a flagpole will always cast a shadow during the day because the Sun will never be directly above the flagpole. The only latitudes where a flagpole will cast no shadow are between the Tropic of Cancer (23° 26´ N) and the Tropic of Capricorn (23° 26´ S). This is due to the axial tilt of the Earth with respect to the plane of the Earth’s orbit. From a frame of reference on the Earth’s surface, it appears as if the Sun is moving north and south with the changing seasons, with the northern and southern most points being the Tropics. This oscillation means that twice a year between the Tropics, and once on the Tropics, the Sun will be directly overhead and cast no shadow. Since Oxford, Ohio is approximately at 40º N, the Sun will never be directly overhead, making the correct answer “Never from your current location.” Only 20% of the students in each grade gave the correct answer. The most popular alternate conception found by this question is that a flagpole will not cast a shadow everyday at noon. This alternative conception can also be
seen in “Common Alternative Astronomical Conceptions Encountered in Junior Secondary Science Classes: Why Is This So?” by Danaia and McKinnon. The “every day at noon” alternative conception is more prevalent in this study, with in-between 50 and 65% of students holding this alternative conception opposed to only 20-35% in the study from the article. One can observe a considerable decline in the thought that there is no shadow every day at noon between fifth and eighth grades. However, instead of shifting their thoughts to the correct conception, the students’ responses were shifted to the first days of the seasons.

![Figure 4.6: Results of Question 7: When the Moon appears to completely cover the Sun (an eclipse), the moon must be at which phase?](image)

This question is a prime example of the focus of our study. In order for the Moon to block the Sun, the Moon must be in-between the Earth and the Sun. This, in turn,

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means that the entire light side of the Moon would be facing the Sun and the entire dark side of the Moon would be facing the Earth. When the entire dark side of the Moon faces the Earth, it is, by definition, called a new Moon. One can see by the graph that 70% of the students were split between two answers: the correct answer and that a full Moon would be necessary. For the most part, the other answers were largely dismissed. If we look at the correct answer, we can see a 30% increase of correct answers between fifth and eighth grade. We see this same 30% as a decrease in the full Moon alternative conception between fifth and eighth grade. This suggests that through teaching, this alternative conception has been dramatically overturned and would seem to be a victory for our educational system. However, we can see a 25% decline in the right answer from eighth to college, which corresponds to a 10% increase of the alternative conception from eighth to college. This data would suggest that a substantial amount of students reverted back to the old alternative conception, even after instruction. There is also a 15% increase in the answer “no particular phase” between eighth and college. This may suggest a combining of the correct answer and the alternative conception. Unable to reconcile the two ideas in their minds, some students may choose to believe both are true and mark the only answer that encompasses both conceptions.
Figure 4.7: Results of Question 8 - Imagine that the Earth's orbit was changed to be a perfect circle about the Sun so that the distance to the Sun never changed. How would this affect the seasons?

This was the one question going into this study where I was the most confident of getting interesting results, and interesting results are indeed shown. The correct answer is “we would continue to experience seasons in the same way we do now.” Both this question and question 6 probe an understanding of the axial tilt of the Earth with respect to its orbital plane. As described in question 6, this tilt causes the flagpole shadow discussed previously. This tilt affects the seasons by making one hemisphere closer than the other depending on the time of year. This tilt also gives the summer hemisphere direct sunlight and the winter hemisphere indirect, angled sunlight. It is easy to understand how the idea of “closer is hotter” can be internalized. This idea is learned from childhood; however, this idea can also lead to alternative conceptions if misinterpreted. It is true that the Earth’s orbit around the Sun is slightly elliptical and not completely circular.
However, the eccentricity of Earth orbit is only 0.0167\(^2\). This means that the furthest and closest distances from the Earth to the Sun differ from the mean Sun-Earth distance by less than 2\%. Although this eccentricity does not affect the seasons in any substantial way, the knowledge that the Earth’s orbit is not completely circular skews some of the students’ minds into believing that the elliptical orbit is cause of the seasons. This idea is only exacerbated by the pictures in physics textbooks. These pictures, such as the example given below, depict an exaggerated view of Earth’s orbit, making it appear that the orbit is tremendously eccentric.

![Diagram of Earth's orbit with labeled points: Aphelion, Perihelion, Pernice, Apogee, Moon Orbit, Earth Orbit]

**Figure 4.8: Example of an exaggerated depiction of Earth’s elliptical orbit\(^ {27} \)**

In the results, we can see these two conflicting ideas: the seasons being caused by the Earth’s tilt and by its orbit.

It is first interesting to note the considerable upward trend in the “…LESS noticeable” answer and the downward trend for the “…MORE noticeable” answer. It is also noteworthy that the most consistent answer comes from the belief that the season are caused only by the orbit of Earth around the Sun. Approximately 30\% of the students in each grade gave this answer. Finally, the pattern seen in the correct answer for this question is very similar to the pattern for the correct answer of question 7. The first shift

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\(^{26}\) Williams, David R. “Earth Fact Sheet.” 2007. NASA. 10 Jun 2009
<http://nssdc.gsfc.nasa.gov/planetary/factsheet/Earthfact.html>

\(^{27}\) NASA “Solar System Exploration” 2008 NASA 10 Jun 2009
<http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=6763>
in the correct answer is an upward shift, due to the understanding gained by classroom learning. I think it is a fair assumption that this phenomenon is not easily observed and understood, and therefore any knowledge of this phenomenon must be facilitated. However, the second downward shift would seem to indicate that the students have either forgot this imparted knowledge or reverted back to their original ideas. However, if this recursion did occur, we would see similar results for fifth and college students, which we clearly do not. So the question becomes, in which direction do the students’ ideas sway? The answer is that the students combine the two ideas. Almost 50% of college students said that the seasons would be much less noticeable if Earth’s orbit was circular. It stands to reason then that the college students believe that the seasons are dependent on both the Earth’s orbit and some other factor, which we can assume is the Earth’s tilt. Also, the percentage of individuals who chose the correct answer here was similar to the percentages given in “Common Alternative Astronomical Conceptions Encountered in Junior Secondary Science Classes: Why Is This So?” 28 Between 10% and 23% of the subjects in the articles study chose the correct answer, where 9% to 25% chose the correct answer in this study. With this combination of pure alternative conception and scientifically accurate ideas, the student deduces that changing the orbit would greatly affect, but not wholly eliminate, the seasons.

