INTRODUCING A LAB COMPONENT INTO AN ASTRONOMY 101 LECTURE

COURSE

by

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ABSTRACT

This descriptive study follows the work of an Astronomy 101 Community College instructor during the transition of a lecture based course to a lecture/lab course. The transition occurred because of the addition of a planetarium and computer lab to a new campus science building and the instructor's desire to update his course. This paper discusses the process of transition, including a conceptual framework for the transition, establishing course goals, finding and implementing labs, and examining and analyzing student assessment data to measure the effectiveness of the labs. Instructional and pedagogical changes are also presented. The most significant finding of this study was the increase in student engagement in the astronomy content due to the implementation of a lab component.

CONTRIBUTIONS OF AUTHORS AND CO-AUTHORS

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Contributions: Conceived the study, collected and analyzed data, and wrote the manuscript.

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Contributions: Provided the classroom for the study, assisted with study design, discussed results and implications, and commented on the manuscript at all stages.

MANUSCRIPT INFORMATION PAGE

1. INTRODUCTION AND BACKGROUND

1.1. Introduction

This study describes the transition of a lecture-based Astronomy 101 course to a lecture/laboratory course. This transition occurred in response to opportunities afforded by the addition of a planetarium and computer lab to a new science building on the community college campus and because of the instructor's desire to update his course.

Incorporating a lab component into a lecture course required research into effective science instruction, critical assessment of content in astronomy, and effective introductory astronomy labs. Using the work of other instructors and available online lab resources, the instructor was able to incorporate labs into the course that had previously been only lecture-based. This paper describes the research that documented the process of incorporating a lab component into a lecture course, and determined what was effective and what might be changed for the future. It also provides guidelines for other instructors of introductory astronomy courses who may want to do similar revisions to their courses. Table 1 shows the primary and secondary research questions for this study along with the forms of data that are used to assess each question.

1.2. Background

Spokane Falls Community College is set in Eastern Washington with a student population of 9,500. In 2010, a new science building was added to the campus, including a state-of-the-art digital planetarium. The focus of this study is the work of the college's astronomy instructor, who has thirteen years of Astronomy 101 teaching experience,

using various modes of instruction including lecture, telecourses, and online instruction.

Table 1 describes the study questions and the data sources used to assess those questions.

Table 1

Data Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
Primary Question:			
What successes and challenges does an instructor face in undergoing a transition from a lecture based college-level introductory astronomy lecture course to a lecture/lab course?	Formative assessment data from students	Observations and journal entries from researcher and instructor interviews	Summative assessment data from students
Secondary Questions:			
1. Does the inclusion of a lab component in an introductory college astronomy course result in a change in student understanding and retention of course content?	Weekly Quiz data and Formative Assessment data using I-clickers	Comparison of pre-test at the beginning of the quarter to the end of the quarter test results	Comparison of summative assessment results between lab-driven units to lecture driven units
2. How does the instructor change his pedagogy and instruction when teaching a lecture/lab course versus a lecture course?	Observations from the researcher	Self-reflection from the instructor through interviews	
3. What resources does the instructor use to transition his course?	Lists of resources used and literature review	Observations and journaling from researcher	Interviews with instructor
4. How do students feel the labs help their understanding of the content?	Student surveys at the end of a unit	Observations by instructor and researcher	Interviews with the students
5. What is the role of the researcher in this descriptive study?	Journal entries from researcher	Interviews with instructor	

The treatment for this study involved adding a lab component by changing the original course from five lecture hours per week to four lecture hours per week and two lab component hours per week. The lecture format was modified to allow for the reduced contact time during lecture. Some of the content that was in the lecture was moved to the weekly lab time, and some was removed altogether. Weekly labs were developed using both existing online astronomy lab resources in addition to other labs developed by the instructor and the researcher. Assessments were developed to determine the effectiveness of the labs. Finally, a detailed journal documented the process including weekly interviews with the instructor about the successes and challenges of the incorporation of the lab component.

2. CONCEPTUAL FRAMEWORK

This conceptual framework includes research about effective science instruction and how that can guide an instructor's course design. Also included is a discussion about previous work done by other Astronomy 101 instructors and the resources they suggest for this type of course revision. A discussion about current research in critical astronomy concepts leads us to a focus for the new course. Included in this discussion are important resources for Astronomy 101 instructors to consider as they incorporate lab components into their courses. Finally, research behind the data collection instruments is included explaining why those tools were chosen.

2.1. Making the Change

An extensive study undertaken by the National Research Council indicates that three key principles dictate how students learn (Bransford, Carey, Egan, Wilson, & Wineburg 2005). The first principle implies that students enter a classroom with preconceptions about the world. An effective science lesson will confront those preconceptions. The second principle explains that students learn science through engagement in scientific inquiry, thus developing deep content knowledge through scaffolding from experience. Finally, students should be reflecting on their learning and how their thinking has changed over time. A traditional lecture course may engage students' preconceptions and build a scaffold of content. However, because students are not engaged in the process of science, they are less likely to experience conceptual change (Bransford et al. 2005).

