A LIVELY ELECTRONIC COMPENDIUM OF RESEARCH, NEWS, RESOURCES, AND OPINION

Astronomy Education Review

Volume 2, Feb 2003 - Dec 2003
Issue 1

Activities-based Astronomy: An Evaluation of an Instructor's First Attempt and its Impact on Student Characteristics

by **William J. Straits**
L. L. Hotchkiss Elementary, Dallas Independent School District
R. Russell Wilke
Angelo State University
Posted: 04/28/03

The Astronomy Education Review, Issue 1, Volume 2:46-64, 2003

Abstract

This study assessed the effectiveness of an instructor's first attempt at an activities-based, non-majors astronomy course. Although students in this course performed as well as those in a lecture-based course, students in the activity-based course had a significant reduction in their self-efficacy with regard to science. Findings suggest that activities were most effective when they helped students to visualize spatial relationships, provided equal opportunity for engagement, and were clearly related to course content. However, activities often led to student confusion regarding the relevancy of activities to course content, the importance of information presented, and the connection between class and textbook information.

1. INTRODUCTION

The teaching method of choice at America's colleges and universities has long been and continues to be didactic (Boyer Commission 1998). Colleges and universities have remained relatively unaffected by the improvements that have occurred in elementary and secondary science education and have done little to answer challenges set forth by teams of scientists and educators dedicated to promoting undergraduate education (Boyer Commission 1998; National Research Council 1996; National Science Foundation 1996). Active learning is viewed by these organizations as a key for meeting the challenges involved with improving undergraduate science education.

In response to the aforementioned criticisms of undergraduate education and to specific problems within the College of Natural Sciences at a large southwestern university--including poor retention, poor course instructor surveys, and low grade point averages (Rankin 1998)--the Department of Astronomy has worked to improve instruction. Included in this effort is the implementation of activities-based instruction in non-major and lower division courses. The course examined in this study was developed in response to departmental and college-level goals of improving education, and the instructor's goal of fostering greater student interest in astronomy.

Active learning has been characterized as learning that: 1) involves students in more than listening; 2) places less emphasis on transmitting information and more on developing students' skills; 3) encourages higher-order thinking skills; and 4) places greater emphasis on students' exploration of their own attitudes and values (Bonwell & Eison 1991). Active learning is grounded in cognitive learning theory, which posits that learning occurs when the learner constructs an understanding of new information by associating it with prior knowledge in an organized and systematic way. There are several positive aspects of active learning, including increased attention to task(s); construction of a response as opposed to simple recognition; early and frequent feedback; personal associations; and creation of an episodic memory from which students can reconstruct knowledge (Svinicki 1998). Previous studies have demonstrated the effectiveness of active learning on various student outcomes, such as achievement and attitude toward instruction (Ebert-May, Brewer, & Allred 1997; Johnson, Johnson, & Smith 1991).

This study was conducted to evaluate a preliminary effort at incorporating active learning into the non-majors astronomy curriculum. By observing this initial attempt, we hoped to gain insight into the structure and dynamics of the course, which would then serve as the basis for reform in the curriculum and improvements to other astronomy courses. We hoped to identify both factors that contribute to success and constraints that limit active learning in astronomy. Findings will serve as the basis for further study and development of the activity-based curriculum. The specific objectives of this study were to determine: how students' attitudes toward science, understandings of the nature of science, instructional preference, and self-efficacy with regard to science are influenced by this activity-based course; how student achievement in this course compares to a traditional lecture-based course; the relationship, if any, between student attitudes and student performance; and students' perceptions of how they came to their understandings of specific content areas in astronomy and of the course overall.

2. COURSE DESCRIPTION

The course studied was a semester-long section (15 weeks) of non-majors' introductory astronomy, and was small--with only 46 students enrolled--relative to other introductory astronomy classes offered at this university. This was the instructor's first attempt at implementing an activity-based college course, which she designed based upon her experience teaching traditional lecture-based courses and leading activity-based in-service programs for K-12 science teachers. The course was taught via activities intermixed with short lecture segments. Many of the activities used in this course were drawn from Cooperative Learning Activities in Introductory Astronomy for Non-science Majors (Deming, Miller, & Trasco 1997). Activities ranged in complexity and frequency throughout the course of the semester. As many as three or four active learning strategies were employed per class meeting, each designed to introduce, teach, reiterate, or expand topics in astronomy.

3. DESIGN AND PROCEDURE

Quantitative techniques were used to determine the effects that active learning strategies have on students' achievement, attitudes toward science, and self-efficacy with regard to science. The Astronomy Diagnostic Test (ADT) Version 2.0 (Hufnagel et al. 2000) was given to assess achievement. To determine students' attitudes toward science, attitudes toward instruction, and self-efficacy with regard to science, a 24-item survey was constructed. The instrument was determined to have a reliability coefficient of 0.60 (Cronbach's alpha; see Note 1). Instruments were administered in a pre-test/post-test fashion to determine students' content acquisition and attitudes toward science. A control group was available for assessment on some portions of the study, but different class sizes, course content and structure, and textbooks limit the ability to make strong comparisons. Alpha coefficients for all instruments were set *a priori* at the p .05 level.