This question is very closely tied into question 6. The tilt of the Earth with respect to the plane of Earth’s orbit causes the appearance of the Sun “moving” north and south as the year passes. In the northern hemisphere, two weeks after September 22 will be closer to winter, and the Sun will therefore appear to set further south. Every answer drew approximately 30% of the students in each grade level. This distribution suggests random guessing and does not reveal any information on alternative conceptions. There is one interesting blip in the data, and that the fact the eighth graders overwhelming picked “farther north.” I have uncovered no research explaining these results, nor can I think of

Figure 4.9: Results of Question 9 - On about September 22, the Sun sets directly to the west as shown on the diagram below. Where would the Sun appear to set in two weeks?

This question is very closely tied into question 6. The tilt of the Earth with respect to the plane of Earth’s orbit causes the appearance of the Sun “moving” north and south as the year passes. In the northern hemisphere, two weeks after September 22 will be closer to winter, and the Sun will therefore appear to set further south. Every answer drew approximately 30% of the students in each grade level. This distribution suggests random guessing and does not reveal any information on alternative conceptions. There is one interesting blip in the data, and that the fact the eighth graders overwhelming picked “farther north.” I have uncovered no research explaining these results, nor can I think of
any reasons to rationalize this alternative conception. Perhaps this topic should be more thoroughly covered in the classroom while talking about seasons and the tilt of the Earth’s axis.

Figure 4.10: Results of Question 10 - If you could see the stars during the day, this is what the sky would look like at noon on a given day. The Sun is near the stars of the constellation Gemini. Near which constellation would you expect the Sun to be located at sunset?
This question has a very clear alternative conception that overshadows all of the other answers. The correct answer is “Gemini.” Although it may appear as if the Sun is revolving around the Earth, the Earth is the object revolving. Because it is the Earth that is moving, the entire sky would appear to rotate with the Sun. This being the case, if you could see the stars during the day the Sun and Gemini would appear to overlap throughout the day. In fact, all celestial bodies have rise and set times. With all of this being said, a staggering number of students still believe that the stars appear to be stationary in the sky, which leads students to believe that the correct answer is “Pisces.” Also, the number of students with this alternative conception only grows from fifth grade to college. This indicates an alternative conception that is not being effectively battled in the classroom and actually gains more of a foothold over time. There is a 61% gap between the correct answer and the alternative conception in college students. This amazingly large gap indicates that this is the strongest alternative conception presented in this study. By “strongest,” I mean that this alternative conception is held by more students in a single age range than any other alternative conception in this study. This alternative conception can also be seen in “Early Elementary Students’ Development of Astronomy Concepts in the Planetarium,”29 where 86% of grade 6 students didn’t recognize the fact that the stars appear to move across the sky just as the Sun does. Even at night, the rotation of the stars is very slow and, because starlight is much dimmer than sunlight, this phenomenon is not apparent to a casual observer. This, coupled with the fact the question asks the student to assume they can see the stars during the day, which is a practical impossibility, makes it hard for any kind of real life experience to battle this alternative conception.

Figure 4.11: Results of Question 11 - Compared to the distance to the Moon, how far away is the Space Shuttle (when in space) from the Earth?

The Moon orbits at a distance of 382,500 km above the Earth’s surface, while the international space station hovers at a measly 354 km. This means the space station orbits at 0.09% of the distance that the Moon orbits. Because the space shuttle is usually even closer to Earth than the space station, this indicates the answer is most certainly “very close to the Earth.” The fifth grade students’ data exhibits a somewhat even distribution, with the answer percentages lying between 17% and 32%. This suggests no strong alternative conceptions and perhaps an insufficient knowledge about the subject. The eighth grade and college data tells a more interesting story. The majority of eighth grade students, about 40%, thought that the space shuttle (when in space) was about half way to the Moon. The college students overwhelmingly, with 56% of the students, chose “Very close to the Earth.” This represents a substantial growth in the understanding of

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shuttle orbits. Part of this may be due to teaching, and part of this may be due to the publicity of orbiting objects such as satellites and the space station in the media. The alternative conception seen here is that the space shuttle travels much further away from the Earth than it actually does. However, this alternative conception seems to be less potent than some of the others in this study.

Figure 4.12: Results of Question 12 - Which of the following lists is correctly arranged in order of closest-to-most-distant from the Earth?

The correct results for this question follow a very nice upward trend. This is a good example of learning and retaining information. Each consecutive grade level has a sizeable increase in the correct answer; a 19% jump between fifth and eighth, and a 12% jump between eighth and college. This indicates a greater understanding of locations of celestial object in the solar system and beyond. The only significant alternative conception observed here, which states the stars are closer to the Earth than Pluto, drops in a stepwise fashion, indicating a non-persistent alternative conception. Although fleeting, this inability to place these simple and common bodies in an order is somewhat
disturbing. Approximately 24% of the college students surveyed, that is to say almost one quarter of the 172 students surveyed at Miami University, either thought that Pluto was further than the stars or closer than the Sun. It is also worth mentioning that 15% of the eighth graders surveyed said that the Sun was closer than our Moon. These statistics are unnerving, despite the fact that over half of the eighth grade students and two thirds the college students surveyed answered correctly.

![Diagram showing the Earth, Sun, and five possible positions for the Moon, with percentages for each position across different grade levels.]

**Figure 4.13: Results of Question 13 - The diagram below shows the Earth and Sun as well as five different possible positions for the Moon. Which position of the Moon would cause it to appear like the picture at right when viewed from Earth?**
This is another example of the alternative conception that the phases of the Moon are caused by the Earth’s shadow on the Moon, as in an eclipse. The correct answer is position “D”. With the Moon slightly in-between the Earth and Sun, most of the dark half would be visible, and only a crescent shaped sliver of the light half could be seen from Earth. Examining the fifth grade data indicated random guessing and unfamiliarity with the subject material. The fifth grade distribution varies between 14 and 20%, suggesting that the fifth grade students surveyed either lacked the spatial recognition skills needed to solve the problem, or lacked in any conception about the phases of the Moon, correct or otherwise. However, the percentage of students who chose the right answer increased 33% between fifth and eighth grade. This, of course, indicates a substantial growth in the understanding of the causes of the phases of the Moon and, in turn, an understanding of the positions necessary to create those phases.