Astronomy 101 is a common course taught at most higher education institutions, is generally designed for non-science majors, and is often a student's only exposure to college-level physical science. Since roughly 10% of all college students take the course, the American Astronomical Society (AAS) realized the need for systemic change to the traditional lecture course. In conjunction with the Astronomical Society of the Pacific (ASP), the AAS developed Goals for Astronomy 101 as a start to this systemic change (Partridge & Greenstein 2004). Many of the goals listed involve engagement in the scientific process. This underscores the need to transition Astronomy 101 courses from traditional passive lecture courses to active courses with laboratory components. Redish (2000) describes several models of physics instruction that involve active, student-centered learning. "Reading and listening to lectures are, for most students, ineffective ways of changing their mental models" (Redish 2000, p. 4).

Astronomy education research also indicates that student engagement in science

courses and attitudes about science are heavily influenced by the type and format of the

course.

> Some of the difficulties include that both physics and astronomy students do not
>
> achieve conceptual understanding of physics or astronomy topics through
>
> traditional, lecture-based instruction alone, and that they leave their physics and
>
> astronomy courses with little to no improvement in their attitudes toward, values
>
> about, or interests in science (Prather, Rudolph, Brissenden, & Schlingman 2009,
>
> p. 320).

2.1.1. *How to Add an Astronomy Lab Component*

As with any course making a curricular change, goal-setting guides the

development of the syllabus. Goals for an Astronomy 101 course can be separated into

two categories: astronomy content and scientific skills (Partridge & Greenstein 2004).

These goals can be further separated into a few overarching goals, then specific course

goals. Once goals have been identified, specific learning targets can be developed that

will guide how to present the material (Slater & Adams 2003). Further study of the

important concepts in astronomy coupled with common misconceptions found in

astronomy emphasizes which core ideas would best be taught through a lab experience

(McCrady & Rice 2008).

As with any science, the breadth of content in astronomy is vast. The *Framework*

for K-12 Science Education (Board on Science Education 2011) uses research to develop

some common goals for science education. While these are developed for the K-12

sphere, they can be adapted for higher education. The recommendations from the

National Research Council can help with lab development and what types of scientific

skills should be developed in students.

> Seeing science as a set of practices shows that theory development, reasoning, and
>
> testing are components of a larger ensemble of activities that includes networks of
>
> participants and institutions; specialized ways of talking and writing; the
>
> development of models to represent systems or phenomena; the making of
>
> predictive inferences; construction of appropriate instrumentation; and testing of
>
> hypotheses by experiment or observation (Board on Science Education 2011,
>
> p.43).

The *Framework for K-12 Science Education (2011)* also establishes criteria for

the Earth's place in the universe. This provides a guideline for teaching goals around

astronomical concepts. Key ideas include the use of integrated science such as physics

and chemistry to describe the origin of the universe and solar system. Students should

also have a solid understanding of stellar motions including an explanation of the Earth-

Moon-Sun system. The *Framework* suggests that students should be able to describe the

life cycle of a star including our sun. Students should also be able to describe forces and

principles that dictate the motions of the solar system. Finally, students should be able to

explain how variations in the motions of the Earth cause climactic events (Board on

Science Education 2011). These concepts can be used as a baseline for an Astronomy

101 course with the expectation that there will be additional concept development.

Once the instructor has determined the goals for the course and the lab component

of the course, the selection of materials becomes a challenge. When choosing materials

for the development of a lab component, the instructor should consider the characteristics of a quality lab such as the confrontation of commonly held misconceptions or preconceptions in astronomy. The lab should also include research-based practices by incorporating components of how students learn science. Students should be able to understand the purpose of the lab and how it relates to the course goals (McCrady & Rice 2008).

2.1.2. *Lab Resources Available for Astronomy 101*

The Nebraska Astronomy Applet Project (NAAP) is a resource that has been designed for the introductory astronomy student (Lee 2011). The project developed several labs covering a wide range of astronomy topics using computer simulations. The labs can easily be modified to accommodate the goals and teaching style of the instructor. Other resources about astronomy activities suggest an open inquiry approach. These lab activities provide students with an astronomy experience, usually virtual, although accommodations can be made to use actual equipment. Then students engage in independent research projects (Slater, Slater, & Lyons 2010). These labs are less content driven than the NAAP labs and focus more on the inquiry process. Lillian McDermott's work at the University of Washington teaches the Earth-Moon-Sun system through the inquiry process. These labs are designed for introductory physics students, but can be used in an Astronomy 101 course (McDermott 1996).

The Astronomical Society of the Pacific has developed a website specifically designed for astronomy instructors interested in developing those courses. This website includes references to labs, activities, and simulations (Fraknoi 2004). Fraknoi (2004)

also includes guides for instructors, interdisciplinary approaches, and suggestions for new

approaches to astronomy instruction. This site is specifically focuses on the practice of

teaching astronomy rather than the content specific details (Fraknoi 2004).

3. METHODOLOGY

3.1. Treatment

The treatment for this study involves changing the original Astronomy 101 course

from five lecture hours per week to four lecture hours per week and two lab component

hours per week. The instructor first established content goals for this course (Appendix

A) based on previous research (Partridge & Greenstein 2004). Once the goals for the

course were developed, the instructor researched, modified, or developed an appropriate

lab for each major concept (Table 2). The resources used for each lab will be described

in the data analysis section.

