

THE FLIPPED CLASSROOM MODEL IN AN INTRODUCTORY
ASTRONOMY COURSE

by

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DEDICATION

I dedicate this professional paper to my father Merle for his belief in me; my uncle Bill Bolles for being one of my role models as a teacher; and to my wife Tracey, whose love and support made completion of this degree possible.

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ABSTRACT

In higher education presentation of science content to students has traditionally been through lecture. Lecture, or direct instruction, is a very passive mode of learning for students. This study investigated whether the flipped classroom model of instruction is effective in improving student engagement and achievement in an introductory high school astronomy course. Students were surveyed and interviewed about their feelings of engagement in previous science classes as well as their feelings about the flipped classroom model. Achievement was measured using the Astronomy Diagnostic Test prior to and following the course and a comparison of the treatment semester to the previous four classes in the areas of assignments, quizzes and labs.

INTRODUCTION AND BACKGROUND

Historically science education was centered on the conveying of facts and information in the form of lecture. This method of instruction has changed little over the years and is still in use today. In most science classes, students listen passively, take notes and rarely ask questions (Weih, 2015). Assignments are completed at home, without the help of the instructor and often without help from classmates. Students usually take a test or quiz at the end of the chapter or unit to demonstrate their level of understanding. This model of teaching is commonly referred to as direct instruction (Direct Instruction, 2014). Poor achievement in math and science can be linked to the passive nature of this form of classroom instruction (Weiss & Pasley, 2004). Today, there is an increasing demand for science courses to include an inquiry component to augment student understanding (National Research Council, 2012, 2000). While the amount of inquiry in science classes has increased, there has not been a corresponding reduction in the amount of content to be covered (Tomory & Watson, 2015). The expanding content, the need for deeper engagement and increased inquiry has led to a number of innovations in science education, including peer instruction, mini lectures, think-pair-share questions, just-in-time teaching, and flipped classrooms (Larsy et al., 2014; Weih, 2015).

Direct instruction is the method teachers are most familiar with and it is the easiest way to deliver content to students. A teacher can simply use the same lecture slides, problem sets, quizzes and exams year after year. However, direct instruction is a

very passive learning mode for students. While students may listen, or take notes, they are not actively engaged in the learning.

Traditionally, student test scores following direct instruction fell along normalized or bell-shaped curves. The majority of students received grades of C, a smaller percentage received B's and D's while the smallest number received A's or F's (Felder, 1998). Yet whether this distribution of scores adequately reflects actual learning is unknown.

Kelly Walsh High School is one of four high schools in Casper, Wyoming. Casper is the second largest city in Wyoming with a population of approximately 60,000. Kelly Walsh is home to approximately 1800 students in grades 9 through 12. The demographics of Kelly Walsh are 84% Caucasian and 16% minorities. The ratio of students to teachers is approximately 17 to 1. The fall 2005 semester was the first year Kelly Walsh High School offered astronomy as a high school science course. Astronomy was offered as a dual enrollment course in cooperation with Casper College. Students had the option to earn four hours of college credit, just as if they had taken survey of astronomy at the college. My unique position as the lead educator at the Casper Planetarium allowed me to become the teacher for this course. During the first six years of the course I relied on direct instruction. Although the course was taught in the planetarium theatre instead of a classroom, most of the instruction was in the form of lecture. In the spring of 2011 I attended a workshop entitled *Improving College Introductory Courses Through Active Engagement* presented by NASA's Center for

Astronomy Education. This workshop revolutionized the way I taught astronomy and how I viewed my role as instructor.

During the semester following my participation in the workshop, my lectures became shorter and there was more engagement with students. In addition, I began having students work in pairs or small groups on activities known as lecture tutorials (Prather, Slater, Adams, & Brissenden, 2013). However, this new more engaging mode of teaching still relied on a certain amount of direct instruction. My astronomy course was still not as constructivist as I envisioned. In the summer of 2014, I stumbled upon a book that allowed me to take the next step. *Flip Your Classroom: Reach Every Student in Every Class Every Day* by Jonathan Bergmann and Aaron Sams, offered the tools and guidance to provide an active, inquiry based learning environment.

The flipped classroom model, as outlined by Bergmann and Sams, changed the setting in which various learning activities occur. In the traditional classroom, lecture occurs in class while assignments are completed at home. The flipped classroom reverses this order so lectures are watched on video at home, while assignments are completed in class. The advantage of watching lecture videos at home is that students can pause the video to write notes, rewind the video to re-watch a difficult section, or use the video to review for a test. The advantage of completing assignments in class is that students work with peers on assignments and are encouraged to discuss their methodologies and results. In addition, the instructor is available to help and answer questions at the stage when students need the most help, specifically when they are working through assignments or labs.

The flipped classroom model is not a new mode of classroom instruction, but research regarding its impact on student achievement and engagement is relatively fresh territory for educational research. The goal of my classroom research study was to investigate the impact of this innovative method on student engagement and learning in an introductory astronomy course. The primary question for this action research study was, *to what extent does the flipped classroom model improve student engagement in a high school introductory astronomy course?* The following sub questions were developed.

1. *To what extent does the flipped classroom model improve student achievement in a high school introductory astronomy course?*
2. *How does the flipped classroom change student self-perception about the learning of science?*
3. *What are students' attitudes and perceptions of the flipped classroom?*

CONCEPTUAL FRAMEWORK

A number of studies have been conducted on the impacts of the flipped classroom model, particularly in science and mathematics. These studies generally describe five areas where the flipped classroom positively impacts students including: student academic engagement, peer-to-peer interactions, student-to-instructor interactions, classroom preparation, and student achievement (Gross, Pietri, Anderson, Moyano-Camihort, & Graham 2015).

The flipped classroom is designed to eliminate the passive nature of traditional lecture and replace it with active learning. Effective instruction in mathematics requires

students to interact directly and regularly with the topic (Clark, 2015). When Bergmann and Sams (2012) introduced their students to the flipped classroom they encouraged students to take notes while watching the lecture videos. Some instructors supplement the videos with readings from the textbook and have students answer a few short questions about the video in order to engage students and foster thinking (Love, Hodge, Corritore, & Ernst, 2015). After students watched the video, they were ready to engage in classroom activities, practice skills, and explore what they learned. At this stage students are more engaged in learning and problem solving (McCallum, Schultz, Sellke, & Spartz, 2015).

Several studies described how the flipped classroom improved the level of engagement among students. Because students have unlimited access to the lecture videos they felt they could control the pace of their learning and were more independent learners (Tomory & Watson, 2015). A study of college students found that they were more likely to work through online homework problems before an exam, indicating they have deeper engagement in the topic than students in the standard class group (Gross et al., 2015). This engagement translates to classroom work as well. Students collaborate on projects, homework assignments, and other learning activities instead of in isolation as in the traditional classroom. Clark's (2015) interviews of students consistently encountered the word *active* to describe classroom activities. In fact, many studies of the flipped classroom describe the learning experience as active and engaging. These studies also note an increase in student-to-student interactions.