Qualitative analyses were used to explore students' views of the activities and the class in general. Data included interviews with 26 of the students enrolled, students' written comments on course evaluations, and researchers' classroom observations. Interviews were conducted during the fourth and the thirteenth weeks of the semester. Students were not obligated to participate in the interviews, but received extra credit for doing so. This strategy allowed access to student participants, but obligated researchers to continue interviews long after thematic saturation was reached (see Note 2). Excess data were used as referential adequacy materials supporting the validity of the findings (see Note 3).

To gain insight to students' perceptions of how they came to their understandings of specific content areas, the first exam was used as a basis for the first round of interviews. Students were asked to assess their understanding of the major concepts included on the exam and to describe how they had learned the information. Guiding the second round of interviews was an instrument created to test major themes of the first interviews, explore minor themes, and investigate other questions that did not necessarily arise during the first set of interviews. During these interviews, students answered 12 questions, discussed their answers with the researchers, and shared their overall perceptions of the course. All interviews were transcribed, member-checked, and coded as prescribed by Coffey and Atkinson (1996). The resultant data were framed to illustrate major themes and the relationships among them.

4. QUANTITATIVE FINDINGS

4.1 Achievement

To determine students' content acquisition of basic astronomy content, the Astronomy Diagnostic Test was given to the treatment and control group. The results of the ADT, published elsewhere (Hemenway et al. 2002), showed significant gains for both the treatment and the control, but no significant differences were found between the two.

4.2 Attitude

To assess students' attitudes toward science, understanding of the nature of science, self-efficacy, and instructional preference, a 24-item Likert scale instrument was given to the treatment group. T-tests revealed significant differences in items two, six, and eight between the pre-test and post-test (Table 1). Contrary to our hypotheses, students participating in this activity-based course developed a less accurate view of the nature of science and a decreased self-efficacy.

Table 1. Results of attitude survey, n = 29. Higher means indicate more agreement with the statements. 1 = disagree strongly; 5 = agree strongly.

	Pre-test		Post-test			
Survey Item	**Mean**	**SD**	**Mean**	**SD**	**t-value**	**sig**
1. Scientific questions are answered by observing things.	3.90	0.77	4.19	1.07	1.25	0.22
2. Scientific work is too hard for me.*	2.38	1.08	3.10	1.15	3.19	0.00
3. The laws and/or theories of science represent unchangeable truths.	2.14	0.95	2.03	1.05	-0.43	0.67
4. Science is something I enjoy.	3.38	0.94	3.34	1.01	-0.24	0.81
5. I prefer classes where lecture is the primary means of instruction.	2.41	0.98	2.76	1.22	1.84	0.08
6. Scientific work is useful only to scientists.*	1.34	0.48	1.79	1.08	2.10	0.05
7. I have always been good at science.	3.28	0.96	3.14	0.99	-1.28	0.21
8. Some questions cannot be answered by science.*	3.93	1.07	3.55	1.02	-2.01	0.05
9. I would do well in science if I tried to major in it.	2.72	1.07	2.66	1.01	-0.40	0.69
10. I do not like to answer questions in class.	2.97	1.02	3.24	1.06	1.55	0.13
11. No matter how hard I try, I cannot understand science.	2.00	0.76	2.10	0.90	0.62	0.54
12. The search for scientific knowledge would be boring for me.	2.10	0.90	2.24	1.06	0.66	0.52
13. I learn more from doing than from listening.	3.72	1.00	3.38	1.18	-1.91	0.67

14. Scientists are always interested in explaining things better.	3.57	1.20	3.64	0.87	0.31	0.76
15. I learn more from lecture than from activities.	2.61	1.20	2.96	1.04	1.63	0.12
16. I enjoy activities performed in class.	3.64	1.13	3.36	1.19	-1.49	0.15
17. I can judge the accuracy of scientific ideas I have read about in the popular media.	2.82	0.98	2.93	1.05	0.45	0.66
18. Anything we need to know can be found out through science.	2.54	1.04	2.82	1.06	1.55	0.13
19. Scientific discoveries tell us exactly what is going on in nature.	3.07	0.90	3.29	0.98	1.14	0.26
20. The only reason I'm taking science is because I have to.	2.86	1.30	2.93	1.30	0.30	0.77
21. I enjoy talking to other people about science.	3.04	0.96	3.21	1.03	1.15	0.26
22. I like participating in group discussions in class.	3.07	1.15	3.04	1.11	-0.18	0.86
23. Most people can understand science.	2.86	0.76	3.14	0.89	1.77	0.09
24. I can personally use the methods of science to answer everyday problems and questions.	3.41	0.93	3.33	1.04	-0.44	0.66

*indicates significance at $p < .05$

Cluster scores were determined for each of the constructs of the attitude survey (i.e., self-efficacy, nature of science, attitude toward science, and attitude toward instruction). These scores were calculated by adjusting for negatively worded statements, summing the responses, and dividing by the number of items in the construct. Group means were then compared between the pre-test and the post-test. Analysis indicated that self-efficacy with regard to science declined significantly (Table 2). The means of the other three constructs shifted--although not significantly--toward a less accurate view of the nature of science, a decreased attitude toward activities-based instruction, and a poorer attitude toward science. No significant correlations were found between any of the individual attitude survey items or attitude survey constructs and students' final exam grades.