Table 2
Treatment Schedule

Lab Number	Lab Title	Dates Administered
Lab 1	Celestial Coordinates/Seasons	Week 2
Lab 2	Atomic Structure/Spectroscopy	Week 3
Lab 3	Kepler's Third Law	Week 4
Lab 4	Planetary Conference/Sun Observation	Week 5
Lab 5	Sunspot Lab/Planetarium Show	Week 6
Lab 6	Binary Stars Lab	Week 7
Lab 7	Hertzsprung-Russell Diagram	Week 8
Lab 8	Cosmic Distance Ladder	Week 9

	Lab	
Lab 9	Hubble Law Lab	Week 10

Weekly lab quizzes were given to assess content knowledge derived from the lab experiences as well as to inform the instructor which concepts needed to be reiterated. Significant research on formative assessment indicates that students experience the highest gain in achievement in classrooms that use formative assessment strategies (Black & Wiliam 1998). The weekly lab quizzes: a) provided data for the acquisition of the content delivered in the lab experience, b) allowed students to self-assess their conceptual understanding thereby giving them an opportunity to reengage with the content as needed, and c) provided data that allowed the instructor an opportunity to re-teach key concepts where student learning was deficient. When assessment data is used in a timely and formative way to involve students in the learning process, and to adjust instruction, student achievement is expected to improve (Black & Wiliam 1998).

3.2. Data Collection

This study follows the students in both sections of the instructor's lecture course and all three sections of the lab. The students in the lab sections were not necessarily in the same lecture section. The research study was conducted using both sections of lecture and all three sections of lab. There were 67 students total, 36 males and 31 females, with 93% non-science majors, and 67% under the age of 21.

While the focus of this research study is to document some of the successes and challenges of introducing a lab component to a lecture course, there is a secondary focus to determine if the introduction of the lab component has an immediate impact on

understanding and retention of astronomy concepts. The Astronomy Diagnostic Test (ADT; see http://solar.physics.montana.edu/aae/adt/) was used to establish a baseline of understanding of astronomy concepts (Slater & Adams 2003; Adams 2001). The ADT was developed to uncover common and persistent misconceptions in astronomy. In this study, the ADT was administered at the beginning of the quarter, then again at the end of the quarter to assess change in understanding of astronomy concepts and misconceptions.

A previous analysis of the ADT indicated that course format does impact normalized gain on the test (Brogt, Sabers, Prather, Deming, Hufnagel, & Slater 2007). In that study, researchers assessed 5000 pre-test and 3200 post-test results to determine how students' understanding of astronomy content changed after instruction. Pre- and post-tests were not matched by students. Brogt et al. (2007) then measured pre- and post-test mean scores for each class and calculated a normalized gain. In the current research study, pre- and post-tests also are not matched. Normalized gain is calculated as: Normalized gain = (% post - % pre) / (100 - % pre) (Brogt et al. 2007). Unlike the Brogt et al. study, the current study does not include a comparison of the results of the ADT to a non-treatment group. Rather, patterns were identified in conceptual change between concepts addressed by the lecture and lab vs. concepts addressed by the lecture only.

Short surveys and interviews were administered to students to determine their perceptions of the affect of the lab component to their understanding of the content. The surveys relied on a Likert scale. Students were also interviewed to determine how they think the lab component has changed their understanding of content. The interviews were used to corroborate the surveys (Mills 2011). Quotes and survey results were used to describe successes and challenges associated with specific lab experiences.

In addition to measuring understanding and retention of content, this study focused on the process an instructor undertakes in introducing a lab component to a lecture course. The instructor was interviewed throughout the process including weekly interviews focused on the outcome of the implemented lab component for the week. These interviews were first coded based on specific labs. Pedagogical changes and general comments by the instructor were coded and sorted to provide an overall picture of how the instructor's pedagogy and methods changed throughout the quarter. Additional conversations included some overall expectations of the course and how those expectations may have changed over time. Brogt et al. (2007) focused on how the instructor's view of the course changed as the course progressed. The interviews supported the instructor's perception over time.

As a collaborator, this researcher also had a role in instructional support as documented through journals. Personal journals, particularly from an outside observer can prove to be valuable entries when corroborating an instructor's viewpoint (Brogt et al. 2007). Further, the journal information can include the researcher's observations as well as documentation of dialogue between the researcher and the instructor. This can also provide a means for the instructor to review their thinking and change their instructional practice (Mills 2011). The researcher's personal journal provided a means of recording the steps throughout this study.

Current educational research in science was initially considered. As the theoretical framework for the research was developed, pertinent findings and research were shared with the instructor, giving him a scaffold for course development. Course goals then were developed in a collaboration of the instructor and the researcher. It was

helpful for the instructor to have a collaborator in this process to be able to focus on more general content goals and skills rather than smaller content details.

Throughout the development of the labs, the instructor shared his potential labs with the researcher to ensure they would meet the content goals of the course, run in the time allotted, and positively engage students to improve learning. The researcher also helped the instructor develop weekly quizzes and formative assessment strategies to monitor the progression of the lab component. After the weekly quizzes were completed, the researcher analyzed the data with the instructor helping him make future instructional decisions as well as help assess student success in learning the content goals of the course.

