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Teaching Astronomy Online

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Abstract

This article is intended to provide an overview of the practical, pedagogical, and philosophical considerations in designing a Web- based astronomy course, and to demonstrate the educational benefits that such online courses can afford students.

Because online students need to take more responsibility for their learning, faculty must make course expectations extremely clear. Online education allows for increased student participation and equal access to college by such groups as the military, the handicapped, full-time employees, and rural and senior citizens. Teaching the sciences online-- especially astronomy--gives students more time to think critically about new information. This article also includes tools, checklists, and resources helpful for introducing faculty to online course development in astronomy.

1. THE ONLINE EDUCATION PARADIGM SHIFT

1.1. A New Era

Distance learning has prompted a "paradigm shift" (Kuhn 1962) in education. Astronomy instructors entering the distance education arena must reconsider strategies that work in face-to-face classrooms, but that are inappropriate online (Dabbagh, Bannan-Ritland, & Silc 1999). With increasingly sophisticated Internet and powerful computer technology that allows us to efficiently deliver online astronomy instruction (and every other kind of information), many educators have been thrust into an alien environment commonly called a virtual classroom. Many of us have come to this "place" out of curiosity, while others are exploring it because they have been required to adapt to this still-emerging teaching format even though they may not be ideally suited for it.

And though scientists and science educators have historically been the most likely to use newfangled gizmos and discoveries, very few such developments actually ever fundamentally changed our basic instructional methods at schools or universities. The World Wide Web, however, is the most recent paradigm-shifting, revolutionary development in education today (Abrahamson 1998).

The responsibility--and, to some, the burden--of exploring the best instructional use of this new tool has mostly fallen to technology and science teachers and education experts. It has become clear that the learning environment must be entirely re-engineered so as to respond to the needs of the online student (Abdelraheem 2003; Dabbagh et al. 1999), and that these needs are vastly different from those in traditional face-to-face classrooms. It is now apparent that to be successful at online teaching, astronomy faculty (and faculty in other disciplines) must develop a new "vision of learning" (Muirhead 2001) that includes changing their roles from information transmitters to facilitators or guides. The problem is, just how does one go about doing that?

1.2. Revising Our Educational Philosophies

Beginning online astronomy instructors can start by looking at current thinking about how we should best teach so that students can best learn. This includes consideration of the ideal teaching environment, materials, and nature of our interactions. It is now incumbent upon us instructors to take into account "the changing nature of society, the changing nature of students, [and] new developments in technology" (Glatthorn 1994, p. 24).

In most human endeavors, there is great resistance to dramatic change, as anyone who has made a new scientific discovery already knows. To truly adopt new assumptions and incorporate them into personal practice may take a considerable amount of time, sometimes years.

And although different educational philosophies are tolerated today, the dominant one in higher education has remained the same for centuries. In traditional classrooms (with cinderblock walls and bolted-down chairs), we can lecture with illustrations (first hard-copy pictures, then overhead projectors, now LCD projectors) showing comets and planetary nebulae, or bring in meteorites, orreries, or other demonstrations. Students know what is expected of them, so while we talk, they take notes, answer our questions, and indicate (or feign) interest for three hours per week, and then try to memorize everything the night before the final exam. We too know the system--how to try to inspire students, how to "read" them, and how to answer their awkward questions that they can sometimes express only through gestures or facial expressions.

But this old paradigm is being challenged because new kinds of technology--and thus, new kinds of learners--are emerging. Even though the traditional lecture will always work for students who can learn in spite of any instruction foisted upon them, such strategies are less well adapted to an online classroom. In fact, students taught by professional facilitators who had no prior content knowledge but were experienced in keeping students on track and encouraging discussion scored better on tests than students taught by content experts who had no training in facilitating online discussions (Guzley, Avanzino, & Bor 2001). Nevertheless, we do not by any means advocate removing knowledgeable instructors from online or face-to-face classrooms.

