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

Astronomy Education Review

Volume 3, Mar 2004 - Oct 2004
Issue 1

Assessment of an Internet-Delivered Interactive Approach to Introductory Astronomy for Non–Science Majors

by **Timothy F. Slater**
University of Arizona
Lauren V. Jones
Gettysburg College Department of Physics
Received: 11/22/04, Revised: 03/15/04, Posted: 10/05/04

The Astronomy Education Review, Issue 1, Volume 3:17-25, 2004

Abstract

This project explores the effectiveness of learner-centered education (LCE) principles and practices on student learning and attitudes in an online interactive introductory astronomy course for non-science majors by comparing a high-quality Internet-delivered course with a high- quality on-campus course, both of which are based on the principles of LCE. To date, there have been numerous comparisons of conventional lecture courses with distance-learning courses described in the literature, which show little significant difference between the two learning environments. A careful review suggests that these are often noninteractive lecture courses, compared with traditional reading and correspondence courses in which assignments are submitted via e-mail. In contrast, this study compares an interactive Internet-delivered course with a learner-centered on-campus course, both of which use highly interactive teaching techniques characteristic of LCE. To do this, we created a hypermedia learning experience for introductory astronomy that matches Internet technology with how people learn. This course weaves multimedia visualizations into a structured learning environment by breaking down complex concepts into bite-sized pieces. Each cognitive piece contains hyperlinks that explain all terms. Illustrations consist of high-resolution images, animations, and videos that students manipulate to answer questions. Each module helps students engage in the pursuit of learning astronomy by providing activities in which students use astronomical data. Learners are required to answer premodule questions-- not as multiple-choice questions, but as written narratives--about the concept under study to make their knowledge explicit. At the conclusion stage, students compare new ideas with their initial answers and evaluate various alternative explanations. We find that although this innovative course accomplishes its goals and students achieve an acceptable level of achievement, the high-quality on-campus course experience yields

significantly higher achievement gains.

Learner-centered education places the student at the center of education. It begins with understanding the educational contexts from which a student comes. It continues with the instructor evaluating the student's progress towards learning objectives. By helping the student acquire the basic skills to learn, it ultimately provides a basis for learning throughout life. It therefore places the responsibility for learning on the student, while the instructor assumes responsibility for facilitating the student's education. This approach strives to be individualistic, flexible, competency-based, varied in methodology, and not always constrained by time or place. (Arizona Board of Regents 2002)

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1. BACKGROUND AND CONTEXT

As CD-ROM technology became commonplace in the early 1990s, educators were excited about the possibilities for student learning because electronic textbooks and encyclopedias were, for the first time, easily searchable. Publishers rushed to insert CD-ROMs into the backs of textbooks at considerable development costs. This technology, however, fell far short of the anticipated positive impact on student learning, mostly because CD-ROMs were not created from a pedagogical perspective centered on engaging students in critical thinking. Instead, they were designed to impress students with visually captivating imagery without concern for conceptual development.

Educators had a similar ecstatic response in the mid-1990s with the growth of the Internet. The Web provided the world's largest living encyclopedia (e.g., an Internet search on "penguins" yields 616,000 hits today). Unfortunately, the educational response was primarily to use CD-ROMS and the Internet as giant encyclopedias, and the vast majority of student assignments were to blindly go out on the Web and "learn about something." In fact, the only measurable shift in student thinking was to adopt the skill of sifting through mountains of Internet information and reducing it to synthesize a term paper instead of searching the library to piece together enough information to build a term paper.

Today's distance-learning courses often suffer from these same ills. With the growth of Internet access and the hope for reaching previously unreachable student populations, Internet-delivered distance-learning courses have become ubiquitous at colleges, universities, and even in high schools. It is our experience that the vast majority of these courses are created by very well-meaning individuals, but all too often, these courses can be primarily characterized as electronic correspondence courses in which students are assigned weekly text readings or videos to observe (which might be provided via the Internet), and weekly homework assignments that bear considerable similarity to the same assignments given in an on-campus course. This is mostly unsurprising, because most distance-learning courses follow the traditions of self-paced distance learning used in the latter part of the last century in the form of mailed videotaped lectures, teleconference-style lectures delivered via telephone lines, faxed homework, and even two-way live video that might as well have been one-way. These can be summarily characterized as one- way information transfer--the same critique of conventional college science lectures. It is not our position to criticize these efforts, many of which were created at considerable expense and personnel time, but it is clear that the bulk of these efforts remain largely unaltered by current research on how people learn.