Table 2. Construct analysis of the attitude survey, n = 29.

	Pre-test		**Post-test**			
	Mean	**SD**	**Mean**	**SD**	**t-value**	**sig**
Self-efficacy*	3.30	0.73	3.09	0.75	-2.16	0.04
Nature of science	3.33	0.38	3.16	0.51	-1.68	0.10
Instructional preference	3.03	0.34	3.02	0.48	-0.05	0.96
Attitude toward science	3.50	0.60	3.40	0.66	-1.04	0.31

*indicates significance at $p < .05$

An interview survey was constructed based on students' responses from the first round of interviews, and instructor and researcher questions that did not necessarily arise during the interviews. This survey was used during the second round of interviews to further investigate students' perceptions of such things as activities, instructional resources, and feedback. Items 1-11 (Table 3a) indicate students' perceptions of the activities and the class structure in general. Findings suggest that students were comfortable doing activities, believed that the activities were enjoyable and interesting, and appreciated the different forms of feedback that were provided during activities. In addition, students reported that they attended this course more frequently than other classes, a finding that may be related to interest in and enjoyment of activities (see Note 4).

Not all of the outcomes of the survey instrument were positive. Students reported that they did not think about activities outside of class and didn't believe that activity-based instruction would be possible in a larger class. Additionally, students thought that many of the activities were too elementary, a finding supported by qualitative data. However, the results of item 8 (Table 3a)--which suggest that students understood the point of the activities--are in disagreement with the results of qualitative analyses. Qualitative findings strongly indicate confusion regarding the objectives of activities, and will be discussed in further detail in the following section. Also of interest are student perceptions of the importance of their knowledge of mathematics in this course (Table 3a, item 9); the bimodal distribution indicates two differing opinions regarding this item. Additional data were not gathered regarding this finding, but further study seems to be merited.

Item 12 of the interview survey (Table 3b) asked students to rank the text, activities, lecture, and homework in order of importance in helping them to learn and/or clarify topics in class. From these data, composite scores and rankings were determined (see Note 5). Of those interviewed, most identified the text as the most helpful and homework as the least helpful. The role of these different instructional resources also will be discussed further in the following section.

Table 3. Interview survey instrument, n = 15. (a) Disagreement with the statement is denoted by a score of 1, a score of 5 denotes agreement. (b) Percentage and overall rank scores for different instructional resources.

Table 3a

Survey Item	**1**	**2**	**3**	**4**	**5**	**Mean**	**SD**
1. The activities used in class are enjoyable.	0.00	13.33	26.67	46.67	13.33	3.60	0.91
2. The activities are too elementary for a college-level class.	6.67	13.33	33.33	20.00	26.67	3.47	1.25
3. The activities used in class are interesting.	0.00	20.00	33.33	33.33	13.33	3.40	0.99
4. Participating in the activities during class makes me uncomfortable.	40.00	33.33	6.67	13.33	6.67	2.13	1.30
5. I receive adequate feedback on my answers to questions the instructor raises in class.	0.00	0.00	33.33	46.67	20.00	3.87	0.74
6. I think the activities could be done in any size class.	66.67	20.00	6.67	6.67	0.00	1.53	0.92
7. I receive adequate feedback (from the instructor, TA, or peers) during activities.	6.67	0.00	40.00	33.33	20.00	3.60	1.06
8. I understand the point of the activities we do in class.	0.00	13.33	13.33	40.00	33.33	3.93	1.03
9. My knowledge of math influences my learning in this class.	33.33	20.00	6.67	6.67	33.33	2.87	1.77
10. Sometimes, I find myself thinking about the activities even when I'm not in class.	33.33	26.67	13.33	20.00	6.67	2.40	1.35
11. I attend this class more regularly than other classes I'm taking.	6.67	6.67	13.33	33.33	40.00	3.93	1.23

Table 3b

12. Rank the following in helping you to learn/clarify topics in class.	Students Ranking (percentage)				Overall Composite	
Resource	1st	2nd	3rd	4th	Score	Rank
Text	42.9	38.4	7.7	14.3	3.07	1st
Homework	7.1	23.1	23.1	42.8	1.69	4th
Activities	14.3	30.8	23.1	28.6	2.31	3rd
Lecture	35.7	7.7	46.1	14.3	2.71	2nd

Although previous studies have demonstrated the effectiveness of active learning on various student outcomes--such as achievement and attitude toward instruction (Ebert-May, Brewer, & Allred 1997; Johnson, Johnson, & Smith 1991)--no significant quantified benefits were found here. With regard to achievement, students in the activities-based course did show greater (though not significant) improvement than students in the traditional lecture-based (control) course (Norman & Schmidt 1992). Despite the benefits of activities reported by students on the interview survey (Table 3a, items 1, 3, 4, 5, 7, and 11), many measures of attitude decreased. Significant among these is students' self-efficacy with regard to science. This result is explained in part by the qualitative findings presented below.

5. QUALITATIVE FINDINGS

5.1 Characterization of the Course

Qualitative analysis of students' perceptions of the course showed five major themes: 1) students valued activities; 2) students did not value activities; 3) students found the course confusing; 4) students sought other, non-activity sources of information; and 5) students viewed exams as important. The relationship among these themes in represented in Figure 1.