Students in a flipped classroom are no longer isolated when working on application problems. Since problems are completed in class, students can work together to share ideas and solutions. Clark observed that students in his class increased not only their participation but also their communication with each other (Clark, 2015). Students in a study in Taiwan felt that the time for discussion with peers was not long enough and needed to be extended (Chao, Chen, & Chaung, 2015). Love (2015) found the flipped classroom helped her students become more comfortable when working with their peers and improved peer-to-peer interactions. Yet in order to improve student-to-student interactions students must adequately prepare for class.

The types of problems students encounter in the flipped classroom setting involve higher order thinking and real world applications. In the study by McCallum et al. (2015), students felt that the classwork was easier to complete when they engaged in all pre-class activities. The flipped model also allows students to more deeply interact with the course content over a longer period of time. Gross (2015) found that students interact with the out of class material more regularly and are less inclined to cram for a test. Better preparation not only improves student-to-student interactions, but also improves student to teacher interactions.

With the flipped classroom model, instructors are available for one-on-one work with students on a daily basis. Bergmann and Sams (2012) realized that the time when teachers are most needed is when students are stuck on a homework problem. In one class students not only improved their peer interactions, but also felt more comfortable asking the instructor for help (McCallum et al., 2015). Another advantage to increased

one-on-one interaction with the instructor is that students became more aware of their own learning. Clark (2015) found that being able to talk with every student every day showed where students had understanding and where they needed additional assistance. The impetus for any classroom innovation is to improve student understanding of the given topic. While the flipped classroom improves student engagement, studies have shown wide-ranging results regarding improved student achievement. One study of an Algebra I course observed no statistical difference between the flipped classroom and the standard classroom on a summative assessment (Clark, 2015). However, a study of a college-level thermodynamics course revealed students in the flipped class scored significantly higher on three unit exams than students in the control class (Gross et al., 2015). The study of a Taiwanese design engineering class showed significantly improved scores on summative assessments (Chao et al., 2015).

METHODOLOGY

The primary purpose of this classroom research project was to determine the level of impact the flipped classroom model had on student engagement and achievement in an introductory high school astronomy course. This project was conducted over a single semester in a class consisting of three high school juniors and 15 seniors ($N=18$). Students were introduced to the flipped classroom model early in the semester using EDPuzzle. EDPuzzle is a website that allows instructors to search for, upload and assign videos relating to the topic they wish to teach. It also allows the instructor to embed questions within the video that students must answer as they watch. The site keeps track

of when students watch the videos, how many times they watch a particular section and how many questions they answered correctly.

The majority of lecture videos were from the series *Crash Course Astronomy* presented by astronomer Phil Plait. Videos from other sources were used to cover some topics in greater depth. Students were encouraged but not required to take notes while watching the lecture videos. Following the lecture videos students used class time to work on lecture tutorials from the book *Lecture Tutorials for Introductory Astronomy Third Edition* (Prather, 2013). A lecture tutorial is a series of application questions designed to develop a deeper understanding of the topic. Lecture tutorial questions require students to explain their reasoning for answering a question a certain way. After completing the lecture tutorial, students used the following days to explore simulations, complete labs, work on the end of chapter review questions and take the chapter quiz. Students worked on these activities at their own pace during class in pairs or groups of three to four. End of chapter review questions and chapter quizzes were administered using Mastering Astronomy, a learning website that accompanies the textbook. Having students work on assignments in class also allowed me to assist students when they were confused or having trouble with a difficult problem. The research methodology for this project received an exemption from Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

To examine the effect of the flipped classroom model on student achievement, the Astronomy Diagnostic Test (ADT) from the Astronomy Education Research Center was used (Appendix B). The ADT is a multiple-choice test designed to uncover common

misconceptions about various topics in astronomy. The ADT was administered at the beginning of the semester and at the end of the semester. Student responses to each question were collected using a Google Form and tabulated in a spreadsheet. The mean, median and normalized gains were then calculated. The pre- and posttest scores on the ADT were compared using a Wilcoxon Signed Rank Test and visually illustrated using box and whisker plots.

In addition to the Astronomy Diagnostic Test, each student's percentage score in the categories of assignments, quizzes and labs were collected at the end of the semester. These percentage scores were compared to the past four years of student scores in the same categories. The semester score for each student from the previous four years reflect classes in which the flipped model was not used. This data was collected into a spreadsheet and the means, medians and standard deviations for each year and category were examined to see if there was a difference in the current semester's student scores compared to past years. In addition, the percentage scores from previous years and the current year were compared using a Wilcoxon Rank-Sum test. To visualize the data, box and whisker plots for the categories of assignments, quizzes and labs were created to compare each class in each category.

A few weeks into the semester the Engagement in Previous Science Classes Questionnaire (Appendix C) was administered to the class. The questionnaire probed student perceived engagement in science classes in the previous two years, specifically in areas of note taking, asking questions during lecture, collaboration with other students and perceived test or quiz preparedness. Six of the eight questions on this survey had

choices of *never*, *hardly ever*, *sometimes*, *often*, or *all the time*. The questionnaire was administered to students using Google Forms and the results were tabulated in a spreadsheet. Results of this survey were analyzed to look for qualitative trends in students' feelings about their engagement from previous science classes. At the end of the semester the Flipped Classroom Engagement Questionnaire was used to probe how engaged students felt while in the flipped classroom (Appendix D). As with the Engagement in Previous Science Classes survey, this end of course survey was administered using Google Forms and the results tabulated in a spreadsheet. Results of this survey were also analyzed for qualitative trends in student's feelings toward the flipped classroom model. Bar graphs were created to illustrate the percentage of each response on each question.

Following the Engagement in Previous Science Classes Questionnaire, three females and three males were chosen at random to participate in the Interview Regarding Past Science Class Engagement (Appendix E). At the end of the semester, the same six students were chosen to answer the Flipped Classroom Engagement Interview questions (Appendix F). Results of the two interviews were analyzed to look for qualitative trends in student's feelings about their engagement in the flipped class compared to previous science classes. The interview questions also asked students to discuss their feelings on doing assignments, collaboration, the lecture videos and ways to improve the flipped model in astronomy. The primary study question, secondary question and the data sources used to address those questions are described in Table 1.