As a first step toward using the Internet as an intellectually engaging instructional tool rather than an encyclopedia of facts or for one-way information transfer, a considerable amount of time and effort were spent creating inquiry-based science lessons that focus on analyzing actual astronomical data--something to which the Internet is ideally suited. Students monitor and interpret sunspot changes, analyze and predict the movement of weather systems, determine current satellite positions from measured orbital periods, and map the Earth's plate movements using recent earthquake locations and real-time GPS satellite stations. These highly successful projects are described in considerable detail elsewhere (Beaudrie et al. 1998; Slater 1998; Slater & Beaudrie 1997, 2000; Slater, Beaudrie & Fixen 1998; Slater & Fixen 1998).

Simultaneously, we recognized that the Internet environment might also allow us to communicate more effectively with high school science teachers across the country. Through substantial National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA) awards, we created a suite of distance-learning courses that focus on science concepts through student-centered laboratory activities that access, manipulate, and analyze Internet databases from NASA, the United States Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), and many others (Prather & Slater 2002; Slater et al. 2001).

We were successful in creating Internet-delivered distance-learning courses, specifically designed for in-service science teachers, that integrated online collaborative group learning strategies with real-time data laboratory exercises. We designed our active learning activities to motivate our students to communicate with each other and with the instructor frequently through electronic discussion boards, and we provided students with immediate feedback on their progress through online testing. This course was built on the principles of learner-centered education (LCE; National Research Council [NRC] 2000), which puts students at the center of the learning process in a supportive environment unconstrained by time or place. We focused on building skills that the students would be able to use in a variety of contexts both inside and outside the classroom. These efforts positioned us to pursue a much more complex problem: effective online courses for undergraduate non–science majors.

2. INNOVATIVE ONLINE COURSE DESIGN

Over the last two years, members of the Conceptual Astronomy and Physics Education Research (CAPER) team, our education research and development team in the Department of Astronomy at the University of Arizona, have been concentrating on constructing a new program called *Astronomy Online (AOL)*. *AOL* (Figure 1) is an Internet-delivered introductory natural science course for non–science major undergraduates, typically freshmen, and is aligned specifically with the tenets of LCE. What makes this online course design innovative is that it addresses the overriding principles of learning: (1) recognition of prior learning experiences that students bring to a course; (2) a focus on the interconnectedness of big ideas; and (3) the frequent use of meaningful feedback for student self-monitoring of their learning (NRC 2000). The goal is to make a course centered on LCE more flexible for a more diverse set of learners, while being sensitive to what we know about how people learn.