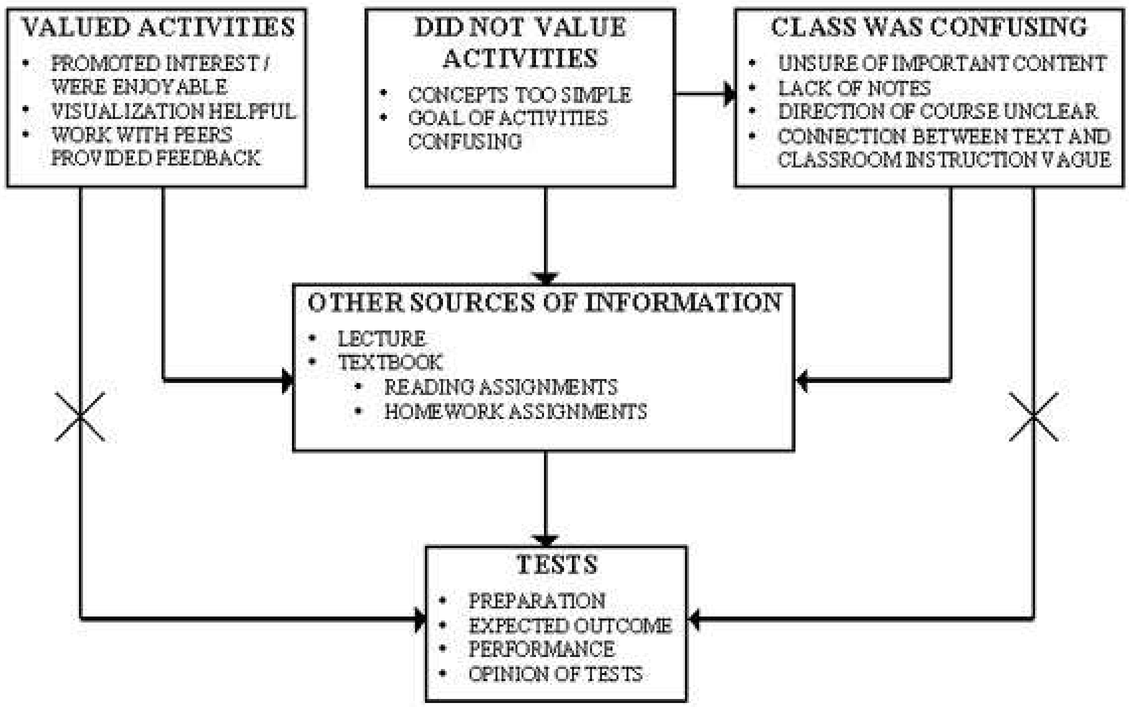

Figure 1. Diagrammatic representation of students' perceptions of an activities-based astronomy introductory course for non-majors.

Many students believed that the activities were useful learning tools. Students reported that particularly beneficial activities were those that promoted interest, assisted in visualizing motion and spatial relations, enabled interaction among classmates, and were useful in reinforcing material presented earlier. Observation data also suggested that many students enjoyed the activities and valued interaction with their peers. Two of these reported benefits--specifically that activities were interesting and enjoyable and that peer interaction provided an important opportunity for feedback--are consistent with the interview survey results (Table 3a, items 1, 3, and 7).

Enjoyable and promote interest

> We did some visual aides (activities) and those have always been really helpful, but I can't always remember what they are. I don't know if they're so helpful for learning as much as they make the class interesting and make you want to go to class [laughs]. Because it's 9:30 in the morning, you know.

> If she (the instructor) just lectured, you know, if she just went up there and lectured and wrote stuff on the board, I don't think I'd be learning as much or having as much fun.

> The activities we did were both instructional and enjoyable.

Visualizing motion and spatial relations

> She made that (celestial motion) a lot easier to visualize just by our things in class were you'd stand up and move around and use our fist as a Moon and stuff like that. But I love the activities we do, that helps me a lot. Like we've done stuff with constellations...and I'm very visual and to see that helps me a lot.

> I enjoyed and learned a lot from the hands-on activities. Astronomy is such a spatial science that activities are good to put it into perspective.

Reinforcing material

> I think (I remember information about the Sun and its position) because daily we kind of...talk about the Sun and have a random discussion of the Sun.

Working with peers

> We do a lot of in-class actives and that's really good because that's where we find out what's going on. Because it's kind of hard to ask the teacher because you don't know what to ask exactly because you don't have a narrow enough question. But when you're in your groups with your peers and stuff you can just say, "What exactly are we talking about?" and if they know what's going on they'll help you out.

> The interactions with hearing what the other students say...help you know, helps me to understand. In our class I get more feedback from my classmates. Some of them can understand things that I don't get the first time around. (We get to talk with classmates) during the activities that we do, we do a lot of group activities.

Despite these reported benefits, many students also stated that understanding activities did not necessarily translate into success on the exams. Students did not view the tests as representative of what they had learned, especially in terms of the information they learned through activities.

> A lot of them (the activities) I don't really see the point to them...it helps explain some stuff but, in relation to the test and stuff, I don't know, we don't really talk about them on the test.