Table 1
Data Triangulation Matrix

Focus questions	Data source 1	Data source 2	Data source 3
<i>Primary Question</i> To what extent does the flipped model of classroom instruction improve student engagement in a high school survey of astronomy course?	Engagement in previous science classes questionnaire	Flipped classroom engagement questionnaire	Student interviews following both questionnaires.
<i>Secondary Questions</i> 1. To what extent does the flipped classroom model improve student achievement in a high school survey of astronomy course?	Pre-course and post-course Astronomy Diagnostic Test	Comparison of current semester class scores in assignments, quizzes and labs to previous six years scores in same areas.	In-class formative assessments including: assignments, think-pair-share questions quizzes and labs.
2. How does the flipped classroom change student self-perception about learning astronomy	Engagement in previous science classes interview	Engagement in flipped classroom interviews	Flipped classroom engagement questionnaire
3. What are student attitudes and perceptions about the flipped classroom?	Engagement in previous science classes interview	Engagement in flipped classroom interviews	Flipped classroom engagement questionnaire

DATA AND ANALYSIS

Student Achievement

Results of the Astronomy Diagnostic Test revealed an increase of mean from 41% on the pre-test to 68% on the post-test. The normalized gain was determined to be

medium at 46%. The range of percentage scores changed from 48 on the pre-test to 38 on the post-test, an improvement of 10 points. ($n=18$ pre-test, $n=15$ post-test) (Figure 1).

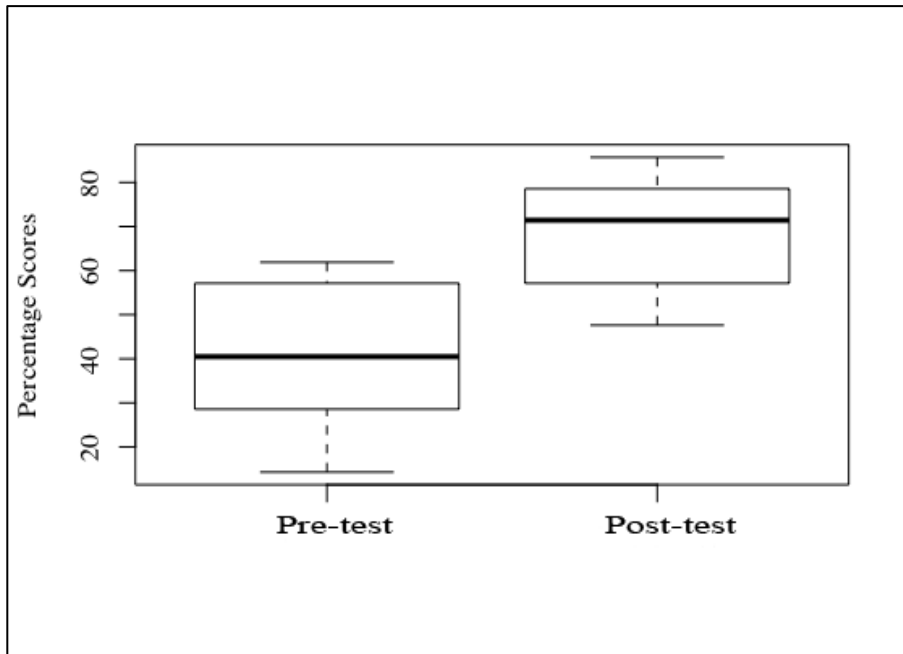


Figure 1. Results of astronomy diagnostic test, ($n=18$, $n=15$).

A comparison of the 2016 semester to each of the previous four semesters in the area of assignments shows the mean assignment score in 2016 was 83%, eight points higher than the 2015 mean and 11 points higher than the 2014 mean. The mean assignment for 2016 score was similar to the 2013 mean and 12 points higher than the 2012 median (Figure 2). Results of the Wilcoxon test used to compare the 2016 semester to the others indicated no significant difference for years 2016-2015, 2016-2014, and 2016-2013. However, there was significance for 2016 compared to 2012, $p=0.023$ (Table 2). When asked about the advantages and disadvantages of doing assignments in class one student responded, “It’s helpful because you can ask questions about it when you get stuck.”

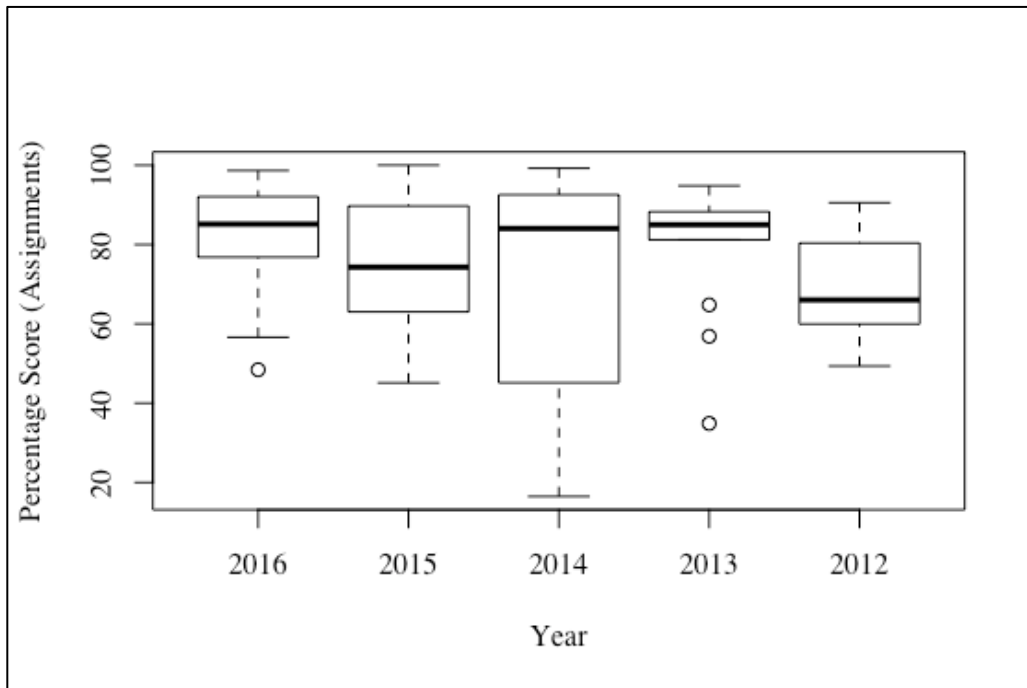


Figure 2. Comparison of assignment scores, ($n=18$, $n=17$, $n=21$, $n=13$, $n=18$).

Table 2

Statistical Analysis of Assignment Scores

Semester Comparison	Wilcoxon p -value	Statistical Difference?
2016 to 2015	0.1259	No
2016 to 2014	0.6726	No
2016 to 2013	0.904	No
2016 to 2012	0.023	Yes

A similar comparison of percentage scores from 2012 to 2016 was done in the category of quizzes. The mean quiz score from the 2016 semester was eight points higher than the 2015 median and comparable to the median scores of 2014 and 2012. The 2013 semester had a mean that was four points higher than the 2016 median (Figure 3).

Results of the Wilcoxon Rank-Sum test to compare the 2016 semester to the other

semesters found no significant difference for years 2016-2014, 2016-2013, and 2016-2012. There was significant difference between the 2016 class and the 2015 class, $p=0.044$. (Table 3).