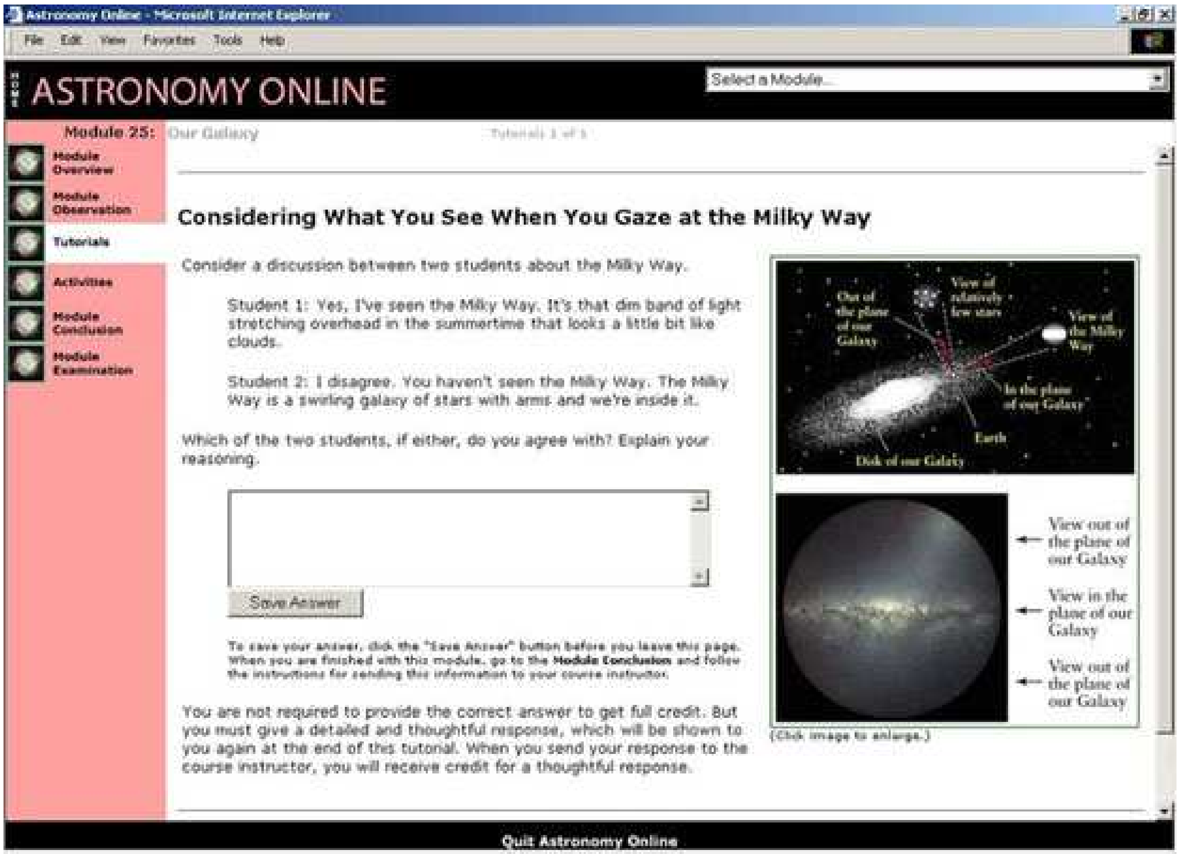

Figure 1. The *Astronomy Online* interface.

(As a side note on the online course implementation, one postdoctoral fellow was hired to run the online course through WebCT™, and nine upperclass undergraduate students were employed as online peer mentors. Each mentor virtually supervised, interacted with, and electronically graded a subset of 12 student-participants enrolled in the course who worked collaboratively as an electronic learning community.)

We realized early on that creating an interactive learning environment that combines electronic data, digital movies, synchronous and asynchronous communication, and automated immediate feedback to our students would require computer programming beyond our capabilities. We decided to partner with W. H. Freeman Publishing of New York, which currently publishes and distributes the most widely adopted introductory astronomy textbook series and who pioneered the development of electronic course packages in WebCT, Blackboard™, and MetaText™ electronic learning environments. This partnership provided three important components that we did not personally possess: (1) a digital library of the best images, videos, and artwork in astronomy with copyright permissions already secured; (2) an international infrastructure for dissemination; and (3) on-demand computer programmers and graphic artists with experience in the WebCT online learning environment. We were initially concerned that such a partnership with a commercial entity might result in a fiscal burden on our students, but we were relieved when the economy-of-scale of a large publisher brought the net cost of the electronic course materials down to only $15 (as compared with $87 for the cost of a current introductory astronomy textbook). *AOL* has now completed its external professional review by astronomers across the country and is available to faculty for adoption as a standalone e-book/e-course or as a supplement to existing on-campus courses.

Although we created *AOL* to closely align with the principles of LCE, we did not have the resources at our university to fully implement a systematic quantitative and qualitative educational research study on its impact on student learning gains, student attitudes toward science, and student satisfaction toward an online LCE environment. Further, we, as a teaching and learning community, must understand the time requirements for faculty to implement online LCE. This aspect is critical with respect to cost effectiveness and scalability issues. Indeed, skeptical faculty need such research-informed insights because they can seriously consider the advantages and disadvantages of teaching with the principles of LCE in an online learning environment. Therefore, we pursued and were generously awarded an Arizona Board of Regents learner-centered education research grant to implement a summative evaluation of our LCE project and share the results widely. This article describes the project and the evaluation results.