The 35% gap between the correct answer and the second most popular answer indicated, which was “B”, suggests a confident knowledge base about the phases of the Moon. The strong base does not seem to exist among college students, as only 29% chose the correct answer. This rise and fall pattern is very similar to the results for the correct answer from question 7, which was also a question involving the “phases of the Moon.” This, as before, suggests either a retention problem or a reversion back to the students’ previous alternative conception. If it were indeed a retention problem, the college students’ scores would be more dispersed. Instead, 80% of the college students selected either the right answer, “A”, or “B”. Both “A” and “B” contain a Moon, Earth, Sun configuration that is consistent with an “eclipse” theory about the phases of the Moon. The students who chose the “eclipse” answers most likely believe, falsely, that the phases of the Moon are caused by the Earth’s shadow being cast on the Moon. To simplify the nomenclature, this belief will be called “The Eclipse Alternative Conception.” 21% fewer college students than eighth grade students picked the correct answer, and almost all of those 21% of college students shifted their thoughts to “A” or “B”. This indicates that between eighth grade and college, the students reverted to The Eclipse Alternative
Conception. These results seem to support both Wilson Gonzalez-Espada\textsuperscript{31} and Julia Plummer’s\textsuperscript{32} articles, in which they discuss the phases of the Moon alternative conceptions; specifically The Eclipse Alternative Conception. Although not obvious from Figure 4.13, I believe that this is also a popular theory in early space science development, which is why college students revert.

![Graph showing results of Question 14]

Figure 4.14: Results of Question 14 - You observe a full Moon rising in the east. How will it appear in six hours?


This question, although about the phases of the Moon, does not follow the same pattern as the previous questions about similar subject matter. This question is less about direct knowledge of the cause of the phases of the Moon, and is more a question of the length of the phases. Moon phases are on a monthly cycle. That is to say that the time between two consecutive full Moons is 29.53 days.\textsuperscript{33} This is because that is the amount of time it takes Moon to orbit the Earth. Of the fifth students surveyed, 49\% seemed to think that the phases change more quickly and therefore, 6 hours after the full Moon rose, the Moon would be in one of its less full phases. This alternative conception, although somewhat prevalent in the higher grades, largely was discounted for the correct view. Both the eighth grade and college students surveyed chose the correct answer by a vast majority: 56\% and 60\% respectively. However, the second most popular answer among older students was the most popular fifth grade answer. It appears that although the alternative conception, that the Moon changes phases nightly, held by the surveyed fifth graders has been severely weakened by eighth grade and college, it is not completely eliminated.

Figure 4.15: Results of the Probative Question - Mrs. Timmins asked her class to share their ideas about what causes the different phases of the moon. This is what some of her students said:

The probative question has more possible choices than the rest of the questions, and therefore, is perhaps also more telling. The question, along with the ideas proposed by the students of Mrs. Timmins’ class, can be found in Appendix A-2 or A-3. Sophia gives the correct answer for this question by stating, “Parts of the Moon reflect light depending on the position of the Earth in relation to the Sun and Moon.” This is the third question involving the phases of the Moon in which the data for the correct answer shows the same pattern. There is a 12% rise in percentage for the correct answer between the fifth and eighth grade data sets. There is also a 6% drop in percentage for the correct answer between the eighth grade and college data sets. This rise and fall, as before, represents overcoming and subsequent reversion to previous alternative conceptions. Analyzing the fifth grade data for alternative conceptions bears little fruit. The uninteresting spread of the alternative conceptions coupled with the small subject population size makes the fifth grade data, other than the 42% who chose the correct
answer, uninteresting. With this being the case, it may be beneficial to examine just the eighth grade and college data, which can be viewed in Figure 4.16.

It can be seen from this graph that 27% of the eighth graders are split between Drew and Oofra, whose explanations of the causes of the phases of the Moon involve shadows in some way. Where Drew confuses the phases of the Moon with eclipses, and Oofra mentions the shadow of the Sun blocking part of the Moon, which in turn causes the Moon’s phases. These explanations are most likely chosen by those students that know that the phases have something to do with shadows, but don’t fully understand what role the shadows play. It does not take much evaluation of the college data to discover which alternative conception is most prominent. The Eclipse Alternative Conception of the phases of the Moon once again surfaces. The number of students that agreed with Drew’s explanation increases by 13% between eighth grade and college. This alternative conception seems to be the most persistent and the most prominent of all the alternative conceptions.
Also, as part of the question, students were given the opportunity to explain why they agreed with the explanation they chose. Although not every student wrote something interesting, many took advantage of the opportunity and gave insight into their perceptions of the phases of the moon beyond what was put forth by the explanations given by the fictional students in the question. An “interesting” response is a response that gives an insight into the students’ conceptions beyond what is put forth by one of the fictional students in the probative question. Of the 181 college students that answered this question, 43 gave insight into their conceptions. Of the 131 eighth grade students, 35 wrote interesting comments. Finally, of the 31 fifth grade students that chose to agree with one of the explanations put forth in the problem, 17 were interesting. The students that answered the question, but did not write something considered to be of interest, wrote something similar to,

“I agree with Sophia because hers seems closely accurate to what I’ve been told about the Moon’s phases. Plus it sounds right to me.”

which was taken from an eighth grade student’s survey. Most explanations merely reiterated the fact that the student chose the explanation they thought was right.

“Oofra. Because I Picket Oofra is that it does reflect off the Sun…” [sic]

“Oofra because the sun causes it.”

These examples of fifth grade students illustrate some of the difficulty in interpreting the data received. Without sufficient explanation by the students on their thought processes, this probative question become little more than another multiple choice question for those students.

However, those students who wrote their reasoning and explanations told a great deal about their alternative conceptions.

“Drew. Duh.” [sic]
Although this statement does not give any insight into the thought process of this college student, this quote is an example of the confidence some students have about The Eclipse Alternative Conception.

However, some student explanations contained discrepancies between the explanation the student chose to agree with and the ideas the student actually held.

“I agree with Sophia because she says that it has to do with the position of the Earth in relation to the Moon and the Sun the Earth casts shadows on the Moon. And because of the Earth’s tilt we get Moon phases.” [sic]

This fifth grade student agreed with Sophia, but also stated The Eclipse Alternative Conception, which clearly matches with Drew’s explanation. The student, in this case, just used Sophia’s explanation to help support The Eclipse Alternative Conception. Several students, like the eighth grade student below, picked one explanation, but gave their own explanation that agreed with a different student in the question.