We do acknowledge the resounding call to ensure that online astronomy instructors are aware of the need to redesign their traditional curricula to achieve optimal student online participation (Guzley et al. 2001), group reflection, and meaning-making (Scardamalia & Bereiter 1994), and to discuss interpretations (Murphy & Laferrière 2003). The creation of such effective learning environments, both online and in the classroom, shows significant gains in student understanding, as when using learner-centered instruction, for example (Slater & Jones, 2004).

Admittedly, many enlightened astronomy instructors have taken the first steps in making the paradigm shift by replacing some of their lectures with cooperative learning activities, interactive multimedia lessons using real data, and alternative assessments, some of the more effective and efficient teaching techniques.

Such efficiency will be needed if we are to educate an increasing percentage of the world's population. With more students needing a college education because of society's requirements for technological literacy and content knowledge, higher education must adapt to meet those expectations. If it fails, it puts today's students at a disadvantage with other players in the world's interconnected society, economy, and culture.

2. ADVANTAGES OF ONLINE ASTRONOMY EDUCATION

As we describe some of the positive features of online astronomy education in this section, we are not trying to compare online education with classroom education, and we are not asserting that online education is, in general, preferable to classroom education. We are simply explaining how the availability of online education can be beneficial to students.

A formal learning environment is now accessible worldwide. Learning science at the college level is no longer limited to those who are lucky enough, able-bodied, or rich enough. Our classrooms no longer have bolted-down chairs, limited access to educational materials, or linear rules of interaction. People in remote areas or who move frequently are no longer excluded from the intellectual stimulation of a college astronomy course. Other advantages and obstacles to online education are also manifesting themselves (Sunal et al. 2003).

2.1. Increased Student Participation

In an online astronomy class, students have greater opportunities to ask questions about complex concepts, seek individual help, participate more effectively, and customize their education to meet their needs. This occurs in a community of learners linked not geographically, but by a common interest. This type of education also affords a safe kind of anonymity, so students are not as hesitant to participate (Hartman et al. 1995).

Students are still responsible for solving problems individually, but they must also respond to others. Such opportunities facilitate the creation of an environment of peer instruction and generally increased peer interaction, especially among quieter students (Rheingold 1994). If the instructor can teach students who in turn provide new perspectives and ideas to other astronomy students, then education is spread exponentially instead of just arithmetically.

Over the course of a few days or a week, for example, students can be required to contribute to other students' discussion threads about pseudoscience, the scientific method, or current astronomical events. (For resources on debunking pseudoscience, see Fraknoi 2003.) All students have time to think, find something of interest, and open a meaningful dialogue as they take on the role of "thinkers and transmitters of ideas" (Rheingold 1994). In contrast, in a traditional classroom, this could take enormous amounts of instructional time, so students would likely not have the quality of in-depth discussion that they would online. It is recognized, however, that online faculty and students must spend more time, especially in the beginning, on their Web-based classes (Teeter 1997). Students realize that the courses are not easier just because they are online, and faculty realize that they must more carefully word their explanations in order to be understood, and that this often takes more time. Our students have frequently remarked at how much more difficult it is to meet the high standards and self-regulation needed to succeed online. The difficulties are not limited to content, but include the lack of imposed structure (discussed in further detail below).

In online classes, although we cannot see, hear, and experience our students as we do in face-to-face settings, we have the opportunity to project our personalities and information through an ancient form of communication: writing. With adequate time and number of exchanges, participants can develop just as meaningful a teacher-student or student-student relationship as elsewhere (Walther 1992; Lea & Spears 1992). More important, some will learn more from us, as reported by students who prefer the online classroom to the face-to-face one (Chester & Gwynne 1998). In Chester & Gwynne's study, two thirds of online students reported that they participated more online than in person, and nonnative English speakers, especially shy Asian students, preferred online courses over traditional ones.

In general, the availability of online education benefits society by offering everyone the chance to better understand the world and its people, partly because students have greater accessibility in cyberspace, and partly because "conceptions of tribe, race, community and other societal constructs may be explored, reconstructed, and reprioritized" (Gammack 2002, p. 2). Does this actually occur in online Astro 101 classes? There is evidence to indicate that it does, and thus warrants formal study. The authors have observed students discussing within the confines of a course assignment their cultural perspectives, which has in turn led them to discuss a variety of views about the interaction between science and society. These aspects of online classrooms are addressed in the next section.

