Effectiveness of Two Interactive Learning Techniques in Introductory Astronomy

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As a part of the shift to active learning environments in the Department of Physics and Astronomy at Eastern Kentucky University, we implemented the use of a clicker system in all the introductory astronomy courses. The clickers were used in class on a daily basis to allow students to actively participate in lectures. Several of the astronomy courses at Eastern Kentucky University also include interactive laboratory sessions. Here we present pre- and post-test data from the solar system astronomy class utilizing the Astronomy Diagnostic Test (ADT) from the first semester of clicker use compared to previous semesters. We also compared the differences between the laboratory and non-laboratory sections of the introductory astronomy course by comparing their ADT results. In both cases the students' normalized gain on the ADT is higher when taught the concepts using the interactive techniques.

I. INTRODUCTION

Much work has been done to show the effectiveness of interactive instruction in introductory astronomy. Most of this work, however, has focused primarily on interactive activities during a lecture course, e.g. Prather, et al. (Prather et al., 2009). Very little work has been done on the effectiveness of traditional laboratory exercises in astronomy. Jacobi et al. studied the effect of nighttime laboratories and showed an increase in correct answers on their assessment on questions that were directly related to the nighttime activities (Jacobi et al., 2009). In this work, we investigate the effect that traditional laboratory activities have on student learning, as well as the practice of using a classroom response system, "clickers," to enhance interactive learning in the classroom setting.

As experienced by many instructors, the traditional lecture setting is often cost-effective but is not learning efficient. Encouraging student engagement has always been the greatest challenge for instructors in large classroom settings. Hake's study shows that physics courses using interactive methods have a significant advantage in enhancing student conceptual understanding over the traditional pure lecture course (Hake, 1998). Mazur's peer instruction method also demonstrates that interactive learning is an effective way to teach introductory astronomy (Mazur, 1997). The classroom response system is a natural continuation of the latest trend in college education based on new, emerging technology. The use of clickers automatically turns a traditional lecture class into an interactive teaching and learning environment. In the past ten years, clickers have been adapted into college classrooms and have helped many students in their learning process. In physics education, studies show that clicker systems are effective tools to enhance students' conceptual understanding (Reay et al., 2006). In astronomy education, however, similar observations are yet to be taken.

The assessment for this study was done with The Astronomy Diagnostic Test (ADT). The ADT was developed over a number of years to be a standard concept inventory for undergraduate-level introductory astronomy for non-science majors. The predecessor instruments to the ADT were the Project STAR Astronomy Concept Inventory and Zeilik's Misconceptions Measure (Sadler, 1992; Sadler, 1998; Zeilik, 1997). The ADT Version 1.0 was a combination of questions from those two instruments (Zeilik et al., 1998). The most recent version of the ADT (Version 2.0) was released in 1999. The test consists of 33 questions, 21 of which are content and 12 are demographic. The content questions were written in such a way so as to avoid the use of jargon, cover only one concept per question, and include topics recognizable to most high school graduates (Hufnagel et al., 2000).

II. EXPERIMENT DESIGN

Eastern Kentucky University (EKU) is a comprehensive regional university located in Central Kentucky. The service region of the university consists of twenty-two counties located in south-central and southeastern Kentucky. The University has approximately 16, 500 students with 86% of the students being in-state residents. One rather unique aspect of the student population of the university is that about 52% of incoming freshmen are first generation college students, meaning that neither parent earned a baccalaureate degree. Many of these students have unrealistic expectations of what they will experience in college courses. The University is an open enrollment institution providing an opportunity to students that may otherwise not be able to pursue a college degree. One result of this is that 28% of the undergraduate population is considered non-traditional (defined as 24 years old or older). Deming and Hufnagel showed that the demographics of introductory astronomy courses mirror the demographics of the home institution (Deming & Hufnagel, 2001).

The Department of Physics and Astronomy (PHAS) at EKU offers three introductory astronomy courses. Two of the courses cover essentially the same content, solar system astronomy, and the other course covers stellar astronomy, galactic astronomy and cosmology. The two solar system astronomy courses differ in that one course, AST 130, is a standard three credit-hour lecture and the other, AST 135, has two hours of lecture and a two-hour associated laboratory section. All three of these courses satisfy the general education science requirement of the University. This study was done using multiple sections of both the laboratory and non-laboratory versions of the solar system astronomy course.

Table 1: Demographic statistics of two introductory astronomy courses.