“Natasha because this is like an eclipse.” [sic]

Natasha’s explanation was that clouds cover the parts of the Moon we can’t see. This student not only believes that the phases of the Moon are caused by cloud cover, he/she also believes that cloud cover cause eclipses. This is similar to The Eclipse Alternative Conception, except that this student also holds an alternate conception about the cause of eclipses.

“Oofra is the best answer. I think because most of the class said something about the Earth casting a shadow on the Moon and its just the position the Moon is at and how the sun always hits the side facing it so it created a shadow on the side that doesn’t face it.” [sic]
Although this eighth grade student claims to agree with Oofra, the explanation given mentions part of Drew’s and Sophia’s explanations. This student speaks of their class referencing the Earth’s shadow, but does not indulge any further in The Eclipse Alternative Conception. Instead the student accurately describes the first half of the correct cause of the phases of the Moon; all that is missing is Sophia’s Earth, Sun, and Moon argument. Obviously confused, this student seems to be holding onto 3 different conceptions at once.

In general, the only students to write extensive explanations did not agree with Sophia. A large number of people who wrote explanations agreed with Drew and The Eclipse Alternative Conception.

“Drew because the Moon reflects sunlight and, if the Earth is blocking the sunlight, the Moon would be dark.”

“Drew. As the Moon moves different shadows from the sun on the Earth darken the view of the Moon. The area where no shadow is cast is illuminated.”

These fifth and eighth students’ quotes, respectively, are just a few of the comments written by some of the 63 students that thought Drew’s explanation was correct. However, not everyone held The Eclipse Alternative Conception; some students held other alternative conceptions, such as this fifth grade student.

“Jared because as the seasons of the year change the Earth rotates so the Moon appears to be in different phases.” [sic]

Some of the students surveyed agreed with two different explanations given by the students in the problem: especially Sophia and Drew.
“Agree with Sophia & Drew b/c they both spoke of either we see the Moon because of light reflected off it from the sun and that the dark portions of the Moon are caused by the shadows of the Earth.” [sic]

“I agree w/ Sophia + Drew, because the Earth casts its shadow on Moon, which depending on their position shows how big the Moon will be.” [sic]

“Either Jared or Sophia b/c they sound most reasonable.” [sic]

These quotes by college students are perfect examples of how a student can learn the correct theory behind a phenomenon and still retain their old alternative conception. Instead of the correct theory replacing the incorrect, the student will merge the two. The last student intuitively picked them both, without any rationale for doing so, other than they sounded “reasonable”. This is yet another illustration of how ingrained these alternative conceptions can be; blindly choosing wrong answers without any rationale.

There were also students that either did not retain any knowledge imparted in the classroom or chose to ignore that knowledge and chose to use direct observation.

“I agree with Natasha because I have seen clouds cover the Moon and I think that is right.” [sic]

I find this quote by a college student especially disturbing. Even if the student did not remember anything learned in school about the phases of the Moon, on the same survey in which the student gave this quote there were pictures of different phases of the Moon that clearly were not caused by cloud cover. Fortunately, there were only 3 students, one in each grade surveyed, that agreed with Natasha.

The question clearly states, “Mrs. Timmins asked her class to share their ideas about what causes the different phases of the Moon,” however there were students that instead chose Raj; a students who described the phases of the Moon.
“Raj because when the Moon revolves around the Earth that’s kind of what it does.”

This explanation was given by a fifth grader. Thankfully, a total of only eight students, three college students and five eighth graders, chose to agree with Raj’s explanation. Such a small population would not notably affect the results or, therefore, the analysis of those results.

Now that each question has been examined and analyzed individually, it may be beneficial to examine the overall scores, categorized in various ways. First we investigated the trends in overall scores by grade level.

![Figure 4.17: Average Overall Score by Grade Level](image)

Although not as profound as the trend in some of the individual questions, the rise and fall pattern can be seen. There is only a 1.60% difference between the college and eighth grade scores. This number at first glance seems slight, but when compared to the meager 12.88% variance between eighth and fifth grades, the relevance is made apparent.
This rise and fall suggests that the alternative conceptions seen throughout this test are, overall, resilient. Although there were some individual questions in which the college students had a better score, the eighth grade students prevailed in overall score.

Not only can we check for alternative conception among different grades, but we can also break the subject population up into their demographics and see if these factors play any roles in alternative conception susceptibility. For this study, we can divide the data three ways for each grade. The fifth and eighth grade data can be split into gender, ethnicity, and immediate family member’s highest level of education. The college students can be divided into gender, ethnicity, and elementary school location.

![Figure 4.18: Average Overall Score by Gender](image)

This data clearly shows that male students’ score considerably higher on the overall score. Even though the female fifth grade student outscore their male counterparts by 4%, the eighth grade and college males outscore their respective female equivalents by 8% and 10%, respectively. This gap is consistent with the article “Trends in gender
differences in mathematics and science (TIMSS 1995–2003),” which states that males, at least for now, are on the top side of the science gender gap.

None of the fifth grade students who responded to the ethnicity question answered anything other than “White,” which is why the fifth grade data is not depicted on this graph. For white students, there is relatively no difference between the eighth and college overall scores. There is, however, a 15% drop in the under-represented minorities score and a 19% drop in the Asian students’ score. This drop seems noteworthy, even with the small sample sizes of two college URMs and 11 college Asian students, and five eighth grade URMs and five eighth grade Asian students. It can also be seen that under-represented minorities underscored White and Asian students in both grades. Looking at the college data, it is clear by the 19% difference between URMs and White students that ethnicity does play a factor in susceptibility to alternative conceptions. The percent

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The data also suggests that ethnicity plays a role in reversion to alternative conceptions from the correct conception, as demonstrated by the score differences between grade levels.

![Figure 4.20: Average Overall Score by Parents Highest Level of Education](image)

This graph shows two different trends for the different grades. First, the fifth grade data seems to support the article previously mentioned, “Parents’ education, cognitive ability, educational expectations and educational attainment: Interactive effects” by Yoav Ganzach, who states

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36 Ganzach, Yoav “Parents’ education, cognitive ability, educational expectations and educational attainment: Interactive effects” British Journal of Educational Psychology 70. 419- 441(2000)
“The education of the parents and the cognitive ability of the child are probably the most important determinants of educational attainment.”

(419)

The overall score of the fifth grade students clearly climbs as the education level of the family member increases. There is an observable 13% difference between the students who have family with graduate/professional degrees and those students whose family didn’t receive a college degree.