In this descriptive study, the role of the researcher was not passive. While not involved in the instruction or facilitation of the course, the researcher functioned as a colleague and collaborator in the beginning stages of the implementation of the lab component. The researcher also suggested strategies for implementing labs as well as shared educational research on effective science instruction.

3.2.1. *Validity and Reliability*

Validity of this study is ensured through detailed records of the process of incorporating a lab component into a lecture course. The primary question, "What are some of the challenges and successes in undergoing a conversion from a college-level introductory astronomy lecture course to a lab course?" is addressed through the analysis of multiple measures including observations, interviews, surveys, and content

assessments. The analyses of the different instruments are examined in concert to find overall patterns that answer the study questions.

The reliability of this study comes from multiple measures of each research question. The primary research question is answered through examination of the entire body of research. Individual research questions are addressed through multiple measures. One example is in addressing the question "To what degree do students feel the labs help their understanding of the content?". Students were given surveys asking them their opinions of the lab component. They were also interviewed by the researcher to corroborate their survey answers.

An additional measure of validity and reliability of this study is the use of well-researched and well-established instruments such as the ADT. The surveys were based on similar surveys used to assess attitudes. Finally, the research design has been used previously and is well-established in the literature (Bailey et al. 2011; Brogt 2007; Slater & Adams 2003).

4. DATA AND ANALYSIS

Much of the data from this study has been combined to provide a broader perspective to give other instructors a picture of how to successfully accomplish this type of change. Each secondary research question is discussed individually, culminating in a larger analysis of the primary research question, "What successes and challenges does an instructor face in undergoing a transition from a lecture based college-level introductory astronomy lecture course to a lecture/lab course?"

4.1. Changes in Pedagogy and Instruction

When introducing a lab component into a lecture course, an instructor will have to make both instructional changes and pedagogical changes. The research question, "How does the instructor change his pedagogy and instruction when teaching a lecture/lab course versus a lecture course?" was addressed through interviews with the instructor and observations by the researcher. The interview questions designed to test this were "What changes in instructional practice did you make this week?", "What are your next steps?", and "How will you use this week's quiz data?". Documenting the specific instructional changes will allow the instructor to reflect on those changes and improve practice (Mills 2011).

The instructor implemented two major instructional changes, the incorporation of a lab component into a lecture course and the use of formative assessment strategies to inform instruction. After having taught Astronomy 101 for 13 years without the lab component, substantial change to the structure of his instruction was required, summarized in Table 3 under "Instructional Changes." Introducing a lab component also invites pedagogical change. Pedagogical change is any change in the way the instructor delivers instruction. These are summarized under the column titled "Pedagogical Changes" (Table 3). Separated are changes made in the lecture part of the course; changes made to implement the lab component of the course; and changes made that applied to the course as a whole.

One of the greatest instructional challenges was the need to reduce lecture content to accommodate the inclusion of the lab. This was a source of frustration for the

instructor because he did not feel as though he is doing justice to the content after making the change.

> Before the lab (in previous quarters) I felt as though the lecture worked well and tied all the material together. It was a nice sequence. I did not like the change to the lab and also think they may not have understood the material as well (Week 3).

The instructor felt that what he was doing before worked well and that what he is doing now is an intrusion. In contrast to this perception, his observation and reflection that students were more engaged in a lab setting and that the labs helped students make the connections to the lecture material.

The instructor is aware of the value of looking at student understanding as a vehicle for conceptual change. One pedagogical change initiated by the instructor has led to instructional changes in both the lecture and lab. He was asking students weekly "What is your muddiest point?" and using student responses to inform further instruction. He was also examining results of weekly lab quizzes to see how well students understood the lab concepts. For example, in one weekly lab quiz students' identification of their muddiest point specifically indicated a need to further review Kepler's third law. In response, the instructor reviewed Kepler's third law the following week: "I reviewed it in both lecture and lab and it went well because there was good discussion with the students and it seemed like productive conversation" (Week 6). He also had students grade their own lab assignments so they could look at the best answers for the lab questions and self-evaluate their understanding. Students supported this strategy saying, "The self-

correcting of the labs has been really useful because then I have to really process the

information."

Table 3
Interview Results- Instructional and Pedagogical Changes

	Instructional Changes	Pedagogical Changes
Lecture Only	- Decreased content covered in lecture to accommodate decrease lecture contact time - Re-writing lecture notes to accommodate lab	- Created specific content goals for the course - Decrease of in-class activities because of decrease in contact time
Lab Only	- New weekly labs - Implementing weekly lab quizzes to asses students understanding of lab concepts - Students grade their own labs - Intentional use of available equipment (such as telescopes, celestial spheres, computer lab)	- Looking at students' muddiest points from the lab to see if there are patterns in misunderstandings - Intentionally reflective to make positive changes for subsequent courses.
Lecture and Lab	- Wants students to bring lecture notes and book to lab as a resource and reference - Moving content specific to the lab out of lecture time and into the lab time	- Focus on making connections between lecture and lab - A renewed focus on student engagement - A focus on ensuring the students understand the big ideas in astronomy - Intentionally examining data measuring student understanding

While the benefits of using formative assessment data in the form of weekly

quizzes, muddiest points, self-correcting, or other assessment strategies has been shown

to improve student learning (Black & Wiliam 1998), finding the time to leverage the

information has been a challenge for the instructor. "Giving the quizzes during lecture takes too much time, so while I like the data and the muddiest point, I either need to drop the weekly quiz, or find a better way to do it" (Week 7). In the future, the instructor will continue to find ways to formatively assess students in an effort to continue to improve the course.