> She (the instructor) doesn't really ask anything about the activities on the test... They're kind of a waste of time... It doesn't help me study for the class. It doesn't help me learn, I mean I guess it kind of does, but I mean for the test it doesn't really help.

> You never really find out what we are supposed to learn from the activities.

This confusion, which was often apparent in class observations, emerged during interviews and on course evaluations as one of the factors that contributed to students' negative views about activities (Table 2). As stated in the last quote above, students were unclear as to the learning outcomes they were supposed to achieve. Contrary to what was found through the interview survey (Table 3a, item 8), during interviews students regularly reported confusion about doing the activities and at times had difficulty following the steps involved in them. However, the most common reason students offered for disliking activities was that they were too simple. Students disliked going through the exercise of an activity when the concept it demonstrated was obvious or could easily have been learned from the book or by lecture. Interview survey results (Table 3a, item 2) are in congruence with these reports against the use of activities for simple concepts. Students seemed to have a clear understanding of time constraints and believed that the activities that took a lot of class time were often "not worth it."

Too simple

> They had the same picture in the book and all you were doing (during the activity) was just moving around the Earth... I mean you can do that in your mind.

> The activities are interesting but a lot of times I find them a little boring; they seem very elementary. And they don't keep the attention span of at least a lot of the people I sit around. And they don't require, to me they don't require a lot of thought. You know, you're just going step by step.

> I really didn't learn much from them (the activities)...They were more supplemental than anything...They really didn't have that much meaning for me... I liked the more in-depth activities...they just made you think.

Confusion regarding goal of activities

> She does a lot of exercises where I don't really see what the point is. I mean, I'm not really getting the concepts from them. They don't really make sense to me.

> A lot of times on the activities... I don't see the point of why we were doing them. I mean...sometimes I get it, but sometimes I'm like why are we doing this? She never really goes over why we did something at the end.

> She doesn't explain what they (the activities) have to do with what we're talking about and that just confuses me.

Students who didn't understand or didn't value the activities looked for non-activity sources of information, including lectures, the textbook, homework problems, and asking questions. However, dislike of the activities was not the only reason students sought additional ways of understanding the material. Many students found the course structure--or perceived lack of structure--confusing. Students did not readily understand the relationship between topics as presented in class, nor did they understand the connection between the class and the textbook. They were also unsure of the important content to be learned and did not take many notes in class.

Direction of class

> The lectures are splicy for lack of a better word. It's like...I don't know, it just doesn't come together well...you know what I mean? I feel like it jumps around...like we'll get on one topic and before you know it, we'll be in to this topic and I don't even know how we got there.

Connection between lectures and textbook

> I think the one thing that would be the most useful would be if (the instructor) actually assigned specific reading assignments. I find that the book is very helpful... So if we actually had specific reading assignments I think that would be the most helpful thing in the class.

> It's not like something I can follow along in my book, I never know like what section we're doing what chapter we're doing, because we're jumping around, skipping around so much. Even if I wanted to go back over my book and review what we've done, I can't because it's just a little thing here and a little thing there. And that's why I'm having trouble.

Unsure of important content

> Sometimes I study the complete wrong things that aren't even on the test.

> I didn't know what I needed to know. The book covers stuff not talked about in lecture... I think I have the most difficulty with knowing what information we need to know. Some of it, like to get a certain exact number, are you supposed to memorize that and know it, or just have the general idea, the distance is greater from here to here? I don't know when you read what you need to know.

Lack of notes

> Before the test I went back and read about all the people and read all the chapters and tried to understand it because I felt like...we didn't have that many notes...she doesn't give us that many notes. I felt like we didn't have enough material in our notes to be tested over, so I knew I needed to read, just to try to understand it. From my notes I couldn't really tell what she was going to test on because I felt like she hadn't...You know she kind of talks but never really emphasizes exactly.

> I take notes about what she talks about and I don't have a whole lot of notes. And in all my other classes I have these really in-depth notes and mine are seemingly vague from astronomy because she doesn't really go into depth really on a lot of things; she just sort of touched on it.

Some students attribute this lack of notes directly to the activities.

> We don't really take a lot of real notes about it, because we're so busy doing stuff. We'll be sitting there in little groups or whatever and she's not really saying this is how it is and this is what you need to know. She just kind of says, OK we're going to do this demonstration.

As is evident from the quotes above, students felt unable to prepare for exams. Because of the lack of notes to study from and confusion about importance of material presented in class, students looked toward other sources of information. Qualitative findings suggest that many students tried to use the textbook and class notes, a finding supported by quantitative data (see Table 3a). However, confusion regarding the relationship of the textbook and topics covered in class (as described above) made this difficult. During interviews, students often said they prefer lecture, reading, and/or homework assignments.

Prefer textbook - reading assignments

> I (read the book) as she's talking most of the time because she doesn't tell us what we're going to be doing, so it's hard to read the book and prepare, but you can always read it afterward and helps solidify what she said. I like it better when you know what you're going to be doing ahead of time you know...it helps you to prepare a little bit.

> When I read it in the book, it makes sense. I don't understand the importance of what she's saying sometimes, like how that relates to the main concept. But when I read it in the book, it all comes together, Oh I realize she was talking about that and now I know why it was important.