However, the eighth grade data seems to show no difference between educational levels. With a variance of only 4.5%, which is the percent difference between the bachelor and graduate degree, any differences in the eighth grade data seems to be simple data noise. So the data suggests that the educational level of immediate family has more of an impact on younger students, and the younger students with degree holding family members score higher than those students without. Perhaps this is because fifth grade students receive more help from their parents than eighth grade students. More study is needed to solidify a reason behind these results.
Finally, to make sure the college data was not skewed by students who were educated outside Ohio, the data depicted above was analyzed. With a variance of only 4%, is it reasonable to state that all of the college students surveyed had approximately the same knowledge and alternative conceptions; educated in Ohio or not.

Figure 4.21: Overall Average College Scores by Elementary School Education Location
Chapter 5

Conclusions and Future Work

When analyzed, the data revealed a great deal of information about space science alternative conceptions. For clarification’s sake, the question numbers used in this examination of the data will be the numbers from the college test. In this study, we examined the tilt of the Earth’s axis and the apparent movement of the sun and stars across the sky, the distances to various celestial objects in the solar system, and the phases of the Moon. These topics were explored by examining several questions dedicated to that topic, and designed with distracters to show any alternative conception that may be held by the student.

Questions 6, 8, and 9, in different ways, investigate conceptions about the tilt of the Earth’s axis with respect to its orbital plane. Question 6 and 9 do this by questioning the students on the apparent movement of the sun across the sky. Question 6 has an exceedingly popular answer, where 50% to 65% of the students believe the sun is directly overhead every day at noon. This suggests that most of the students don’t have the idea of a tilted axis internalized. The results from question 9 suggest that students don’t have any solid ideas on the apparent north/south movement of the sun throughout the year, which says more about retention or understanding of the topic than the alternative conceptions associated with the topic. Question 8 asks the students to think about the cause of the seasons. The results from this question suggest students either believe seasons are solely dependant on the Earth’s orbit, or dependent on both the Earth’s orbit the Earth’s axial tilt. The high percentage of students drawn to this alternative conception implies that this alternative conception is relatively strong. Also, the pattern seen in the data for question 8 implies that the “cause of the seasons” alternative conception is reasonably resilient as
demonstrated by the fall and rise pattern in the answer “We would no longer experience a difference between the seasons.”

Question 10 tested the students’ knowledge of the apparent daily movement of the stars across the sky. This question held the strongest alternative conception, in that the largest number of students was drawn to a single incorrect answer. The results are very clear, in that an increasing number of students believe that the stars do not move as the sun moves. With 72% of the college students believing that the stars would be stationary during the day if visible, this is the strongest alternative conception in this study.

Questions 11 and 12 relate to distances between the Earth and various celestial bodies. Question 11, which asks about the distance from the Earth to an orbiting space shuttle, reveals one of the less resilient alternative conceptions. Where only 25%-30% of fifth and eighth grade students chose the correct answer, 55% of college students chose correctly. Question 12 asks the students to place the Moon, the Sun, the stars, and Pluto in order by distance. While the data this question provides doesn’t seem to support any specific alternative conception, it is unsettling that 37% of fifth grade students, 20% of eighth grade students, and 12% of college students cannot correctly identify that Pluto is closer to Earth than the stars.

Questions 7, 13, 14, and the probative question lead to the most interesting of the astronomy topics: the phases of the Moon. Question 7 and 13 illustrate the exact pattern predicted in the hypothesis, and discussed again in chapter 4. The fall and rise in the question demonstrating the alternative conception clearly illustrates the overcoming of, and eventually reverting to, The Eclipse Alternative Conception. These questions also demonstrate the rise and fall of the percentages of the correct answer associated with a resilient alternative conception. Question 14 is more ambiguous because it is less about direct knowledge of the cause of the phases of the Moon, and more about the duration of those phases. However, this question does give an insight into a fairly strong but only slightly resilient alternative conception that the Moon’s phase changes nightly. However, this alternative conception is most likely just a secondary conception branching off of an alternative conception of the cause of the phases.

To look more deeply into the alternative conceptions of the phases of the moon, a probative question was included in the instrument. While examining this probe, several
alternative conceptions were revealed, including The Eclipse Alternative Conception, that the sun casts a shadow on the moon, and that the Moon “lights up” differently at different times of the month. Looking at the quotes given by the students only adds credence to the discovery that The Eclipse Alternative Conception is the most prevalent and most resilient of all the alternative conceptions uncovered during this study.

Finally, in order to put the results in a context, the students’ demographics in relation to these alternative conceptions were examined. It was found that male students had a better overall score than female students. Also, White and Asian students scored better overall than under-represented minorities. Fifth grade students whose family has a college education scored better than students whose family had lower levels of education. Finally, the results show that the location of the college students’ elementary school did not influence the susceptibility of those students to astronomy alternative conceptions. All of these results support their respective hypotheses.

The results from this study lead to some suggestion for instruction. Using these alternative conceptions and the relative strength and resiliency of those alternative conceptions as a guide, it will be the teachers’ job to attempt to incorporate this knowledge about students’ ideas into the classroom and attempt to battle these alternative conceptions. The dramatic score difference between eighth graders and college students reveals that the level of understanding diminishes greatly while the student is in high school. This suggests two possible solutions to this problem. The first solution is to cover the relevant material in high school. By incorporating this material into high school physics classes, these issues can be once again addressed in the classroom setting and solidified in the minds of the students. Hopefully, with this reiteration of the material in high school, the astronomy misconceptions that students would usually fall back on will be overturned more effectively. The second method involves developing a more effective eighth grade curriculum. While it is true that the current eighth grade curriculum effectively overturns alternative conceptions for a short time, these changes in the minds of the students do not last long and the students eventually revert to their previous conceptions. By taking the data from this study, a new method of teaching eighth grade astronomy can be developed that more permanently overturns the resilient alternative conceptions.
Several of the results found in this study merit a closer look in future studies. In question 9, a majority of eighth grade students chose that the sun seemingly drifts further north as winter approaches. Through this study, we have found no plausible reasoning behind this alternative conception. Also, the results obtained by questioning the highest education level of the students should be studied further. There is such a clear difference in the trends revealed by the fifth and eighth grade data, although there is only a three year difference. It is unclear if this difference is due to the age difference, or by some other unseen factor. This uncertainty illustrates the need for more research in this topic.