The opportunity to integrate labs into the course also prompted the instructor to reexamine the instructional and content goals of the course. At the start of the quarter, the instructor outlined the major concepts that he wanted the students to learn in addition to the astronomical skills he wanted the students to acquire. He then designed the lectures and labs to match those goals and skills. During the weekly interviews with the researcher, the instructor was able to reflect on whether the lecture and/or lab met those goals and skills, and to decide what changes should be made to improve that alignment.

I felt like doing the sun at this point was premature because they haven't had it in lecture yet. I think a global warming lab would work better with the planetary conference part. They would look at global warming data and make some conclusions (Week 6).

In analyzing his course, he determined that some of the material for the lab was misplaced and would work better at a different point in the course. This intentional course reflection is key to continuous instructional improvement (Black &Wiliam 1998).
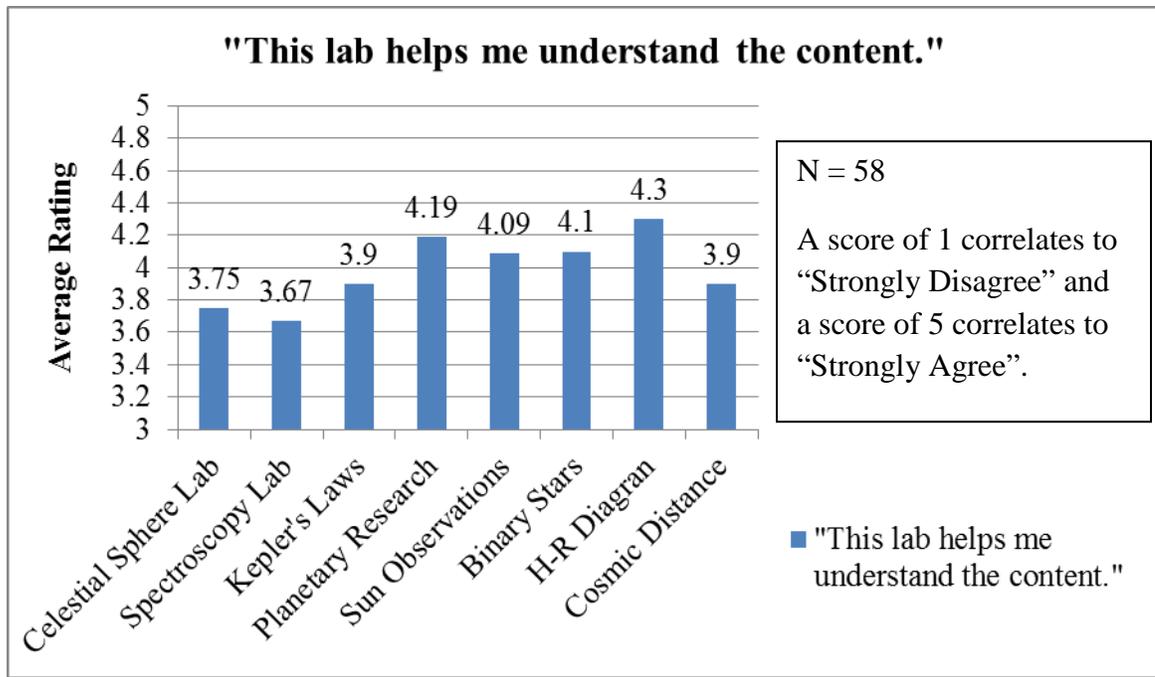
4.2. Student Attitude

Students were asked how effective they thought each lab was in supporting their understanding of the content. They were also asked a more general question to determine