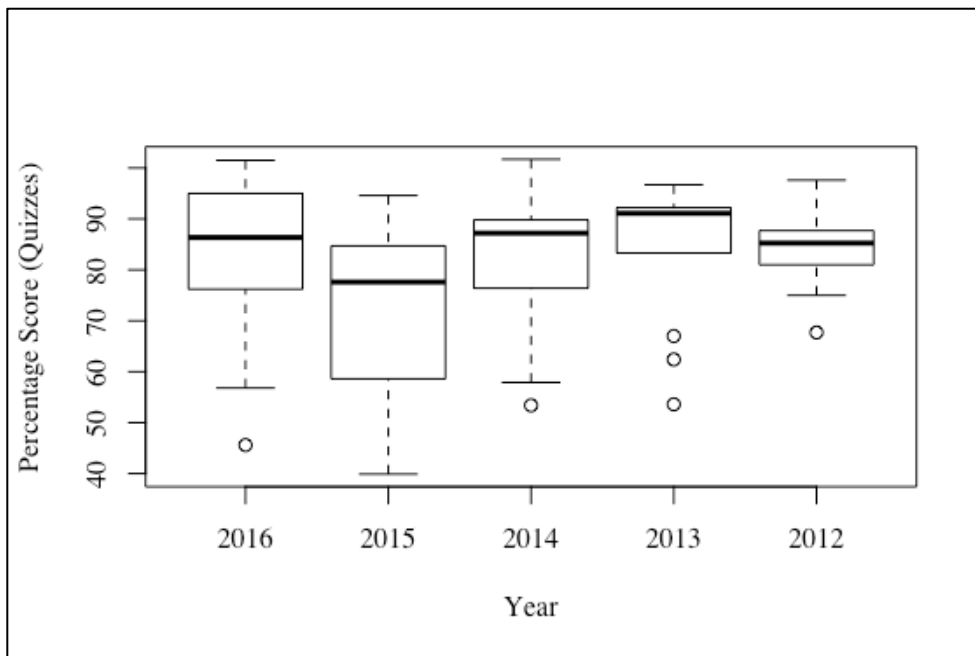


Figure 3. Comparison of quiz scores, ($n=18$, $n=17$, $n=21$, $n=13$, $n=18$)

Table 3
Statistical Analysis of Quiz Scores

Semester Comparison	Wilcoxon p -value	Statistical Difference?
2016 to 2015	0.0440	Yes
2016 to 2014	0.6022	No
2016 to 2013	0.9362	No
2016 to 2012	0.7637	No

The final investigation of the flipped classroom impact on student achievement was in the area of labs. The mean 2016 lab score was eight points higher than the mean

of the preceding year and 15 points higher than the 2014 and 2012 groups. The 2016 semester had a wider range of scores than the 2015 and 2012 semesters, but narrower than 2014 and 2013 (Figure 4). The results of the Wilcoxon test for these showed statistical difference between the years 2016-2014, $p=0.038$, 2016-2013, $p=0.049$, 2016-2015, $p=0.002$. There was no statistical difference between 2016 and 2015.

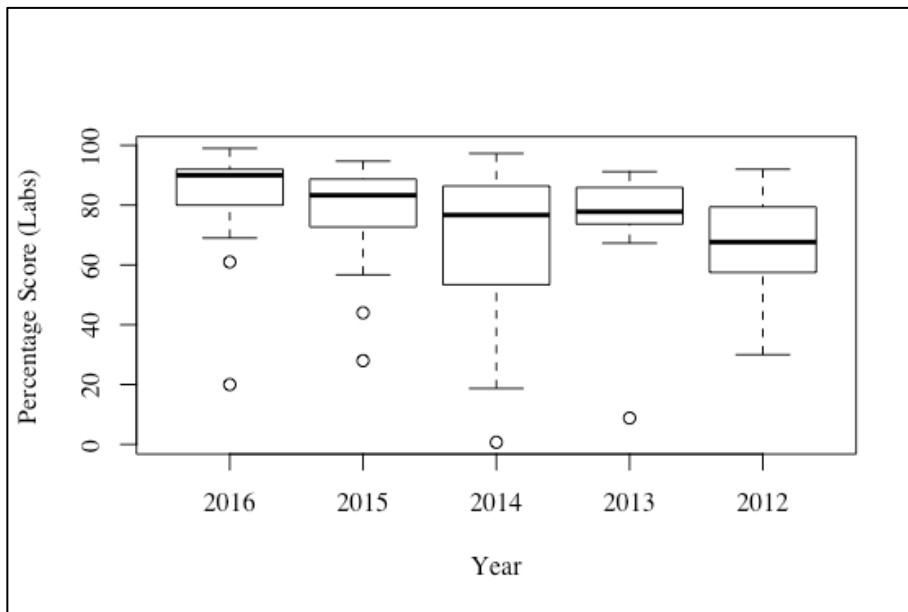


Figure 4. Comparison of lab scores, ($n=18$, $n=17$, $n=21$, $n=13$, $n=18$).

Table 4
Statistical Analysis of Lab Scores

Semester Comparison	Wilcoxon p -value	Statistical Difference?
2016 to 2015	0.117	No
2016 to 2014	0.038	Yes
2016 to 2013	0.049	Yes
2016 to 2012	0.0021	Yes

Note Taking

The Engagement in Previous Science Classes Survey found that 56% of students took notes *often* in their previous science classes while only 6% indicated that they never took notes. In contrast, only 18% of students in the flipped classroom indicated that they took notes *often*. Forty one percent of students in the flipped classroom said they took notes *sometimes* and 35% indicated that they never took notes. No students in the flipped class indicated that they took notes *all the time* (Figure 5). Although students didn't take many notes in the flipped class, responses to the Flipped Classroom Engagement Interview indicated that the students felt the lecture video was a good introduction to the topic. One student remarked: "I felt I knew the topic before I came to class".

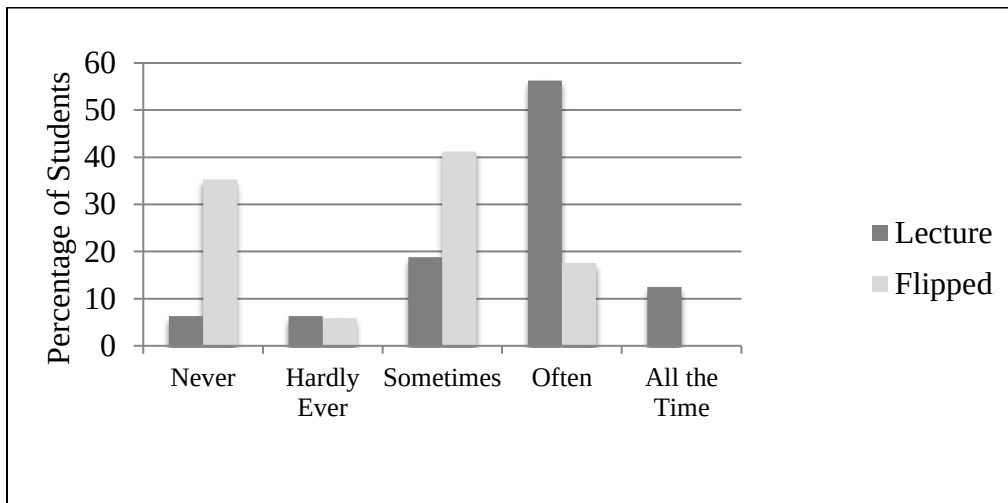


Figure 5. Comparison of note taking in lecture vs. flipped class, (N=16, N=17).