2.2. The Great Equalizer

Distance education--college-level online courses in particular--can become the "great equalizer" in terms of access to higher education. Most online students have families and full-time jobs. Students are often women over 25 (Kramarae 2001; Gibson et al. 2001), and many require flexibility because they work in remote places, travel, or live overseas (Tesone, Alexakis, & Platt 2003).

Although many universities have online courses with a face-to-face component, others, such as the University of Maryland University College (UMUC), have students take an entire course online, except to show up only for a proctored final exam wherever they are located. This system makes the online course accessible to a wide audience.

Students with disabilities especially benefit, because they can get exactly the same education as others without the physical difficulties that sometimes complicate and frustrate their efforts. The deaf need not attend special universities or have an interpreter in order to learn. Rural or poor students who can't afford to leave home or who have no transportation to the nearest college can still take astronomy classes, even if they work full time or have unusual work hours. In fact, such students are twice as likely as other students to take online courses (Moisey 2004).

Men and women in the armed forces deployed across the world, as well as their dependents who do not have full control over their schedules, also benefit greatly from the flexibility of online courses. In FY 2003, UMUC enrolled almost 51,000 active duty military and dependents through its overseas programs under contract with the U.S. Department of Defense. In any given semester, as many as one quarter of the students in UMUC's online Astro 101 courses are in the military, with many overseas. They continue their studies from one post or wartorn country to another, maintaining a sense of normalcy, as they say, in at least one aspect of their lives.

Senior citizens, caretakers of the elderly, or those who stay home with small children can still get the intellectual stimulation they crave (Tesone et al. 2003). Racial prejudice and most other biases nearly disappear from the online classroom (Chester & Gwynne 1998), in part because students are not familiar with each other's status, skin color, accent, clothing, or other physical markers. Over time, online students reported the benefits of getting to know each other online before ethnic or cultural markers interfered with their relationships (Chester & Gwynne).

When skillfully taught, online courses can create a learning community, as mentioned above. These learning communities have been found to significantly benefit individuals who might otherwise feel marginalized (Haythornwaite et al. 2000).

But online students, in astronomy or other disciplines, must either have or learn to develop self-directed study habits and be well-organized learners. Clearly, online learning is not for everyone (Sunal et al. 2003); indeed, there is still much to improve in distance education. It will evolve in ways that we cannot even imagine right now, as the technology develops. But it will likely never entirely replace classroom teaching any more than did, for example, the advent of television courses. Online education will, however, allow us to attack problems in new ways and address new audiences.

3. ONLINE ASTRONOMY

In this new paradigm of online education, especially in the sciences, many of the following issues will be considered.

3.1. Choice of Content and Resources

The online instructor can now easily provide previously inaccessible or difficult-to-obtain educational materials to all students. Sky observing programs on CD-ROM (e.g., *Starry Night Enthusiast*) that can create a virtual solar system for each student are becoming quite popular. Museums in several countries (e.g., Hands-on Science Centers Worldwide; Smithsonian National Air and Space Museum, Space History Division Artifact Collection) have put much of their archives online in several languages so that historic documents, images, and data can be consulted freely by even the most novice first-year astronomy student, as well as the professional astronomer. Hubble (http://hubblesite.org/) and Spitzer (http://www.spitzer.caltech.edu/) telescope images are widely available free online as well.

Instructors at several colleges and universities make their syllabi and lab experiments available to the public. (To review some of these, type "astronomy college syllabus lab list" into any search engine.) Some useful syllabi include Project CLEA (http://www.gettysburg.edu/academics/physics/clea/CLEAhome.html) and The Invisible Universe Online (http://btc.montana.edu/ceres/origins/).