if the lab component of the course helped them understand astronomy. Interviews were conducted with students to confirm and further probe their original opinions.
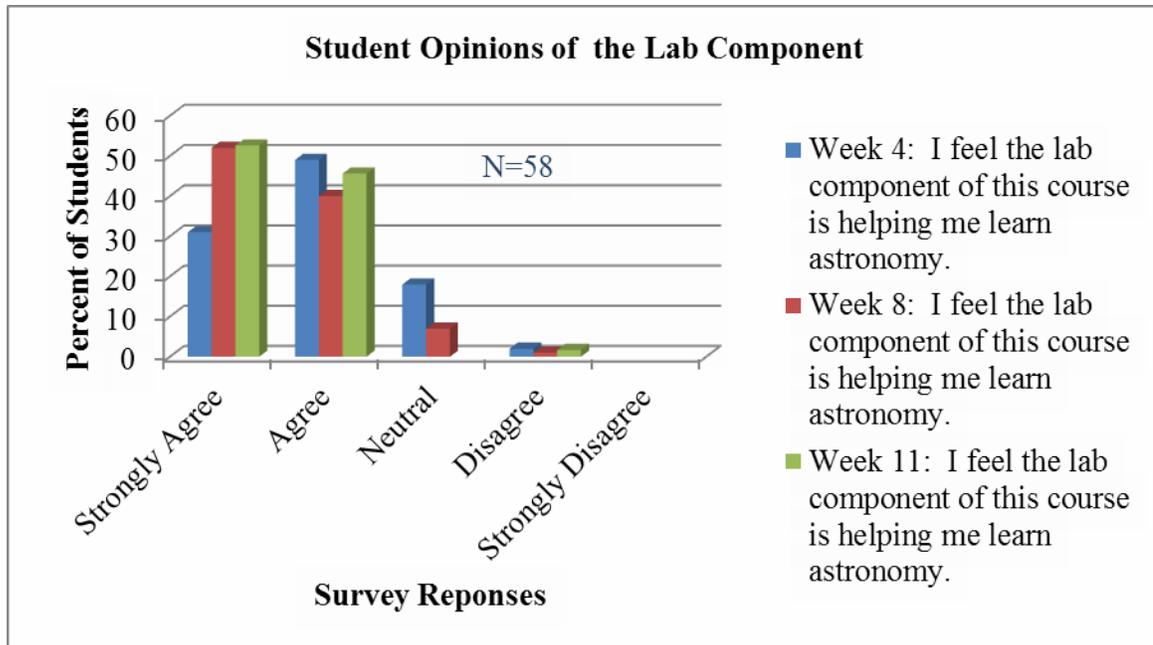
Results varied when students were asked about individual labs. Near the beginning of the course, the instructor was new to designing and facilitating labs, while the students also did not know what to expect from an astronomy lab. As the course progressed, student perceptions of the effectiveness of the labs increased (Figure 1- Labs are listed chronologically on the X-axis). This result suggests that an instructor may expect a lag between implementation of the lab and when students start appreciating the value of the lab component. This appreciation on the part of the students may arise in part because the instructor becomes better at facilitation as he gains experience.

Interestingly, after an increase in rating of the labs in mid-quarter, student ratings of the Cosmic Distance Ladders lab decreased. Student comments indicated that "this lab did not seem as relevant." In initial interviews with the instructor, he felt that the lab went quite well, and did not feel that changes needed to be made. However, after seeing the survey comments, he considered dropping that lab in future quarters and replacing it with something more relevant. In the future, the instructor may want to probe students to determine why they did not feel the lab was relevant. This further emphasizes the value and need to elicit student feedback.

"This lab helps me understand the content."

Average Rating (y-axis: 3, 3.2, 3.4, 3.6, 3.8, 4, 4.2, 4.4, 4.6, 4.8, 5)

- Celestial Sphere Lab: 3.75
- Spectroscopy Lab: 3.67
- Kepler's Laws: 3.9
- Planetary Research: 4.19
- Sun Observations: 4.09
- Binary Stars: 4.1
- H-R Diagran: 4.3
- Cosmic Distance: 3.9

N = 58

A score of 1 correlates to "Strongly Disagree" and a score of 5 correlates to "Strongly Agree".

■ "This lab helps me understand the content."

Figure 1: Student Attitudes about Each Lab

Students were asked about the lab component as a whole and if they thought the lab component helped them understand the content throughout the course. Students were asked after the first third of the course and again after the second third of the course. The results indicate that as the course progressed the students felt that the lab component was more relevant and more helpful to their learning (Figure 2). Interview results corroborate this information. The results clearly suggest that students value the lab component of the course and feel that the lab component was helping them understand the content. Interviews with students further support this result, "The labs give me a better context for understanding the content." The students' active role in the construct of the course likely led to a perception that their participation provided additional value to the course.

Figure 2: Student Opinion of the Lab Component

Several of the labs implemented in the course originated from the Nebraska Astronomy Applet Program (Lee 2011). These labs contain simulators that allowed students to manipulate and analyze data to learn astronomy content. Students appreciated the time using the simulators to look at specific content in depth. Two of the four groups of students interviewed said that often the "talk in the lecture goes over my head, but the lab allows processing of the material." They also felt as though "the lectures are more theoretical and the labs are more practical." Several students mentioned that they appreciated the engagement piece of the lab component.

While students overwhelmingly appreciated the lab component, they also experienced some challenges. Interview comments combined with weekly formative assessment results gave clues about the challenges of the lab component. Most of the labs had some applied math that students needed to use to complete the labs. While the math is algebraic, only 19% report being good or very good at math, while the remaining

81% of the students considered themselves to be average or below average at math. While this has presented a stumbling block for the students, the instructor states "it is important for students to see how math is used and applied in science." One student interviewed stated that "the math content is overwhelming". Again, this data reiterates the importance of making connections between math and science and showing mathematical relevance. Other challenges involve the students that were in the Monday section of the lab. They felt they did not have enough lecture background to be successful in lab. The instructor noted this early on in the quarter and expects to change his sections to eliminate the Monday time and add an additional section of lab later in the week.

4.3. Resources

Most of the labs for the first implementation of the lab component originated from previously published sources. The instructor found the greatest success with the Nebraska Astronomy Applet Project (NAAP), (Lee 2011). Those labs were comprehensive, had good simulators and related directly to the course content. Because NAAP was a publicly funded project, all labs are available online at no cost. They are also available in Microsoft Word© format so they are easily editable to match an instructor's goals. One concern with those labs is that they have many grammatical and typographic errors. Over half of the labs in this study originated from the NAAP website.