Asking Questions of the Instructor

Students in the flipped classroom were more inclined to ask questions of the instructor than in past science classes. In their previous classes, 38% of students asked questions either *sometimes* or *often*. However, in the flipped classroom 53% indicated

they *sometimes* asked questions of the instructor and 18% said they asked questions *often*. Only 6% of students indicated that in their past *never* asked questions in their previous classes and none of the students in the flipped class indicated they never asked questions. No students indicated they asked questions *all the time* (Figure 6).

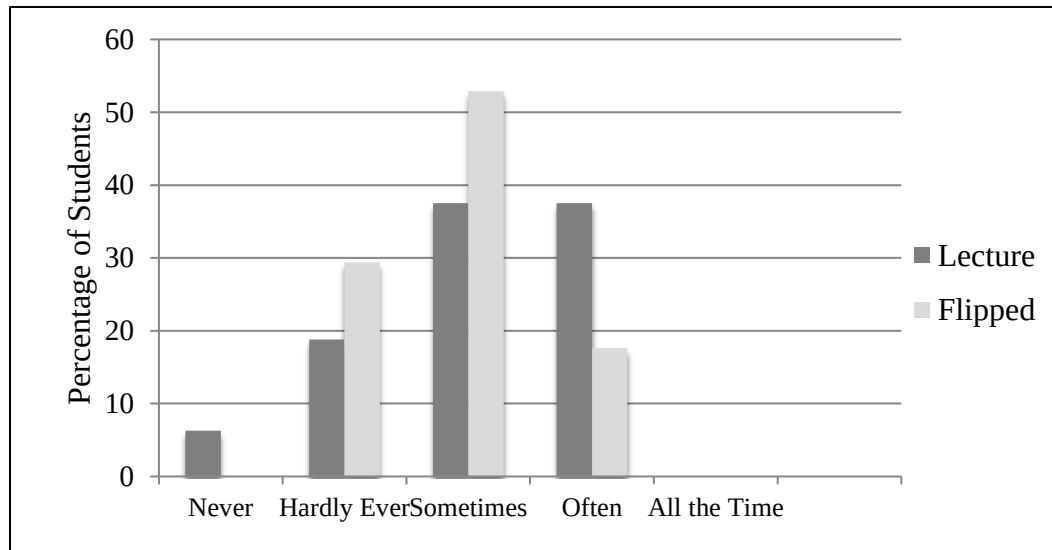


Figure 6. Comparison asking questions on topic, ($N=16$, $N=17$).

Peer Collaboration

Students indicated that they felt collaboration was important to learning science. When surveyed, 31% indicated that collaboration was *important* and 37% indicated that collaboration was *very important*. When asked about their collaboration in previous classes, 37% indicated that they *sometimes* collaborated with classmates and 31% indicated that they collaborated with classmates *often*. By contrast, in the flipped classroom 29% of students indicated that they collaborated with classmates *often* and 35% indicated they collaborated *all the time* (Figure 7). The students also felt collaboration was helpful because it was “a chance to share ideas.” Students also

indicated that they felt that collaboration with their peers helped them understand the material taught in the course. When surveyed, 82% of students either *agreed* or *strongly agreed* that collaboration was helpful in understanding the topic.

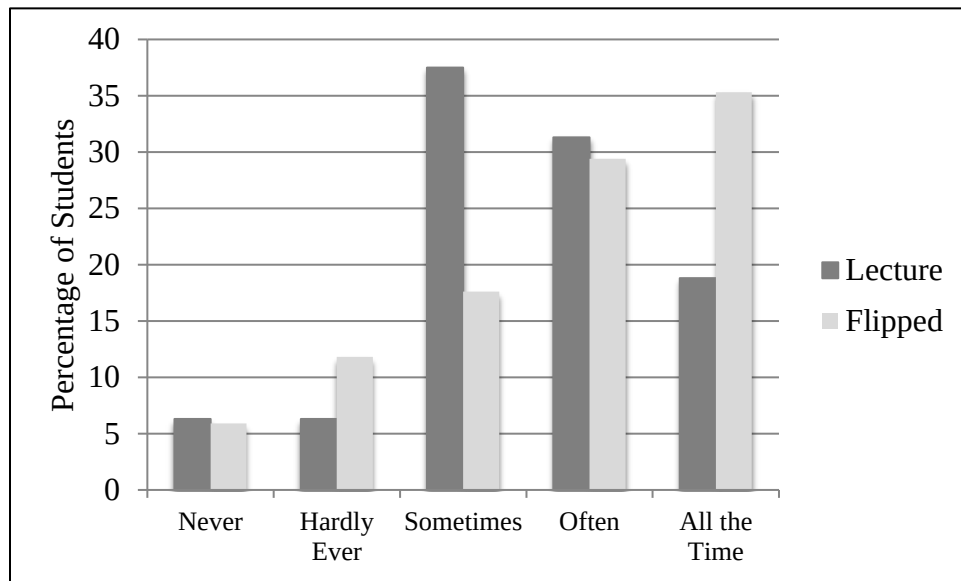


Figure 7: Collaboration with peers, (N=16, N=17).

Quiz Preparation

In the area of quiz preparation 44% of students indicated that in past science classes the lecture helped them prepare for quizzes or tests. When asked if they felt the lecture videos in the flipped classroom aided in their quiz preparation, 47% *agreed* and 35% indicated that they *strongly agreed*.

Student-Teacher Interaction

To determine the level of student to teacher interaction, students were asked about how often they asked their instructor for help with homework in past science classes and in the flipped class. In past science classes 50% of students indicated that they hardly ever asked their instructor for help with homework. While 19% of students said they

asked their teacher for help often, an equal number indicated that they never asked for help. Conversely, 41% of students in the flipped classroom indicated that they hardly ever asked for help but 47% indicated that they sometimes requested help and 12% indicated the asked the instructor for help often (Figure 8).