In addition, the Astronomical Society of the Pacific provides a page of Web sites for College Astronomy Instructors (http://astrosociety.org/education/resources/educsites.html). Thematic chat rooms and "ask an astronomer" discussions both within the online college classroom and in science organizations or agencies encourage investigation of current astronomical phenomena. Some particularly useful sites include "Ask a High Energy Astronomer" (http://imagine.gsfc.nasa.gov/docs/ask_astro/ask_an_astronomer.html); the University of Virginia Department of Astronomy Q&A page (http://www.astro.virginia.edu/AQuA/); and Sten Odenwald’s Q&A site (http://www.astronomycafe.net/qadir/qanda.html). Students have equal access to all of these materials, obviating the problem of limited on-reserve library books and expanding their understanding of the field of study.

Virtual lectures from foreign astronomical institutions could be transmitted in real time or through video in a password-protected online classroom. Interactive discussions can be arranged so that students are able to ask questions of the lecturer, who might be able to respond immediately or over several days.

3.2 Class Design and Preparation Time

The online instructor will need strategies for organizing content and even consulting with other online colleagues using current technology. Such work takes extra preparation time, as much as twice the time needed for face-to-face classes (Visser 2000; Ferdig 2003). Building a new course under the best circumstances is time consuming, but re-engineering it to become an online course poses issues of pedagogical philosophy, writing style, format, participation, audience, and more. Online content might be organized into major units such these:

- The scientific method applied to astronomy
- The tools of astronomy
- The terrestrial planets
- The outer planets, small objects, and formation of the Solar System
- Stars and stellar evolution
- Galaxies and cosmic evolution

Each of these units could then be subdivided into manageable sections.

3.3 Communication Skills

Speaking is replaced by writing, and the instructor has to convey knowledge and draw it out of students in new ways. Listening is replaced by reading. Instructors have to interpret and respond appropriately in terms of tone, content, and organization to incoming information from students without ever having met them. Diplomacy in the online world will need to studied (Lee 1996). In fact, instructors will have to become expert educational guides because, as mentioned previously, it appears that high student achievement correlates more with an online instructor’s ability to "facilitate" learning than it does with the instructor’s content knowledge (Guzley et al. 2001)!

Mastering the technology will, of course, be necessary, and being able to troubleshoot will be a plus. Tech support, however, will need to be strong and should be available 24 hours a day through the university, so that both faculty and students are comfortable with the computer technology necessary for navigating the virtual classroom--and indeed, the virtual university--including its library and tutors (Blocher et al. 2002).

Presenting astronomy content in a Web-based format is already a familiar activity for many astronomers. However, the Web programming needed for an entire online course is sufficiently extensive that the instructor will not usually want to take on this task.

3.4 Setting a Tone Conducive to Learning

There is a unique character to every class we teach. As the student body changes from one semester to the next, so does a classroom "culture." Though institutions must make explicit what behavior is acceptable, students' attitudes, levels of informality, and humor change (Lapadat 2002). Yet it is the instructor's responsibility to develop a rich environment in which all students can "critically reflect, discuss, argue, generate and present new interpretations" (Smith & Winking-Diaz 2004, p. 17). Keller & Slater (2003) recommend creating a collaborative community early in the semester by assigning groups, starting discussion topics at midweek instead of on Mondays, summarizing weekly discussions, and initiating ice-breaker activities.

Expectations must be made clear, and students must be taught how to take advantage of the extended periods of time characteristic of online classes to respond to questions and make thoughtful contributions (Smith & Winking-Diaz 2004). Asynchronous discussions, wherein students may write in to participate in multiple threaded discussions at different times, have thus been found to be a valuable component of online classes (Keller & Slater, 2003). It is especially important that online students realize the importance of self-discipline regarding these discussions, however. Without a class to physically get ready for each week, it is easy for them to let assignments slide, and easy for instructors to neglect grading their assignments on time.

The instructor's personal teaching style is also relevant to the students, who still need to be accountable to a human being--not to a machine or some nebulous institution--in order to have the most satisfactory online educational experience possible (Guzley et al. 2001). Furthermore, the frequent addition of current astronomical research or related events such as spacecraft launches will make the class seem much more "real" for students and help them feel like it's not just a self-teaching textbook experience.