Prefer textbook - homework assignments

> On the homework, when you can take them home and put some thought into it and you're not like feeling nerve racked from the pressure of the classroom...I can just concentrate more...you know? She gives us 4 or 5 questions on there and you have to read about those and get a feeling and understanding of the subject to answer the question. And if you try to do them real quickly, you'll screw them up...You've got to read it. I think almost it would have been helpful for us to have more homework than some of the other junk we did.

> (To improve the class I would) increase the amount of homework and homework problems...they really helped me to understand some of the things she talked about in class.

Prefer lecture

> I learn better by reading and by lectures. The activities are interesting, but a lot of times I find them a little boring; they seem very elementary. And they don't keep the attention span of at least a lot of the people I sit around.

> A lot of them (activities), I don't really see the point to them... I'd rather go over questions everyone has and what not. Or more detailed lectures.

Many students reported that the homework and reading were best used together to learn or clarify concepts.

> Doing those few homework problems just reinforced what I thought I knew or what I didn't. I realized it then and I could go back and double check and make sure that's exactly what I'm messing up, how I'm messing up, and why I'm messing up and I figured out what I needed to know by missing a problem or not getting it the first try... I hadn't been reading the book very much because she didn't really assign reading. I think that would help a lot too, keep up with the reading, not just do the homework but actually read the rest of the chapter, too. There might be some other important stuff in there also.

> I'm not learning as much as I could be if I was just studying at home with the book, doing review questions in the back. Because they're focused. They ask a specific question, and I can look in my book and start grasping the concept, as opposed to in class where they just give general or vague questions. It's more of a concept question, where you have to understand the concept, and I'm not getting that. I have to go to the book to start understanding that.

In addition to attributing their difficulties with exams to studying without thorough notes and being unable to determine which material was most important, students had problems with the instructor's use of standardized questions from a test bank. Many students did not see the exams as relevant to the material presented in class, nor as a reflection of the process by which the material was presented.

> I think what we went over in class was not tested in the exams. I think that the instructor should write her own tests, because the questions she asked, not the questions from the test bank, I was more prepared to answer.

> I hated that the tests were from a test bank. I feel like the questions on the test did not cover what we had discussed in class.

> The tests seem to come out of left field.

5.2 Activities and Lecture Compared

Qualitative data were also used to assess students' perceptions of which topics were learned best through activities. In exploring this question, data were also generated regarding topics that were taught effectively without activities. The concepts referred to by students most frequently as best taught by activities and best taught without activities were celestial motion and history of astronomy, respectively.

The history of astronomy was a topic that was presented to students in a lecture format. Many students valued this approach. They were interested in the discoveries, enjoyed hearing stories about people, and were entertained by the misguided beliefs of earlier astronomers. Students also valued the concrete factual nature of history as it was presented in this course.

Interesting

> The history of astronomy I thought was pretty interesting. I thought it was pretty interesting the way she tells the stories. She's a great lecturer.

> I guess those (Ptolemy's beliefs about concentric circles, heaven being perfect) stuck with me because they're so absurd now; I mean they weren't absurd obviously then.

Factual

> I think for me, it's easier from me to grasp a concept like (history) as opposed to absorption lines where there is a theory behind it. It's definite that that person did that and not it's sort of like this is some theory and it's kind of sketchy. There's some definite thing that I can hang on to.

> It was really straight forward. There's a person and he did this and this and this, you know? It's a person and then it's what they did and you can differentiate between them; they're not the same person; there's no confusion between the two. I think that's just easier to grasp than a theory or concept or something like that.

However, some students questioned their long-term retention of the history subject matter.

> Well I remember mostly about people. We just took an exam, and after sitting through the exam I'm kind of forgetting.

> It was just basically memorization. I kind of just remembered it for the test and don't really remember a lot about them (historical figures) now.

Celestial motion was taught in this course through the use of many different activities. Students believed that their understanding of the motion of planets and stars was improved by the use of activities. As reported earlier, students believed the strength of activities was in helping them to visualize motion and spatial relations. Students also reported that activities were most beneficial when used for difficult concepts. Celestial motion is an example of a difficult topic that was taught effectively through the use of activities.

The specific activity identified by students most frequently during interviews as particularly helpful illustrated the phases of the Moon. Although further explanation of students' views of this activity would be helpful, the few students who did talk about it--combined with researchers' observations of the activity--provide some insight as to why this activity was especially effective. The phases of the Moon activity consisted of each student holding a white polystyrene ball (the Moon) and standing around the edge of the classroom. In the center of the classroom, a lamp with an unshaded light bulb (the Sun) was turned on. Students held their "Moons" in front of their faces and slowly turned around. Students noticed that position of their heads (the Earth) relative to the ball and the light bulb determined the proportion of the ball viewed as lit or shaded. For example, when their heads were positioned between the ball and the light bulb, the surface of the bulb that they could see was entirely lit. Perhaps the primary reason why this activity was perceived as useful is that students were working individually. The group size for many other activities was four or five students. Students found it difficult to be engaged in the activity with groups this large.

> That one (activity) really lost my attention really quick. One person is blowing up the balloon, one person may be coloring, and the other people just sit there. I understood the concept behind it and the reasoning behind it, but at the same time I didn't learn a whole lot from that.