Another resource that was heavily drawn upon was Virtual Astronomy Laboratory- Computer-Based Labs for Introductory Astronomy (Littlewood 2004). This curriculum also has simulations and pre-made labs but the instructor did not find these

labs as immediately relevant or user friendly as the NAAP labs. The Virtual Astronomy

Laboratory curriculum requires a site license, and therefore is not accessible to students

outside of class or to instructors who do not have the site license. One third of the labs

had a component from Virtual Astronomy Laboratory.

The remainder of the labs were instructor originated, or researcher originated

based on a compilation of education research on best practice, the resources mentioned in

the conceptual framework of this study, or the content goals of the course. Some of these

labs were explicitly designed to allow students to manipulate equipment. The Sunspot

Lab, for example, gave students hands-on experience with the telescopes.

4.4. Student Understanding and Retention

Student understanding and retention proved to be challenging to accurately

measure over one quarter. The Astronomy Diagnostic Test (ADT) (Adams 2001) was

administered at the beginning and at the end of the course. While the ADT was a valid

and reliable instrument, well-documented by other researchers (Brogt et al. 2007) it was

not specific to the outline and goals of this course. In addition, weekly quizzes were

compared, using lab-based quizzes compared to lecture-based quizzes. Finally, questions

on the final were analyzed comparing lab-based questions to lecture based questions.

After administering the ADT at the end of the course, the instructor identified 7

questions from the ADT that assessed content exclusively addressed in the lab

component. The remaining 14 questions on the ADT assessed content that was primarily

lecture based, or content that was addressed in lecture then in the lab. Normalized gain

was calculated for the lab-based questions and for the lecture-based using the formula:

normalized gain = (% post - % pre) / (100 - % pre) (Brogt et al. 2007). Lab-based questions had an average normalized gain of 0.464 and lecture-based questions had an average normalized gain of 0.374 (N = 38). This results in a difference of 0.09 in normalized gain, which was not statistically significant (SE = 0.127; P = 0.48).

To assess concepts that were not covered in the ADT, the instructor intentionally added 5 specific questions on his final that were exclusively lecture-based, and 5 specific questions on the final that were exclusively lab-based. The purpose of these questions was to see if students were more successful on the lab-based questions than on the lecture-based questions to further ascertain if the lab component promotes greater understanding and retention. The average number of correct answers was 77% for the lab-based questions and 72% correct for the lecture-based questions, but the difference was also not statistically significant.

Each measure of student retention and understanding suggested that students were at least as successful on lab-based assessment questions as on lecture-based assessment questions. With any curricular implementation, a lag time usually exists between implementation and demonstrable improvement in retention and understanding. Research on educational change indicates that there is often an implementation dip that occurs as an instructor learns new curriculum, but has yet to master the curriculum or pedagogical strategies (Busick & Inos 1992). It is expected that as the instructor of this course continues to revise the course, improve the labs, and design assessments that are better aligned to the instruction and lab experiences, student understanding and retention also will continue to improve.

5. INTERPRETATION AND CONCLUSION

Some clear successes with the implementation of a lab component are the focus on the student and the increased engagement by the students. Students felt that the labs were beneficial to their learning, as evidenced by 96% of student survey responses. The results indicate that they felt that some labs were more directly beneficial than others, this information being helpful to the instructor as he continues to modify the course in future quarters. Students felt the lab component gave them "a better context to understand the material." All interviewed groups echoed similar comments.

Another success is the instructor's intentionality about reflecting on each lab. This has given him the ability to record what has gone well with each lab as well as what he would change for the future and why. This record will make subsequent quarters much easier for planning. In addition, this intentionality allows the instructor to consider the impact of changes on students and student understanding (Hord et al. 2005). An additional success is the pedagogical change of taking student understanding into consideration when designing instruction.

The greatest immediate challenge encountered for the introduction of the lab component seemed to be finding the most effective lab experiences. Through the intentionality of recording specific details for each lab, however, the instructor will be able to improve on the lab experiences for subsequent quarters. Additionally, finding time to adequately and accurately use student data to inform instruction is a challenge.

The instructor feels that the students are better able to connect to the lecture content using the lab component and the diagnostic lab assessments support these observations. When comparing lab-based questions to lecture-based questions, the

students scored at least as well on the lab-based questions (77% correct on lab-based questions compared to 72% correct on lecture-based questions). The instructor will continue modifying the diagnostic assessment used in this study to align more closely with the course goals and objectives, and plans on administering the assessment at the beginning and end of each quarter. This will provide a consistent baseline for student understanding as well as a measure of the effectiveness of the labs as the course is updated. The recently updated Astronomy Diagnostic Assessment (Bailey, Slater, & Slater 2011) will provide another model for the instructor. Other results from this study showed that student understanding and retention of lab-based material was at least comparable to understanding and retention of lecture-based material. As the instructor continues to improve the course and facilitate the labs, understanding and retention should increase.

The instructor is amassing a collection of resources for the lab component of the course. Recording each resource along with the modifications made will help other instructors wanting to make similar changes. The data analysis itself will prove to be a valuable resource for the instructor as he seeks to improve his course in the future.