3.5 Student Grouping

At first, individual work may seem to be the only instructional option in online teaching, especially in science or math, where students need to work out their problems. Actually, online group work has been shown to be extremely effective and enjoyable for most students on both educational and personal levels (Guzley et al. 2001; Lundeberg et al. 2003). In fact, student conferencing was found to foster in-depth discussion of ethics in science and provide multiple perspectives on scientific issues (Lundeberg et al.).

In UMUC Astro 101 classes, instructors break up classes into groups of four to six members for certain tasks. Mixing students with different strengths is preferable because cooperative learning theory maintains that heterogeneous grouping fosters greater learning than homogeneous grouping (Johnson & Johnson 1990). A collaborative assignment (for example, to design a scale model Solar System, keeping both size and distance to scale) is graded based on the accuracy and discussion of the final product and individual contributions, just as would be done in a more traditional environment. An online self-evaluation and critique of other group members is sometimes also required to remind students that they are accountable to each other and to the instructor.

Such problem-solving lessons, especially case-based problem-solving lessons, have been found to be effective tools to engage students in learning science (Stepien & Gallagher 1993). Students participating in online collaborations with students from different walks of life reported having more chances to participate and higher satisfaction than in face-to-face courses. In fact, with regard to their collaborative work on a science assignment, students said that they preferred Internet communication over live discussions (Lundeberg et al. 2003).

3.6 Practical Matters: Class Management

Management and leadership styles vary greatly among educators, and though several of these styles work in a traditional classroom setting, challenges in the online classroom require some adaptation of old strategies. For example, it is helpful to be "present" in the class as often as possible, ideally checking in at least once a day, even briefly, to ensure student participation and answer quick requests for clarification along different discussion threads. This requires the ability to handle nonlinear teaching and a wide array of student expectations (Kimball 2001), and takes more time than dealing with traditional students. For example, sending e-mail to individual problem students who post inappropriate or long comments or who wander off topic is a longer process than stopping a student in a classroom from dominating a discussion. Online teaching thus takes diplomacy and requires the instructor’s willingness to make rational arguments to handle creationists and proselytizers, who often appear in astronomy classes. (To find suggestions for dealing with creationists, see Fraknoi 2003, and Bobrowsky 2000, submitted [2005], and references therein.)

Keeping the class moving forward as a whole while giving students the attention they need individually also takes extra time. "Work-in-progress" feedback is especially important (Kimball 2001). Sending extra e-mail messages, posting science-in-the-news announcements, and noticing when students are "absent" for too long and writing them a quick e-mail are also useful tactics. In most online classrooms, there are links to students’ e-mail addresses, so check-ups are quite easy, and it becomes relatively simple to handle students’ needs for interaction (Kimball).

3.7 Timing of Comments, Questions, and Deadlines

Because being "in" class will occur at different times for everyone (known as the "rolling present," Kimball 2001), students need to see that the instructor is or has been there, as evidenced by his or her responses to questions, comments, arguments, and so on, especially in the asynchronous discussions. Otherwise, students may feel that there is no use logging in, even if other students have posted many interesting comments. It is not the quantity but the quality of student contributions that matters, and quality is influenced by the instructor’s ability to plan and facilitate effective online discussions (Edelstein & Edwards 2002; Guzley et al. 2001). Students should get more credit for critical thinking and synthesis of astronomical concepts than for simply reciting memorized facts.

It is a fine balance to be present but not dominate online discussions. Instructor choices about what is important will have to be made based, at the minimum, on learning outcomes, time investment, and value placed on the topic (Edelstein & Edwards 2002).

3.8 Wait and Response Time

The old five-second minimum wait time for responses to questions (which is often still not observed in many classrooms) becomes meaningless in online asynchronous discussions. It translates into something more like 24-48 hours for threaded discussions (in which students can follow the progress of one or more simultaneous discussions) and 5-7 days for regular assignments. The extra time in online courses allows students to "explore meaning" in new ways (Dabbagh et al. 1999; Henry & Worthington 1999), and for critical reflection to take place (Smith & Winking-Diaz 2004). It is important to establish an understanding of expectations among everyone at the beginning of the semester. An announcement that students can expect answers by a certain time works fine, but should be accompanied by suggestions for how they might effectively study, and by a brief description of the astronomy content to be covered. Just because the online medium allows us to post a message within seconds of writing it, we cannot expect others to respond immediately--in fact, such a rapid response may discourage serious reflection on the topic, which is an important advantage of the online educational experience.