Although many very interesting results were found during this investigating into alternative conceptions, there were several problems that arose during the course of this study. The first and, in my opinion, most prominent, is the sample size of the fifth grade students. Although 5 separate classes were surveyed, only 35 permission slips were returned. This small sample size made it almost impossible to gleam any relevant results from the fifth grade data set. Instead, the fifth grade data acted as a baseline score and was used just to estimate the approximate conditions of alternative conceptions prior to 8th grade instruction. Also, no data was gathered on the college students’ parents’ education level. This data may have revealed an interesting trend when compared to the fifth and eighth grade data if it had been collected. These problems, while not wholly detrimental to the project, did create inconveniences when analyzing the data.

Alternative conceptions such as these are the reason that this type of research has been so popular in recent years. Overcoming alternative conceptions is arguably the most difficult task that teachers must undergo. The resiliency of these alternative conceptions not only makes them difficult to overcome, but also makes it very difficult for a teacher to gauge whether the conception has been permanently, or merely temporarily, corrected. Often the student only overcomes these alternative conceptions for a short time and then falls back into an old mindset after an academic atrophy on the subject in question. Only when a student permanently overcomes alternative conceptions in a subject can that student gain an “expert’s understanding.” Although not every student will reach this level of understanding, every student should be taught to battle these alternate conceptions as if they will.
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Appendix A-1: IRB Application

MIAMI UNIVERSITY
APPLICATION FOR APPROVAL OF RESEARCH INVOLVING HUMAN SUBJECTS

COVER PAGE

All research projects involving human subjects must submit an application for review and approval by the Institutional Review Board for Human Subjects (IRB) or the Psychology Departmental Human Subjects Review Board (DRB) prior to the initiation of the research. Research that will be conducted with external or internal grant funding shall be submitted to the IRB. Research that involves no greater than minimal risk and will be conducted without external or internal grant funding shall be reviewed by the IRB or the DRB. If you have questions, call the Office for the Advancement of Research and Scholarship: (513) 529-3734.

A. PROJECT PERSONNEL

1) Principal Investigator(s) (PI's) and Department Date completed CITI & Practicum or Prior Training Date

Jennifer Blue, physics ________________________________ CITI: November 8, 2005; Practicum: September 11, 2002

Faculty Advisor (if PI is a student) and Department Date completed CITI & Practicum or Prior Training Date

________________________

Other Personnel who will interact with subjects Date completed CITI & Practicum or Prior Training Date

Adam Hicks, physics ________________________________ CITI: March 23, 2008

B. CONTACT INFORMATION FOR PI and Faculty Advisor (if PI is a student)

Campus or Postal Address(es) 133 Culler Hall

PI's E-mail's Address bluejm@muohio.edu Phone 529-1380

C. PROJECT TITLE Assessing Misconceptions Involving Space Science

D. FUNDING SOURCE none

E. PROJECT DATES Beginning November 2008 Ending August 2009

F. TYPE OF APPLICATION

_x_NEW PROTOCOL REVIEW

_REVISIONS OF APPROVED PROTOCOL

_CONTINUING PROJECT REVIEW (See last page for Status Report)

G. Does this project make use of any of the following special types of subjects and/or locations?

Please mark an “X” on the appropriate line:

X_____ Research with Children _____ Research with Prisoners _____ Research with Pregnant Women and Fetuses in Utero
Research in Public Elementary and Secondary Schools  International Research

Research in VA Hospitals  Research Conducted with Clinical Populations in which HIPPA Applies (e.g. Medical, Psychiatrist)

Internet Research  Drug Research in Human Population (FDA Regulated)

In the CITI Training Program <http://www.citiprogram.org>, there is a Training module associated with each of the above special cases. Before your IRB application can be approved, you will need to review the first two modules then, you must pass the quiz associated with the module/s To register your credit, attach the “Grade Book” to your application. Refer to instructions on our website.
H. INVESTIGATOR'S ASSURANCE STATEMENT
I have read Miami University's policy concerning research involving human subjects and I agree to:

1. Accept responsibility for the ethical conduct of this research study,
2. Obtain approval from the Institutional Review Board or Departmental Review Board prior to changing any procedures,
3. Report to the IRB any complications, adverse reactions or unexpected effects on subjects,
4. Submit an Application for Approval of Continuing Projects within one year, or sooner as specified in the approval letter, describing the current status of the project.

Principal Investigator(s) __ Date __

Faculty Review of Student Projects: I have reviewed and approved the procedures to be used in the project described in this application. I agree to meet with the investigator on a regular basis to monitor study progress and assure that the well being of subjects is adequately safeguarded.

Faculty Advisor __ Date __
Research Description

1. Purpose
The proposed project is to determine what Astronomy (Space Science) misconceptions, if any, are presented by fifth grade, eighth grade, and college students. This project will help to determine which of the space science misconceptions held by students are the most resilient and, thus, help teachers eliminate these misconceptions. This assessment of resilient misconceptions is part of my master’s thesis.

2. Subject Population

- Fifth and Eighth grade students of the Talawanda school District.
  - Fifth: 3 schools, each with 2 classes of approximately 25 students. (150 students approx.)
  - Eighth: 2 different classes that run 6 periods, each containing approximately 25 students. (300 students approx.)
  - We expect these numbers to be an overestimation, due to the refusal of some of the subject population to participate.
  - The Talawanda school district is approximately 93% white and approximately 31% economically disadvantaged.

- The students of PHY 172 in the spring semester at Miami University (Oxford)
  - 2 classes each containing approximately 100 students (200 students approx.)
  - Miami university is approximately 90% white

3. Recruitment and Selection of Subjects

- Fifth and Eighth grade students:
The fifth and eighth grade students will be recruited and tested in their respective classes. Permission from the principles has been obtained (see attached). A letter, seeking the consent of a guardian, will be given to the students (see attached). All students will be assured that whether they participate or not will have no bearing on their grade in the course. The students will be given and read aloud a letter asking for their involvement in this study. (see attached)

- Miami University students:
The college students will be recruited in their lab classes. They will be offered the chance to participate in the study and given a letter explaining their participation (see attached). All students will be assured that whether they participate or not will have no bearing on their grade in the course. Letters will be sent to the instructors asking for class time to perform this study. (See attached)

4. Potential Risks and Discomforts
The students will be taken from regular class time to participate in this study, although we will try to perform this study while the teachers are not able to attend. Also, the students will take a test.