3. RESEARCH QUESTIONS AND METHODOLOGY

To date, there have been many comparisons of conventional lecture courses with distance-learning courses described in the literature (viz., Threlkeld & Brzoska 1994). These studies often show little significant difference between the two learning environments. Further, these studies often compare noninteractive lecture courses to traditional reading and correspondence courses in which assignments are submitted via e-mail. However, our study compares an interactive Internet-delivered course with a learner-centered on-campus course that uses highly interactive teaching techniques characteristic of LCE. Consequently, our key research questions encompass how the *AOL* LCE environment impacts: (1) student learning gains, (2) student attitudes toward science, and (3) student attitudes and satisfaction toward an online LCE environment when compared with a high-quality large-enrollment lecture course. The details of the high-quality comparison course are described extensively elsewhere (Prather & Slater 2004). In brief, the comparison course uses an active engagement approach with highly interactive minilectures augmented by 15-minute written Socratic lecture tutorials that students complete in pairs almost every day of the semester. The tutorials were created and systematically field tested using the support of an NSF CCLI award and are widely used across the United States (Adams, Prather, & Slater 2002).

The research design is relatively straightforward. We used a mixed method study design (quantitative and qualitative) on students that uses a pretest/posttest approach to comparing conceptual and attitudinal gains for 150 different students in an online LCE course with 450 students in an on-campus large-enrollment course based on LCE. This was accomplished by modifying existing cognitive, affective, and LCE assessment instruments from previous studies (Hufnagel et al. 2000; Slater & Adams 2002; Zeilik, Schau, & Mattern 1999), in accordance with standard validation procedures, into four distinct measurement instruments: (1) the nationally normed Astronomy Diagnostic Test (Hufnagel et al. 2000; ADT V2.0) on astronomy misconceptions, (2) a 30-item multiple-choice content knowledge exam specific to topics covered in the two target classes, (3) a 30-item Likert-style survey on attitudes about and confidence toward learning astronomy, and (4) a five-item Likert-style survey on the online interactive LCE astronomy modules (see Figure 2).

- Overview of key questions or observations guiding the exploration of a concept
- An interactive activity that focuses on astronomical observations
- Preinstructional questions to elicit students' misconceptions
- Carefully sequenced hypertext pages illustrated with animations and videos
- Regularly spaced concept checks using drag-and-drop interactives
- Postinstructional questions comparing students' initial ideas with new ideas
- Interactive astronomy laboratory activities to increase students' reasoning skills
- An online computer-graded, multilevel multiple-choice exam that provides students with instant feedback on their progress
- E-mailed assignments from students to the professor, which significantly reduces the amount of hard copy paperwork associated with the course

Figure 2. The principal features of each weekly *AOL* learning module.

A fifth component consisted of interviews. Six individual students in the online course were solicited as volunteers and were interviewed at the end of the course by two undergraduate astronomy majors who were NASA Space Grant interns for the astronomy education research group. The lead course instructor (the first author of this article) was also interviewed. Each student was asked about how each of the online module components impacted his or her learning, and his or her overall impression of the online course. Students in the on-campus course were not interviewed as part of this study.

Finally, students in the on-campus course also completed five online LCE modules so that we could compare the attitudes toward online learning modules of both groups.

4. RESEARCH RESULTS

The quantitative instruments used to explore student conceptual knowledge strongly suggest that student conceptual understanding is significantly increased in the online course. The pretest and posttest administration of the Astronomy Diagnostic Test (ADT V2.0) show statistically significant normalized gains. Normalized gains are the standard approach to reporting scores in the astronomy education research community and are computed as the ratio of the pre-post gains to possible gain as in [100% * (post - pre) / (100-pre)]. In terms of the 30-item conceptual knowledge scores, we judge the scores to be indicative of substantial learning gains. In both cases, however, students in the on-campus LCE course outscore students in the online LCE course. These results are summarized in Table 1.