Item	Options	**AST 130**	**AST 135**
General Statistics	Number of Students	154	222
	Pre-test Average	32%	28%
	Standard Deviation	13%	13%
23. What is your college major (or current area of interest if undecided)?	A. Business	5%	10%
	B. Education	40%	24%
	C. Humanities, Social Sciences, or the Arts	13%	21%
	D. Science, Engineering, or Architecture	8%	8%
	E. Other	34%	36%
24. What was the last math class you completed prior to taking this course?	A. Algebra	56%	68%
	B. Trigonometry	8%	4%
	C. Geometry	8%	5%
	D. Pre-Calculus	13%	14%
	E. Calculus	15%	8%
25. What is your age?	A. 0-20 years old	54%	68%
	B. 21-23 years old	32%	23%
	C. 24-30 years old	7%	3%
	D. 31 or older	7%	5%
	E. Decline to answer	0%	1%
27. What is your gender?	A. Female	57%	55%
	B. Male	40%	40%
	C. Decline to answer or did not attempt	3%	5%
32. Which best describes the level of difficulty you expect/experienced from this course? (Pre→Post)	A. Extremely difficult for me	1%→9%	2%→8%
	B. Difficult for me	16%→44%	21%→40%
	C. Unsure	68%→32%	68%→30%
	D. Easy for me	15%→13%	7%→20%
	E. Very easy for me	0%→1%	1%→1%

Table 1 shows the demographic data for the two courses. The largest difference in the student demographics between the two courses is in their major programs. In the non-laboratory course there are a much higher number of students who identify themselves as education majors, 40% versus only 24% of students in the laboratory course. In both courses the highest level of mathematics taken by most of the students is Algebra, and a very small percentage of the students identify themselves as being very good at math and science. Most of the students are from either a small town or rural area, which is consistent with the service region of EKU. Both courses had a considerable increase in the number students that claimed the course to be difficult on the post-test versus the pre-test. This is most likely due to the students' uncertainty of what to expect from the course. This is evidenced by the high percentage of students (68%) that indicated that they were unsure of the level of difficulty that they expected at the beginning of the course.

The laboratory activities that are used in AST 135 are a mixture of hands-on activities and computer based laboratories. There are thirteen laboratories throughout the semester. Three of them are computer-based with two using planetarium software and one using the Internet. One laboratory session is a visit to the on-campus planetarium, two laboratories are outdoor observational activities at our on-campus observation deck, and the remaining seven are hands-on activities done inside the laboratory. Of the thirteen laboratory activities, two cover content directly related to some questions on the ADT. The first is one of the two activities using the planetarium software. This lab, titled “Starry Night I,” covers the topics of sunrise and sunset time and location changes over the year, and the change in the Sun’s altitude at noon throughout the year. The second is called, “Styrofoam Moon.” This laboratory is a hands-on activity that uses a Styrofoam ball as the Moon and light bulbs as the Sun to investigate moon phases and eclipses. The students move the ball around their heads to observe how the portion of the ball illuminated changes with its position. During that process they also simulate lunar and solar eclipses. This is a common laboratory used in many different settings, from K-12 to graduate school.

III. LABORATORY INFLUENCE ON ADT RESULTS

In order to evaluate the effect of laboratory instructions, we compared the ADT data obtained from AST 130 with that obtained from AST 135 on both pre and post-tests. There are 20 questions on the ADT that are relevant to both courses, and five are covered directly in laboratory activities of AST 135. Table 2 shows the results of the comparison between AST 130 and AST 135 for the relevant questions. During the Spring 2010 and Fall 2010 semesters, 96 students from AST 130 and 149 students from AST 135 participated the study.

Among the five relevant questions, three of them (questions 2, 18 and 19) are related to the Styrofoam Moon activity. The other two (questions 9 and 10) are related to the Starry Night I activity. We calculated the normalized gain for the entire test as well as for these five items. The AST 135 students’ normalized gain for the whole test is 19.41%, which is not statistically higher than that of the AST 130 students (18.48%). The striking difference, however, is in the gain on the five questions relevant to the laboratory activities. AST 135 students had a gain of 29.10%, which is statistically more significant than the 20.04% of AST 130 students (one-side t-test p-value = 0.01). For clarification, we calculated the difference in the normalized gain between AST 135 and AST 130. This data is also shown in Table 2. This suggests that the students are significantly benefiting from the activity-based learning environment within the traditional laboratory setting.