5. Potential Benefits

Benefits to the physics education community:
The potential benefits of this study include a greater understanding of some of the more persistent misconceptions, and therefore, a greater understanding of how to replace these misconceptions with scientific thinking.

Benefits to the Talawanda school system:
The results will be presented to the fifth and eighth grade teachers as well as to the Science Instructional Leader of the Talawanda school district. The teachers will see where the gaps are in their students’ understanding and be able to tailor instruction. This could positively affect the fifth and eighth grade Ohio Achievement Test scores.

6. Informed Consent

The researcher will provide subjects and, in the case of the fifth and eighth grade students, the subject’s guardians with consent letters. Please see attached.

7. Exempt Status Request

None.

8. Research Procedures/Methods

a. Nature of activities: Students will take a short physics test in their respective science classes.

b. Data gathering instruments: See attached.

c. Frequency and length of time in each activity and overall length of participation: A one time participation will be required, totaling no more than 50 minutes.

d. Training of persons administering the treatment or collecting the data:
   Adam Hicks: BS in Physics, took CITI in 2008
   Jennifer Blue: PhD in Education, took CITI in 2002.

e. Compensation to subjects for their participation: None.

9. Research Location

The research will be reviewed in Culler Hall, room 129, where there is a locking file cabinet to store the data. The data will be stored until August, at which time I will defend my Thesis and the study will be terminated.

10. Procedures for Safeguarding Confidentiality of Information

Fifth and Eighth grade students: Confidential
We are asking the student’s guardians to indicate the highest level of education for the student’s immediate family. Students’ ID numbers will be used by Jeff Winslow to match their tests to the immediate family’s education level (taken from parent/guardian consent form). Jeff Winslow will also be able to match students
to their teachers, so that we can report detailed statistics about students to each teacher. We will not collect students names, nor will students named be stored with the data. No pseudonyms will be used in the reporting of the data.

Miami University students: Anonymous. No names will be collected.

All of the data will be stored in a locking file cabinet in Culler Hall, room 129. The data will be stored until August, at which time I will defend my Thesis and the study will be terminated.

11. Deception

None.
Permission Request- Miami Instructors

Dear PHY 172 Instructor,

We are conducting research into astronomy misc for Adam's MS thesis. May we come into your class for half the period sometime early in the Spring 2009 semester? We will give your students the opportunity to opt out of the research, but if they consent to participate they will take a short astronomy test without their names on it.

Thank you

Jennifer and Adam
November 14, 2008

To Whom It May Concern:

I give my permission and support for Dr. Jennifer Blue and Adam Hicks to administer an assessment to the students of Marshall Elementary School. I recognize the need for this research to determine the persistence of misconceptions in student understanding so that teachers can modify instruction to overcome these common mistakes. We look forward to using the results of this study to modify instruction and improve student performance.

Sincerely,

Chad Hinton
Principal
November 14, 2008

To Whom It May Concern:

I give my permission and support for Dr. Jennifer Blue and Adam Hicks to administer an assessment to the students of Kramer Elementary School. I recognize the need for this research to determine the persistence of misconceptions in student understanding so that teachers can modify instruction to overcome these common mistakes. We look forward to using the results of this study to modify instruction and improve student performance.

Sincerely,

Dr. Candace L. McIntosh
November 14, 2008

To Whom It May Concern:

I give my permission and support for Dr. Jennifer Blue and Adam Hicks to administer an assessment to the students of Bogan Elementary School. I recognize the need for this research to determine the persistence of misconceptions in student understanding so that teachers can modify instruction to overcome these common mistakes. We look forward to using the results of this study to modify instruction and improve student performance.

Sincerely,

[Signature]

Dee Lancaster
November 14, 2008

To Whom It May Concern:

I give my permission and support for Dr. Jennifer Blue and Adam Hicks to administer an assessment to the students of Talawanda Middle School. I recognize the need for this research to determine the persistence of misconceptions in student understanding so that teachers can modify instruction to overcome these common mistakes. We look forward to using the results of this study to modify instruction and improve student performance.

Sincerely,

Sharon Lytle
Principal
Informed Consent – For Miami University Students

Dear Student,

As part of my Masters Thesis, I am giving this short test to assess misconceptions some students may have about certain astronomy concepts. I am requesting your permission to review the test that will be administered today.

My evaluation of your tests will not be shared with your instructor and will not affect your grade in this course. In addition, your grade will be unaffected by whether or not we are using your tests in this outside project. If you have any hesitation about allowing your tests to be used, please do not give your permission.

You must be 18 years old to consent to have your test results used. Please answer question 1, which asks whether you are over 18. If you answer the question “no”, we will not use your data.

Question 2 on the test asks whether I may use your test results in the survey. If answer “no” to question 2, leave the whole test form blank, or draw a large X across your test form, I will not use your data. If you answer “yes” to question 2 and turn in a legible test form without crossing out your answers, I will understand that you are giving me permission to use your data.

In either case, your test will be anonymous. You should not put your name at the top, nor do I want you to do so. I will not know which student took which test, and I will never use your name in any oral or written presentation of my findings.

You are encouraged to guess the answers even if you are not sure. You may also leave questions blank if you do not want to guess.

If you have any questions about this research project or if you would like to know the results, please contact me, Adam Hicks, at hicksas@muohio.edu or 513-529-5657.

Questions concerning your rights as a research participant may be addressed to the Office for the Advancement of Research and Scholarship at (513)-529-3600 or HumanSubjects@MUOhio.edu.

Thank you for your help.

Yours truly,

Adam Hicks
Dear Student,

Thank you for participating in my research. My name is Adam, and I go to school at Miami University. I am interested in fifth and eighth grade students’ ideas about space science, which is why I am giving you this test. Your parent/guardian has given me permission to give you this test.

Your teacher will not know how you did on the test and this test will not be for a grade. This test will not affect your grade in this class. If you do not want me to use your test, you can turn it in blank. If you start the test and then change your mind, you can put a big X across the test before you turn it in.

If I can use your test in my project, no one will know your name. You should not put your name at the top, that way I will not know which student took which test. Because I will not know your names, I will never use your name in my project.

We do ask you for your student ID number, so we can report the results for the whole class to your teacher.

Thank you for helping me with my research.

Adam Hicks
Dear Parent/Guardian,

I would like to conduct research in your child’s classroom to investigate children’s ideas about astronomy. My research will consist of giving a basic astronomy test that will take about 30 minutes and be done during science class time in school. Your child will be asked to volunteer to participate in this research and to allow me to use data collected from the test for my research.