The implications of this study for other instructors and their students are two-fold. First, instructors considering adding a lab component to their lecture course are presented with considerations to be made both prior and during the transition. This intentionality will help ensure that students have the best chance of increasing their learning and conceptual change. Second, instructors also can infer that while their students may not initially make demonstrable changes in understanding and retention, they will do at least

as well as a lecture only model, and will appreciate the opportunity to use and manipulate astronomical data to formulate conclusions.

6. ACKNOWLEDGEMENTS:

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APPENDICES

APPENDIX A

CONTENT GOALS FOR ASTRONOMY 101 FOR THIS STUDY

Course goals

1. Celestial Sphere
   a. Relation of ecliptic to paths of planets, sun, moon
   b. Solstice/equator positions
   c. Coordinate system- RA/Dec
   d. Precession of NCP
   e. Seasons
2. Moon-Phases: Understand cause of moon phases, eclipses
   a. Use moon logs data, telescope observations, and sketching
3. Application of Kepler and Newton's Laws
4. Spectroscopy: Understand how astronomers know what the Universe is made of
5. Doppler Shift: Understand how astronomers use the Doppler shift to determine the motion of celestial objects
6. Solar Nebula Theory: Understand formation of solar system
7. Sun: Part of 2 lab periods- use of telescope (lab)
   a. Telescope observation of sunspots
   b. Calculate rotation period
   c. Magnetic activity cycle
   d. Solar energy generation/transport
8. Hertzsprung- Russel Diagram- Use the H-R diagram to understand the life cycle of stars
9. Milky Way Galaxy
10. Hubble's Law: Expansion of the Universe
11. Dark energy and dark matter
12. Big bang theory

APPENDIX B

INDIVIDUAL LAB INFORMATION

Interview Results- Instructor Assessment of Each Lab

Lab Title/Interview Date	What went well?	What would you change?	What resources did you use?	If this was an existing lab, what modifications were made?
Celestial Sphere Lab 9/30/2011	• Took the correct amount of time • Students were engaged and worked well together • Great seasons simulation and students understood seasons well	• Post background information in Angel for students to access • De-emphasize the mapping part • Increase seasons, solstices, and equator	Nebraska Astronomy Applet Project (NAAP)- Basic Coordinates and Seasons Student Guide	No modifications
Spectroscopy and Atomic Structure Lab 10/6/2011	• By the end students were clear about atomic structure and energy excitation	• De-emphasize finding the energy ranges • Include the simulation in pre-lab preparation • Students need to bring lecture notes and book to lab • Include spectral lines and electromagnetic radiation to the background information	NAAP for the first half, and instructor-made for the spectroscope part	Removed many of the NAAP exercises such as the Bohr model and the quantum model of the atoms

Lab Title/Interview Date	What went well?	What would you change?	What resources did you use?	If this was an existing lab, what modifications were made?
Kepler's Third Law Lab (finding the mass of Jupiter) 10/14/2011	• Students understood the real-world application of Kepler's third law • Students were able to make the connection between lecture and lab	• Add more questions to the lab after students calculate the mass of Jupiter to add more depth to the lab • Have students calculate how close they were to the actual mass of Jupiter and postulate why there is a difference • Incorporate graphing into the lab	Simulations from Virtual Astronomy Lab	This lab was instructor made
Planetary Conference 10/21/2011	• Students like researching the planets • They worked well together in their groups	• Some accountability for their research • Incorporate a global warming lab with the planetary conference	Students used the computers for research	Researcher created lab
Lab Title/Interview Date	What went well?	What would you change?	What resources did you use?	If this was an existing lab, what modifications were made?

Sunspot Lab 10/28/2011	• Students liked using the telescopes • Students were able to set up a ratio independently • Students appreciated applying their algebra skills to a real situation • Students liked a more concrete experience	• Focus more on teaching students about telescopes and how to use the telescope • Students need more guidance on telescope observation procedures • Model how to observe using a telescope	Telescopes	This lab was instructor made
Binary Stars Lab 11/5/11	• Students liked matching simulator to real data • Easier to grasp the concept • Good visual representation	• Lab was good • Add more explanation about finding center of mass to background	NAAP	Few modifications
H-R Diagram Lab 11/10/11	• Good simulator for demonstrating the relationship between mass, luminosity, and temperature • Seemed	• Take out the proportion question between luminosity and mass • Repetitive	NAAP and Virtual Astronomy	Corrected the verbiage and errors Merged a NAAP and Virtual Astronomy Lab

Lab Title/Interview Date	What went well?	What would you change?	What resources did you use?	If this was an existing lab, what modifications were made?
	intuitive			
Cosmic Distance Ladder 11/17/11	- Students were engaged - Nice example of how the distances rely on each other	No changes Note: After looking at student responses and data, instructor is considering dropping this lab because of the lack of relevance	NAAP	Corrected the verbiage and errors
Hubble Law Lab 12/3/11	- Good simulated data of redshifts - Students constructed and interpreted graphs - Applicable to information presented in lecture	- Make students do unit cancellation so they understand the constant - Would like to be able to change data in simulation so the Hubble value is not too low	Virtual Astronomy	Added a table and empty graph/grid to the lab so students could record their data.