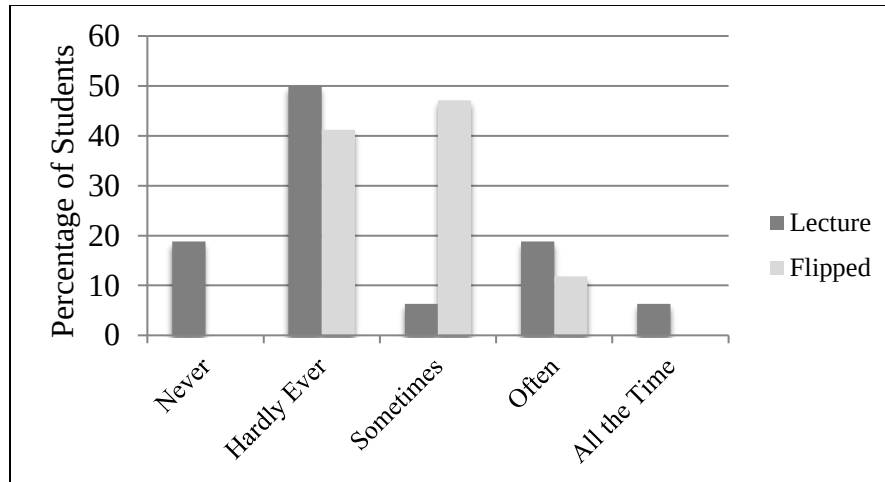


Figure 8: Asking instructor for help with assignments, (N=16, N=17).

Although students in the flipped class didn't ask the instructor for help as much as in a traditional class, they liked having the instructor available if needed. One student said, "I liked being able to ask questions in class instead of waiting until the next day. It made assignments a lot less stressful." Another student summarized her feelings about the flipped classroom in a single sentence, "I really loved the format of this class, it worked really well for me."

INTERPRETATION AND CONCLUSION

Results of the Astronomy Diagnostic Test (ADT) clearly show student growth from the beginning of the course to the end. An increase in median of 30 points and a decrease of range demonstrates improved understanding of basic astronomy concepts.

However, because there is no ADT data from previous years there is insufficient evidence to make any claim that the flipped classroom model had any impact on the observed change.

The examination of data comparing the 2016 flipped class to the previous four years in the areas of assignments, quizzes and labs was more revealing. Comparison of assignment data shows the 2016 semester was considerably better than the 2015 and 2012 semesters and slightly better than the 2014 and 2013 semesters. There is insufficient data to determine if this improvement in assignment scores is due to the flipped classroom model but one student felt the flipped model “reduced the amount of homework I had in an evening.” However, because students in the flipped classroom only occasionally asked the instructor for help with homework there is evidence that they relied more on their peers when solving problems.

The comparison of quiz data was less clear. While there was a significant difference in scores between the 2015 semester and the 2016 semester, the difference between 2016 and the other years was small. On the surface this may indicate that the flipped classroom had no impact on student quiz scores but without interview or survey data no conclusions can be drawn. However, because students in the flipped classroom took notes on the lecture video less often than in a traditional lecture it is possible that students did not use notes as a resource when taking the quiz.

The greatest evidence of student growth is in the comparison of lab scores. The 2016 semester showed significant improvement in average lab score compared to the previous four years. Since lab experiences in this astronomy course were inquiry based

simulations students were encouraged to work with their peers to explore the phenomenon being studied. During these lab experiences that students asked more frequent and thoughtful questions.

There is clear evidence that the 2016 semester astronomy class made growth in understanding and improvements in achievement compared to their counterparts in previous years. However, there is insufficient data to draw any conclusions that the growth was due to the flipped classroom model. There is anecdotal evidence that the flipped classroom kept students engaged and focused on learning. There is also clear evidence that students felt the flipped classroom model helped them learn the topics in astronomy.

VALUE

This project was too narrow in scope to draw any firm conclusions. However, there is value in the information the project provided. The use of the Astronomy Diagnostic Test was useful for examining student growth in the topic. Comparison of percent scores in the categories mentioned provided some data to examine the impact of the flipped model on student achievement but more data is needed. The surveys explored changes in student engagement from their previous science classes to the flipped class. The interviews showed the impression the flipped class made on some students.

The overall conclusion I draw from this project is that the flipped classroom model does have an impact on student engagement and, to a lesser extent, student achievement in astronomy. In order to facilitate improvements in achievement, I plan to provide students with instruction in careful note taking and quiz preparation. In addition,

I plan to instruct students in this use of multiple resources when working on assignments and quizzes.

This educational research project profoundly changed how I view my role as a science teacher. Science is a topic that students learn best by doing and they learn best when they are fully engaged in scientific exploration. The flipped classroom is a pedagogical method that has the potential to revolutionize how we teach science. By simply reversing where certain activities take place, we give students the opportunity to explore science in whole new ways. Through the use of this model, I discovered that I can facilitate student learning and understanding far better than through traditional classroom methods.

REFERENCES CITED

- Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. Eugene, OR: International Society for Technology in Education.
- Chao, C.Y., Chen, Y.T., & Chuang, K.Y. (2015). Exploring students' learning attitude and achievement in flipped learning supported computer aided design curriculum: A study in high school engineering education. *Computer Applications in Engineering Education*, 23(4), 514-526. doi:10.1002/cae.21622
- Clark, K.R. (2015). The effects of the flipped model of instruction on student engagement and performance in the secondary mathematics classroom. *Journal of Educators Online*, 12(1), 91-115.
- Council, N. R. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*: National Academies Press.
- Direct Instruction (2014, December 20). In S. Abbott (Ed.), The glossary of education reform. Retrieved from <http://edglossary.org/direct-instruction>
- Felder, R. M., Felder, G. N., & Dietz, E. J. (1998). A Longitudinal Study of Engineering Student Performance and Retention. V. Comparisons with Traditionally-Taught Students. *Journal of Engineering Education*, 87(4), 469-480. doi:10.1002/j.2168-9830.1998.tb00381.x
- Gross, D., Pietri, E.S., Anderson, G., Moyano-Camihort, K., & Graham, M.J. (2015). Increased preclass preparation underlies student outcome improvement in the flipped classroom. *Cbe-Life Sciences Education*, 14(4). doi:10.1187/cbe.15-02-0040
- Lasry, N., Dugdale, M., & Charles, E. (2014). Just in Time to Flip Your Classroom. *The Physics Teacher*, 52(1), 34-37. doi:doi:http://dx.doi.org/10.1119/1.4849151
- Love, B., Hodge, A., Corritore, C., & Ernst, D.C. (2015). Inquiry-based learning and the flipped classroom model. *PRIMUS*, 25(8), 745-762.
- McCallum, S., Schultz, J., Sellke, K., & Spartz, J. (2015). An examination of the flipped classroom approach on college student academic involvement. *International Journal of Teaching and Learning in Higher Education*, 27(1), 42-55.
- National Academy of Sciences-National Research Council (2000). Inquiry and the National Science Education Standards: a guide for teaching and learning. National Academy Press, Washington DC.