Your child will be permitted to stop participation at any time during the course of the research. There will be no risk to your child whether or not he/she volunteers to participate. All data collected will be handled in a strictly confidential manner. No one will be able to identify your child as a participant in this research through any private or public discussion of the results.

As part of the examination of this research, I would like to know the highest level of education of your child’s immediate family (people who live in the same home as your child). Because your child may not know this information, I am asking that you answer on their behalf. You are not required to answer in order for your child to participate in this study, but it would help further the study if you would answer.

Please feel free to contact me or my research advisor, Dr. Jennifer Blue, if you have any questions regarding this research.

Adam Hicks
Graduate Student
Miami University
Dept. of Physics
138 I Culler Hall
Oxford, Ohio 45056
hicksas@muohio.edu

Dr. Jennifer Blue
Professor of Physics
Miami University
Dept. of Physics
23 Culler Hall
Oxford, Ohio 45056
bluejm@muohio.edu

I understand that my son/daughter will be asked to provide assent to participate in this research and may discontinue the research at any time without consequence. I am aware that, while my child’s name will be kept confidential, the data collected from his/her test will be examined as part of this research project. I agree to allow my son/daughter to volunteer to participate in this research.

☐ I give permission for my child to participate in the study described above.

☐ I do not give permission for my child to participate in this study.

The highest grade level completed of my child’s immediate family is:
   a) Some high school
   b) high school/GED
   c) Some college
   d) Bachelors degree
   e) Graduate/Professional degree

__________________________________  _____________________________________
Name of Student (please print)  Date

__________________________________  _____________________________________
Name of Parent/Guardian (please print)  Signature of Parent/Guardian
Dear Fifth/Eighth Grade Teacher,

My name is Adam Hicks and I am pursuing a MS. degree in Physics at Miami University. My research involves investigating children’s ideas concerning space science. I am seeking a small amount of class time in which to distribute a basic space science test. The purpose of this study is to evaluate misconceptions students may have about space science and to track the most persistent of those misconceptions throughout an individual’s educational development. I conducted a pilot study with 267 college students. Based on the results of this pilot study I would like to interview fifth and eighth grade students.

In order to create a productive learning environment, educators need to be aware of the ideas students bring with them to the classroom so that lessons can be planned in a way that allows the student to understand. By knowing the types of ideas children have prior to instruction, lessons can be targeted to identify and address areas where students may have existing ideas that do not agree with the new knowledge to be learned. My research, therefore, is designed to investigate the ideas children have concerning space science. This space science research is taken from the Ohio Academic Content Standards (OACS), and with the data collected from this study, the student’s knowledge of the OACS can be increased.

I would like to give your students a space science exam during the 2008-2009 academic year, lasting approximately **30-45 minutes**. Your students will be informed that their participation is completely voluntary and that their grades will neither be positively nor negatively influenced for either participating or not participating in this research. All students must have parental consent to participate in the study. A copy of the letter to parents and the consent form to be signed by parents are attached for your reference.

My research has been approved by the Miami University IRB (Institutional Review Board) and [Principal's Name], Principal, [School Name]. Thank you for your time and your support of my research. Please feel free to contact me, my research advisor, Dr. Jennifer Blue, if you have any questions regarding this research.

Sincerely,

Adam Hicks  
Graduate Student  
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Dr. Jennifer Blue  
Professor of Physics  
Miami University  
Dept. of Physics  
23 Culler Hall  
Oxford, Ohio 45056  
bluejm@muohio.edu
Appendix A-2: Fifth and Eighth Grade Test

Test for Talawanda Students
Space Science Test

1) What is your school ID number?

2) Are you a boy or a girl?
   A. Boy
   B. Girl
   C. I don’t want to answer

3) What is your ethnic background?
   A. White
   B. African American / Latino / Native American
   C. Asian
   D. I don’t want to answer

4) As seen from your current location, when will an upright flagpole cast no shadow
because the Sun is directly above the flagpole?
   A. Every day at noon.
   B. Only on the first day of summer.
   C. Only on the first day of winter.
   D. On both the first days of spring and fall.
   E. Never from your current location.
5) When the Moon appears to completely cover the Sun (an eclipse), the Moon must be at which phase?

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

6) Imagine that the Earth’s orbit was changed to be a perfect circle about the Sun so that the distance to the Sun never changed. How would this affect the seasons?

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

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

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

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| South | West | North |
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8) If you could see stars during the day, this is what the sky would look like at noon on a given day. The Sun is near the stars of the constellation Gemini. Near which constellation would you expect the Sun to be located at Sunset?

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

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

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

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

A. Stars, Moon, Sun, Pluto  
B. Sun, Moon, Pluto, stars  
C. Moon, Sun, Pluto, stars  
D. Moon, Sun, stars, Pluto  
E. Moon, Pluto, Sun, stars
11) The diagram below shows the Earth and Sun as well as five different possible positions for the Moon. Which position of the Moon would cause it to appear like the picture at right when viewed from Earth?

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

A.  
B.  
C.  
D.  

13) Global warming is thought to be caused by the
A. destruction of the ozone layer.
B. trapping of heat by nitrogen.
C. addition of carbon dioxide
Mrs. Timmins 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.

Sophia: 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 plants 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 the 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.
Appendix A-3: College Test

Test for Miami Students
Astronomy Test

1) Are you 18 or older?
   A. Yes
   B. No

2) Do you give permission to have you test data reviewed?
   A. Yes
   B. No

3) Where did you go to elementary school?
   A. Ohio
   B. Other state in the USA: if so, write here _________________________
   C. Outside the USA: if so, write here _________________________________

4) Are you male or female?
   A. Male
   B. Female
   C. Decline to answer

5) What is your ethnic background?
   A. White
   B. African American / Latino / Native American
   C. Asian
   D. Decline to answer

6) As seen from your current location, when will an upright flagpole cast no shadow
   because the Sun is directly above the flagpole?
   A. Every day at noon.
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10) If you could see stars during the day, this is what the sky would look like at noon on a given day. The Sun is near the stars of the constellation Gemini. Near which constellation would you expect the Sun to be located at Sunset?

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

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E. Moon, Pluto, Sun, stars
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14) You observe a full Moon rising in the east. How will it appear in six hours?

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B.  
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D.  

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