> Well, a lot of times only one person got to do anything.

> I think some of the activities that have three or four people and there's only one person doing anything, I don't perceive a whole lot of people learning a whole lot. If there's only one person actually doing the activity, everyone else's mind is elsewhere. I think I liked (the phases of the Moon activity) because I could do it by myself, I can do it at my own pace, I can think about it versus just watching someone else do it and them actually getting everything out of it.

Students' preference for individual hands-on activities should be tempered with their reports of valuing working with their classmates. Smaller groups would allow greater involvement with the activity and could perhaps improve or increase interaction among classmates. Classroom observations show that in large group activities, one or more students within most groups did not participate. Smaller groups would encourage these students to become engaged with the activity and allow all students the opportunity to learn.

That students enjoyed and valued the lecture-based instruction of the history of astronomy *and* the activity-based instruction of celestial motion is not a contradiction. It is important to remember that lectures and activities, as with all instructional techniques, have their strengths and weaknesses. Possible problems with shifting from a predominantly lecture-based approach to one that is predominantly activities-based will be addressed in the following section.

6. IMPLICATIONS FOR PRACTICE

Active learning provides a meaningful experience for students and results in students who are motivated, self-directed learners who may be better able to learn and recall information (Svinicki 1998; Norman & Schmidt 1992). In addition, evidence also suggests that active learning promotes the activation of prior knowledge, its elaboration, and restructuring (Schmidt 1993). Despite these research findings, it is important to recognize that no single teaching method or strategy is a panacea. As seen in other studies (Miller, Groccia, & Wilkes 1996; Orzechowski 1995), perhaps much of the students' confusion in this course could be attributed to an excessive use of activities. Other studies have shown a conservative use of active learning strategies to be very successful (Wilke & Straits 2001). Several important considerations for the implementation of activity-based instruction, including the reduction of confusion, have been uncovered by the study presented here.

Students generally liked active learning, although they were less pleased with activities that were used too frequently or to illustrate very simple concepts. Activities in introductory astronomy seem to be of most merit when they help students to visualize motion or spatial relations. The point of activities needs to be explained clearly when they are introduced and again once the activity is completed. Students need to see how an activity and the concept it illustrates are connected to rest of the topics being taught. In addition, exams must include information learned through activities so that assessment reflects the mode of instruction. Students are more likely to value activities that help them prepare for and perform during exams.

The lack of notes was a concern voiced repeatedly by students and was a chief concern identified in a brief interview with the instructor. "I would like to implement some way for the students to take notes on the activities. I believe that part of what contributes to their poor performance is not being able to take notes while they do an activity." Findings support the need for students to have outside sources of information, including detailed class notes and clear reading assignments.

Group size for activities is also important. Students felt that due to large group size, many activities in this course didn't allow them the opportunity to "get their hands on" and subsequently the students viewed those activities as less effective. The strengths of activities are that they are enjoyable and promote interest, assist in visualizing motion and spatial relations, enable interaction among classmates, and are useful in reinforcing material presented in the class or textbook. However, for students to benefit from the activities, they must be engaged. Smaller group sizes would help to ensure active involvement and could help to maximize the reported strengths.

An additional key for effective instruction is maintaining consistency among activities, lectures, reading assignments, and exams. Students value multiple sources of information and appreciate having different resources available to them. Perhaps student confusion, which for many students characterized much of this course, can be ameliorated by provisioning them with multiple resources, presenting information through a variety of teaching strategies, and ensuring that assessment measures match instruction.

Another point to consider is the impact of students' confusion regarding course structure. Although quantitative data collected were insufficient to perform correlation analyses, observations and interviews with students suggest that confusion may have contributed to the significant reduction of students' self-efficacy with regard to science. A key to the development of self-efficacy and other expectancy beliefs is viewing goals as obtainable through effort (Schunk 1994). Students in this course did not feel that the instruction adequately prepared them for exams, and they did not understand how to concentrate their efforts such that they would achieve improved understanding and performance. Subsequently, they may have decreased their appraisal of their ability to perform well on exams, which may have lead to a decrease in self-efficacy with regard to science in general. Reducing confusion is of great importance, of course, particularly given the possible deleterious effects upon students' self-efficacy.

Finally, it should be stressed that this study documented the outcomes of an instructor's first attempt at teaching an activities-based course. Results found here, including decreased student self-efficacy, may be more a result of instructional design flaws than of the shortcomings of active learning. The authors do not attribute results to active learning or to any one component of this course alone, but rather to the course as a whole (active learning techniques, perceived lack of structure, course content, and so on). Goals of this report have been to illuminate some of the possible pitfalls associated with the initial incorporation of active learning into a college-level course and to assess its impact on student characteristics. It is only through the awareness of possible difficulties that they can be avoided in the future and ultimately result in improved instruction. We believe that active-learning strategies, when clearly delineated, used to demonstrate sophisticated concepts, and inclusive of equal opportunity for engagement, coupled with course structure that emphasizes the relevancy of activities, will improve student characteristics and increase achievement.