- Prather, E. E., Slater, Timothy F., Adams, Jeffrey P. & Brissenden, Gina (2013). *Lecture tutorials for introductory astronomy* (third ed.). San Francisco: Pearson Addison-Wesley.
- Tomory, A., & Watson, S.L. (2015). Flipped classrooms for advanced science courses. *Journal of Science Education and Technology*, 24(6), 875-887.
doi:10.1007/s10956-015-9570-8
- Weih, T. G. (2015). *Discussion Strategies for the Inclusion of ALL Students*. Retrieved from
<http://search.ebscohost.com.proxybz.lib.montana.edu/login.aspx?direct=true&db=eric&AN=ED561060&login.asp&site=ehost-live>
- Weiss, I., & Pasley, J. (2004). What is high-quality instruction? *Educational Leadership*, 61(5), 24-28.

APPENDICES

APPENDIX A

MSU IRB EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

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 Cheryl Johnson
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MEMORANDUM

TO: Rodney Kennedy and John Graves
FROM: Mark Quinn *Mark Quinn*
DATE: November 4, 2016
SUBJECT: "The Effects of the Flipped Classroom Model on an Introductory Astronomy Course" [RK110416-EX]

The above research, described in your submission of November 4, 2016, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

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

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

APPENDIX B

ENGAGEMENT IN PREVIOUS SCIENCE CLASSES QUESTIONNAIRE

Participation in this research is voluntary and participation or non-participation will not affect a student's grade or class standing in any way. Student responses will be kept anonymous and no student names will be used at any point in the research.

Instructions: The statements in this survey have to do with your opinions and beliefs about science instruction in school. Please read each statement carefully and circle the number that best expresses your own feeling.

In the past 2 years (not counting this one), how often did you take notes during a lecture in science class?

- ☐ Never
- ☐ Hardly Ever
- ☐ Sometimes
- ☐ Often
- ☐ All the Time

In the past 2 years (not counting this one), how often did you ask questions during a lecture in science class?

- ☐ Never
- ☐ Hardly Ever
- ☐ Sometimes
- ☐ Often
- ☐ All the Time

On a scale from One to Five with one being the lowest, how would you rate your engagement in past science classes?

Not at all Engaged		Somewhat Engaged		Very Engaged
1	2	3	4	5

In the past 2 years (not counting this one), how often did you ask your teacher for help with homework in science class?

- ☐ Never
- ☐ Hardly Ever
- ☐ Sometimes
- ☐ Often
- ☐ All the Time

In the past 2 years (not counting this one), how often did you collaborate or work with other students on homework in science class?

- ☐ Never
- ☐ Hardly Ever
- ☐ Sometimes
- ☐ Often
- ☐ All the Time

On a scale from One to Five with one being the lowest, how important do you feel collaboration with classmates is in understanding science?

Not at all Important		Somewhat Important		Very Important
1	2	3	4	5

In the past 2 years (not counting this one), how often did you feel prepared for tests or quizzes in science class?

- ☐ Never
- ☐ Hardly Ever
- ☐ Sometimes
- ☐ Often
- ☐ All the Time

In the past 2 years (not counting this one), how often did you feel that lectures adequately prepared you for tests or quizzes in science class?

- ☐ Never
- ☐ Hardly Ever
- ☐ Sometimes
- ☐ Often
- ☐ All the Time

APPENDIX C

FLIPPED CLASSROOM QUESTIONNAIRE

Participation in this research is voluntary and participation or non-participation will not affect a student's grade or class standing in any way. Student responses will be kept anonymous and no student names will be used at any point in the research.

Instructions: The statements in this survey have to do with your opinions and beliefs about science instruction in school. Please read each statement carefully and circle the number that best expresses your own feeling. The lecture videos used in this course were clear and easy to understand.

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

How often did you take notes while watching the lecture videos?

- ☐ Never
- ☐ Hardly Ever
- ☐ Sometimes
- ☐ Often
- ☐ All the Time

Watching the lecture videos was helpful in doing assignments and studying for the quiz

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

The notes I took while watching the lecture videos were helpful in doing assignments and studying for the quiz.

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

How often did you collaborate with a classmate on homework during this course?

- ☐ Never
- ☐ Hardly Ever

- ☐ Sometimes
- ☐ Often
- ☐ All the Time

Collaborating with a classmate was helpful in understanding the material in this course

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

How often did you ask the instructor for help with homework during this course?

- ☐ Never
- ☐ Hardly Ever
- ☐ Sometimes
- ☐ Often
- ☐ All the Time

How often did you ask the instructor question about the topic during this course?

- ☐ Never
- ☐ Hardly Ever
- ☐ Sometimes
- ☐ Often
- ☐ All the Time

How often did you re-watch lecture videos during this course?

- ☐ Never
- ☐ Hardly Ever
- ☐ Sometimes
- ☐ Often
- ☐ All the Time

Overall I felt engaged while watching the lecture videos in this course

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

Overall I feel I learned well from watching the lecture videos in this course?

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

Overall I feel that watching the lecture videos helped me prepared for chapter quizzes.

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

APPENDIX D

PAST SCIENCE CLASS ENGAGEMENT INTERVIEW

1. Tell me about how teachers in your past science classes taught science, specifically how did they present material they wanted you to learn?
2. Tell me about how homework was done in past science classes, specifically when were you expected to do homework and were you allowed to collaborate on assignments?
3. Tell me about how you felt about lectures in past science classes, specifically did you feel engaged in the topic?
4. Tell me how you handled confusion on topics in past science classes; specifically how did you go about alleviating your confusion?
5. Tell me about your confidence in past science classes; specifically did you feel in control of your learning and did you feel you were learning effectively?
6. Is there anything else you would like me to know?

APPENDIX E

FLIPPED CLASSROOM ENGAGEMENT INTERVIEW

1. Tell me about your experience with the lecture videos; specifically what advantages and disadvantages do you see with watching lecture videos at home?
2. Tell me about your experience with doing assignments in the flipped classroom; specifically what advantages and disadvantages do you see with doing assignments in class?
3. Tell me about your experience with collaboration with your peers in the flipped classroom; specifically what do you like or dislike about collaborating with classmates?
4. Tell me about your overall feelings about the flipped classroom; specifically how do you feel that this model has helped or hindered your learning of science?
5. Overall tell me what you like and dislike about the flipped classroom model; specifically is there anything you feel would make this model of instruction better?
6. Is there anything else you would like me to know?

APPENDIX F

ASTRONOMY DIAGNOSTIC TEST

June 21, 1999

Version 2.0

Introductory Astronomy Survey

1. As seen from your current location, when will an upright flagpole cast no shadow because the Sun is directly above the flagpole?
 - A. Every day at noon.
 - B. Only on the first day of summer.
 - C. Only on the first day of winter.
 - D. On both the first days of spring and fall.
 - E. Never from your current location.