Table 1. Quantitative Comparison Data

Quantitative Measure	Online Group	On-Campus Group	Significant at α=.05
30-item conceptual test (percent correct)	65.5 % (n=130)	75.6 % (n=400)	Yes
Astro. Diagnostic Test normed pre-post gain scores	8.7 % (<n>=71)	19.9 % (<n>=144)	Yes
Attitude Likert gains (score 1-5)	0.09 (<n>=80)	0.00 (<n>=115)	No
AOL mod ranking (score 1-5)	3.32 (n=46)	3.12 (n=106)	No

Note. Numbers of student-participants vary somewhat because not all students took the same tests and surveys. Different subsets randomly took different instruments.

The two Likert-style instruments included statements that students rated from 1 (lowest) to 5 (highest). The first instrument asked students about their attitudes, values, and interest in astronomy and their confidence in learning astronomy. At the beginning of the course, students provided mildly positive ratings. This was done in a pretest and posttest format, and no significant increases or decreases were measured. The second instrument asked students to rate the degree to which each aspect of the online LCE modules impacted their learning individually, as well as an overall judgment about the materials. This was done only at the end of the course. We find that students generally believe that the online LCE modules are effective in helping them learn astronomy, but not enthusiastically so on average.

To validate and understand more deeply the quantitative results, six interviews with undergraduate student-participant volunteers and an additional interview with the lead course instructor were conducted. These interviews were conducted by undergraduate interns funded by the NASA Space Grant program. The hope was that undergraduate students would be less intimidating than faculty researchers, and that the student-participants would be more forthcoming in their views toward the online LCE environment. In the end, these inexperienced interviewers were not able to provide significant insight into the students' beliefs about the online LCE environment. What limited results we did obtain are consistent with the quantitative scores in that students did learn from the online LCE modules. All six students found that the modules were useful, informative, and required interactions far above those of most Web sites. They did not, however, feel that they received enough detailed feedback on their written responses, and they were not always certain that that computer-graded end-of-module quizzes always indicated the extent to which they learned or did not learn the material.

The lead course instructor felt very strongly that the modules were working as designed and that the online LCE allowed her to communicate individually with students in ways that just did not easily occur in a large-enrollment on-campus course. She also stressed that when not part of a physical classroom community, students require a purposeful effort on the part of the professor to ensure that everyone communicates with each other and the professor. Overall, and perhaps not surprisingly, it seems that the degree to which students enjoy an online course is correlated with high levels of self-motivation.

5. DISCUSSION AND IMPLICATIONS

The results obtained from the quantitative instruments and the interviews suggest two overarching ideas. First, students are indeed learning successfully in this online LCE environment as evidenced by both the content conceptual test and the Astronomy Diagnostic Test; however, they are not showing gains as large as those in the LCE on-campus course. Second, student attitudes toward astronomy and online learning are mildly positive and do not seem to change much over the semester. We consider both to be positive results for the following reasons.

In terms of student learning, we hope that we can always obtain higher cognitive gains when working with a student face-to-face as compared with electronic media. We believe that our result of higher reported gains in the on-campus course is the comparison of two high-quality LCE course designs, as opposed to the more commonly compared conventional teacher-centered student-passive lecture course with the more traditional independent self-paced environment. In the latter comparison, we wouldn't expect there to be much difference in the learning gains between the two approaches.

In terms of student attitudes, previous research has shown that student attitudes toward science all too often decrease after a college science course (Redish, Steinberg, & Saul 1998). On the other hand, it appears that our LCE environment was successful in maintaining students' mildly positive attitudes. In this light, we view the lack of attitude changes as positive as well.

Overall, this study adds weight to the literature about the successfulness of LCE-based courses and suggests that LCE in an online environment can be effective. This does make us wonder about the extent to which student achievement in an LCE online course directly compares with a traditional correspondence-style Internet-based course. (We anticipate great differences but are not in a position to conduct this study because ethically, we are not sure that we are willing to subject students to ineffective courses unnecessarily.) As a future study, it may be possible to conduct a meta-analysis study that sheds light on the specific differences in online course designs without unnecessarily risking student achievement. We believe that this study indicates that an LCE environment can be achieved if LCE is a priority in developing the online environment and, when face-to-face learning is not possible, that online courses are a reasonable substitute if LCE principles are adhered to.

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