Table 2: Comparison of AST 130 and AST 135: Effectiveness of lab activities.

No.	Item Description	AST 130	AST 135	Lab Gain*
	Number of students	96	149	
	Total Normalized Gain	18.48%	19.41%	
	Normalized Gain RELEVANT	20.04%	29.10%	
A2	Styrofoam Moon	33.77%	46.09%	12.33%
A9	Starry Night 1	18.64%	21.10%	2.46%
A10	Starry Night 1	-4.65%	8.51%	13.16%
A18	Styrofoam Moon	12.07%	22.58%	10.51%
A19	Styrofoam Moon	40.38%	47.22%	6.84%

*Lab Gain = AST135 Normalized Gain – AST 130 Normalized Gain

On the questions that cover content related to eclipses and moon phases, students’ normalized gain in AST 135 exceeded 20%. Students’ performance on the other two questions, that are related to content in the Starry Night I activity, is not as consistent. The AST 135 normalized gain on question 10 is lower than 10%, which suggests that the gain barely exists. The difference in gain between the Moon questions and other questions may be explained by the nature of the activities themselves. The Styrofoam Moon laboratory is a hands-on activity, which uses light bulbs and Styrofoam balls to represent the solar system. The Starry Night I activity, on the other hand, is focused on using a computer software package to learn the motion of the sun and planets in the sky. Although statistical comparison is impossible due to the limited number of items, all three items related to the hands-on activity produce better results than the two items related to the computer software activity.

There is another difference in the two courses that could contribute to the better overall gain of the AST 135 students; the number of contact hours for the AST 135 class is higher than for AST 130. We believe that the increased number of contact hours is not a factor for two reasons. First, both AST 135 and AST 130 use the same textbook, and instructors spend the same amount of time in each chapter regardless of the course. The contact-hour difference reflects on the number of chapters covered by each course. In AST 135, instructors usually cover the first 7 to 9 chapters; in AST 130 some instructors can go as far as 14 chapters. Second, the ADT questions only assess content knowledge based on the first five chapters, which is fully covered by both courses. We have enough evidence to believe that the significant difference in the two courses' gain indicates the effectiveness of activity-based learning, specifically hands-on activities.

IV. THE USE OF CLICKERS IN THE ASTRONOMY CLASSROOM

Starting in Fall semester 2010, PHAS began the use of clickers in all the introductory level courses which included AST 130 and AST 135. The goal of this move was to encourage student engagement in large-scale classes, and to provide an active learning environment for the students. In order to evaluate the effectiveness of the use of the clicker system, we compared the ADT results obtained in clicker and non-clicker courses. An ideal experiment design would be comparing two identical courses, one using clickers and not using clickers, taught by the same instructor. In reality, this setting never happened. The whole department started using clickers at the same time. To adjust we compared the data obtained from spring 2010, when none of the courses used clickers, with that from fall 2010, when all astronomy courses used them.

There are several commercial clicker systems available on the market. We chose the "i>clicker" system (www.iclicker.com) because of its simplicity and flexibility. The i>clicker system allows instructors to create questions not specifically attached to any particular software, and provides easy-to-use remote controls. Instructors can also choose questions from various sources and use them directly in class. In the courses for which we collected data, some of the clicker questions came from textbook questions, some from supplementary questions provided by publishers, and also some instructor-developed multiple choice questions.

The normalized gain of Astronomy Diagnostic Test obtained from non-clicker courses and clicker courses are listed in Table 3. We calculated the normalized gain for each individual item as well as the entire test. The results show that use of the clicker system enhances students' gain on most questions, some of them significant. Overall, the clicker courses obtained 21.37% of normalized gain on ADT questions, which is 3.06% higher than similar courses without clickers. While this is a small gain, we do hope that number will increase as instructors gain more experience incorporating the clickers into their courses. As with any new instructional technique, it takes practice for instructors to become comfortable and to be most effective.

V. SUMMARY

In this study we showed that both the use of traditional laboratory activities and the use of clickers in interactive lectures have a positive impact on student learning. It has been established that interactive methods are better, but many instructors find it challenging to make changes to their courses given existing facilities and resources. If a studio-style course for introductory astronomy is not possible, then incorporating interactive methods, such as clicker use or traditional laboratories can improve the student experience in these courses in a more cost-effective way.

ENDNOTES AND REFERENCES:

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