Notes

Note 1: Cronbach's alpha is a statistical measure employed to determine the reliability of a survey. A range of 0.70-1.00 is considered acceptable in the social sciences. The survey used here was constructed by the authors to measure parameters specific to this research, the Cronbach's alpha value reported should inform the reader that further testing is necessary before widespread application of the instrument.
back to text

Note 2: Thematic saturation is the point at which additional input of data fails to result in additional information. Qualitative researchers often use thematic saturation as a determinant for ending data generation.
back to text

Note 3: Referential adequacy materials are additional data used for comparison with researcher interpretations (Erlandson et al. 1993). They are used in qualitative research to assure credibility (i.e., the degree of congruence with which the realities of the participants match those attributed to them by the researcher), helping to ensure that the researcher's voice does not drown out those of the participants.
back to text

Note 4: No clear theme emerged from interview data regarding class attendance. Analysis of interview survey data did show positive correlation between items 1 and 11 (Pearson's r= .87) and between items 3 and 11. (Pearson's r= .85) (Table 3a). Additional study is required to clarify the possible link between activities-based instruction and attendance.
back to text

Note 5: Composite scores were calculated by assigning weights based on a Likert type scale to the students' rankings of the four different resources. A ranking of first received a "four," second received a "three," third received a "two," and fourth received a "one." The weights were multiplied by the number of students who chose a particular rank (first through fourth) for a particular resource, and then summed. The raw scores were then divided by the total number of students who participated in the survey to determine the composite score. The scores were then ranked with the highest composite score reflecting the resource that the students reported using most, and the lowest composite score reflects the resource that the students reported using least.
back to text

References

Bonwell, C. C. & Eison, J. A. 1991, Active Learning: Creating Excitement in the Classroom, *ASHE-ERIC Higher Education Report No. 1* , Washington, D.C.: The George Washington University, School of Education and Human Development.

Boyer Commission on Educating Undergraduates in the Research University. 1998, *Reinventing Undergraduate Education: A Blueprint for Americas Research Universities*, Princeton, NJ: Carnegie Foundation for the Advancement of Teaching.

Coffey, A., & Atkinson, P. 1996, *Making Sense of Qualitative Data*, Thousand Oaks, CA: Sage Publications.

Deming, G. L., Miller, S. T., & Trasco, J. D. 1997, *Cooperative Learning Activities in Introduction Astronomy for Non-Science Majors*, College Park: University of Maryland.

Ebert-May, D., Brewer, C. & Allred, S. 1997, Innovation in Large Lectures--Teaching for Active Learning, *Bioscience* , 47(9), 601.

Erlandson, D. A., Harris, E. L., Skipper, B. L., & Allen, S. D. 1993, *Doing Naturalistic Inquiry; A Guide to Methods*, Newbury Park, CA: Sage Publications Inc.

Hemenway, M. K., Straits, W. J., Wilke, R. R., & Hufnagel, B. 2002, Educational Research in an Introductory Astronomy Course, *Innovative Higher Education*, 26(4), 271.

Hufnagel, B., Slater, T., Deming, G., Adams, J., Brick, C., & Zeilik, M. 2000, Pre-Course Results from the Astronomy Diagnostic Test, *Publications of the Astronomical Society of Australia*, 17(2). http://www.atnf.csiro.au/pasa/17_2.

Johnson, D. W., Johnson, R. & Smith K. 1991, *Active Learning: Cooperation in the College Classroom*, Edina, MN: Interaction Book Co.

Miller, J. E., Groccia, J. E., & Wilkes, J. M. 1996, Providing Structure: The Critical Element, *New Directions for Teaching and Learning*, 67, 17.

National Research Council. 1996, *From Analysis to Action, Undergraduate Education in Science, Mathematics, Engineering, and Technology, Report of a Convocation*, Washington, D.C.: National Academy Press.

National Science Foundation. 1996, Advisory Committee for the National Science Foundation Directorate for Education and Human Resources, *Shaping the Future: New Expectations for Undergraduate Education in Science Mathematics, Engineering, and Technology*, Washington, D.C.: National Science Foundation.

Norman, G. R., & Schmidt, H. G. 1992, The Psychological Basis of Problem-Based Learning: A Review of Evidence, *Academic Medicine*, 67(9), 557.

Orzechowski, R. F. 1995, Factors to Consider before Introducing Active Learning into a Large, Lecture Based Course, *Journal of College Science Teaching*, 24, 347.

Rankin, M. A. 1998, Importance of Instructional Development in the College of Natural Sciences, *Proceedings of the Discovery Learning Conference*, Austin: University of Texas.

Schmidt, H. G. 1993, Foundations of Problem-Based Learning: Some Explanatory Notes, *Medical Education*, 27, 422.

Schunk, D. H. 1994, Self-Regulation of Self-Efficacy and Attributions in Academic Settings, in *Self-regulation of Learning and Performance: Issues and Educational Implications*, D. H. Schunk & B. J. Zimmerman (Editors), Hillsdale, NJ: Erlbaum.

Svinicki, M. D. 1998, A Theoretical Foundation for Discovery Learning, *Advances in Physiology Education*, 20(1), 4.

Wilke, R. R., & Straits, W. J. 2001, The Effects of Discovery Learning in a Lower-Division Biology Course, *Advances in Physiology Education*, 25(2), 1.

ÆR
46 - 64