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

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

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

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

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

5. How does the speed of radio waves compare to the speed of visible light?
 - A. Radio waves are much slower.
 - B. They both travel at the same speed.
 - C. Radio waves are much faster.

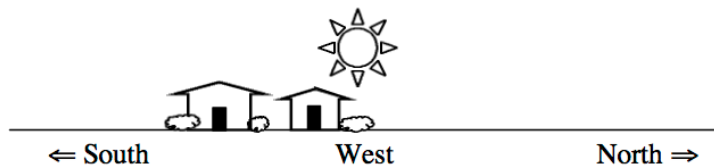
6. Astronauts inside the Space Shuttle float around as it orbits the Earth because
 - A. there is no gravity in space.
 - B. they are falling in the same way as the Space Shuttle.
 - C. they are above the Earth's atmosphere.
 - D. there is less gravity inside the Space Shuttle.
 - E. more than one of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

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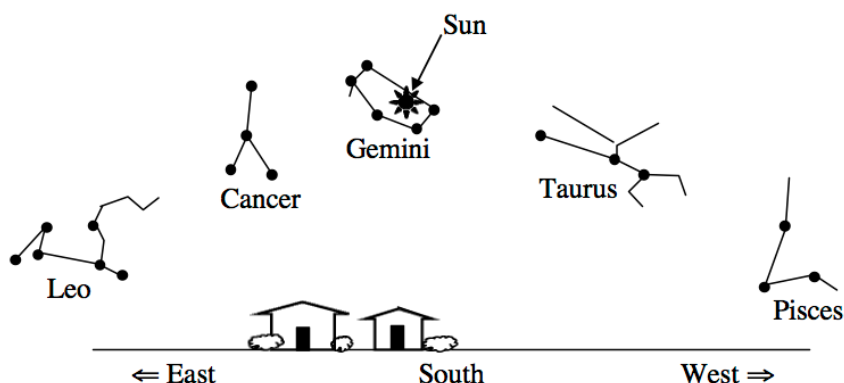
June 21, 1999

Version 2.0

7. Imagine that the Earth's orbit were changed to be a perfect circle about the Sun so that the distance to the Sun never changed. How would this affect the seasons?
- We would no longer experience a difference between the seasons.
 - We would still experience seasons, but the difference would be much LESS noticeable.
 - We would still experience seasons, but the difference would be much MORE noticeable.
 - We would continue to experience seasons in the same way we do now.
8. Where does the Sun's energy come from?
- The combining of light elements into heavier elements
 - The breaking apart of heavy elements into lighter ones
 - The glow from molten rocks
 - Heat left over from the Big Bang
9. On about September 22, the Sun sets directly to the west as shown on the diagram below. Where would the Sun appear to set two weeks later?
- Farther south
 - In the same place
 - Farther north



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



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June 21, 1999

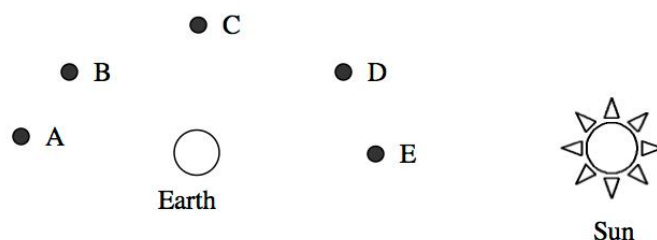
Version 2.0

11. Compared to the distance to the Moon, how far away is the Space Shuttle (when in space) from the Earth?
 - A. Very close to the Earth
 - B. About half way to the Moon
 - C. Very close to the Moon
 - D. About twice as far as the Moon
12. As viewed from our location, the stars of the Big Dipper can be connected with imaginary lines to form the shape of a pot with a curved handle. To where would you have to travel to first observe a considerable change in the shape formed by these stars?
 - A. Across the country
 - B. A distant star
 - C. Europe
 - D. Moon
 - E. Pluto
13. Which of the following lists is correctly arranged in order of closest-to-most-distant from the Earth?
 - A. Stars, Moon, Sun, Pluto
 - B. Sun, Moon, Pluto, stars
 - C. Moon, Sun, Pluto, stars
 - D. Moon, Sun, stars, Pluto
 - E. Moon, Pluto, Sun, stars
14. Which of the following would make you weigh half as much as you do right now?
 - A. Take away half of the Earth's atmosphere.
 - B. Double the distance between the Sun and the Earth.
 - C. Make the Earth spin half as fast.
 - D. Take away half of the Earth's mass.
 - E. More than one of the above
15. A person is reading a newspaper while standing 5 feet away from a table that has on it an unshaded 100-watt light bulb. Imagine that the table were moved to a distance of 10 feet. How many light bulbs in total would have to be placed on the table to light up the newspaper to the same amount of brightness as before?
 - A. One bulb.
 - B. Two bulbs.
 - C. Three bulbs.
 - D. Four bulbs.
 - E. More than four bulbs.
16. According to modern ideas and observations, what can be said about the location of the center of the Universe?
 - A. The Earth is at the center.
 - B. The Sun is at the center.
 - C. The Milky Way Galaxy is at the center.
 - D. An unknown, distant galaxy is at the center.
 - E. The Universe does not have a center.
17. The hottest stars are what color?
 - A. Blue
 - B. Orange
 - C. Red
 - D. White
 - E. Yellow

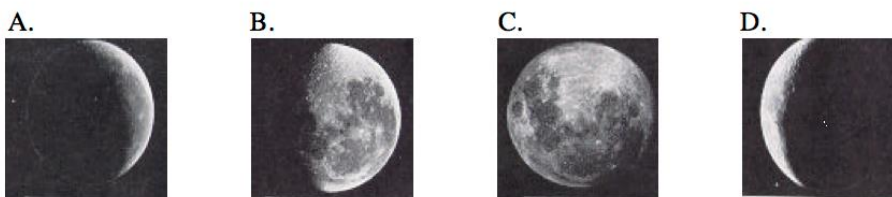
June 21, 1999

Version 2.0

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



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



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20. With your arm held straight, your thumb is just wide enough to cover up the Sun. If you were on Saturn, which is 10 times farther from the Sun than the Earth is, what object could you use to just cover up the Sun?
- A. Your wrist
 - B. Your thumb
 - C. A pencil
 - D. A strand of spaghetti
 - E. A hair
21. Global warming is thought to be caused by the
- A. destruction of the ozone layer.
 - B. trapping of heat by nitrogen.
 - C. addition of carbon dioxide.
22. In general, how confident are you that your answers to this survey are correct?
- A. Not at all confident (just guessing)
 - B. Not very confident
 - C. Not sure
 - D. Confident
 - E. Very confident

PLEASE TURN THE PAGE