3.9 Assessment

This has been the topic of much debate in maintaining standards for the online learning environment; it is also where the field is still changing. At UMUC, a final exam is given at thousands of test centers around the world, where online students must show up with a photo ID for a proctored exam. Even if someone else has been doing the students' work the rest of the semester, students cannot escape the accountability of being present for the final exam, which, depending on the instructor, counts 30%-40% of their grade.

As for ongoing assessment, however, traditional tests may not be the best way to evaluate progress. Instead, students may be expected to post discussions and responses publicly, assemble a portfolio, do homework and open-book tests, work within a study group on a project, and communicate with the instructor for help. Thus, in an online class, students must take a great deal of responsibility for their own learning--something they may not be used to doing, having become accustomed to structured timetables and limited face-to-face interactions with peers and instructors. In reality, our online courses impose significant student participation and interaction, which is actually a highly demanding requirement (Lapadat 2002). It thus follows that grading criteria be developed in coordination with curriculum design. Online discussions are the source of considerable learning, affording students the "potential for conceptual growth" (Lapadat), and count for an important part of the students' grades. Table 1 shows one possible set of assignments and grade weighting.

Table 1. Sample Set of Assignments and Grade Weighting

Online participation	3%
Weekly assignments, including: (1) Study exercises from the textbook (2) Problems and activities from the textbook (3) Planetarium activities (using the *Starry Night* software)	21%
Midterm examination	10%
Clipping file	4%
Constellation observations	4%
Solar System group project	8%
Lunar phase observations	10%
Final examination*	40%
Total	100%
*The (proctored) final exam is weighted so heavily because it is the only work that we can be sure the student does independently, and it provides the most reliable indication of what the student has learned.	

CONCLUSION

Teaching astronomy online gives more students the chance to improve their science literacy, not only in this country, but also abroad. Underserved groups such as the disabled or those far from university campuses would otherwise not have easy access to higher education, nor would they be able to study with experts in astronomy. Yet the online form of independent learning is not for all students, and many still need (or prefer) traditional teacher-student interactions in a classroom. But Internet-based education is growing at such a rate that many classroom instructors will likely have to teach an online course one day. Therefore, it is important for instructors to understand the nature of online learning to help prepare the most effective and appropriate astronomy courses for this new audience.

Note

This article is based on a Cosmos in the Classroom workshop conducted by the authors at Tufts University in July 2004.

APPENDIX: SETTING UP AN ONLINE ASTRONOMY CLASSROOM

Table A.1. Last-Minute Checklist for the Online Instructor (examples in italics)

Course Characteristics
1. Is the virtual classroom's layout and ambiance attractive to students? *Does it have astronomy-related graphics, links, even cartoons?*
2. Is it relatively easy to navigate the classroom? *Do assignment folders and discussion areas have clear, intuitive labels? Do hyperlinks to astronomical Web sites work properly?*
3. Is essential information readily available? *Library resources, technical support, syllabi, current NASA updates, and so on.*
4. Is the course organized in a reasonable way? *Is the order of topics taught with appropriate prerequisites, perhaps following an astronomy textbook?*
5. Are expectations, policies, and deadlines clearly indicated? *Have students been told of required math or other skills needed? Do they need a scientific calculator? Do they need to spend a certain amount of time outside looking at the night sky?*
6. Does the classroom feel like a safe place to explore, make errors, and learn? Are there both public and private, and formal and informal discussion areas for students to address content, technical problems, study issues, and so on? Is there an area where popular astronomical misconceptions are discussed?
7. Can questions be posted and answered at any time? Has the culture been established that students may try to answer other students' questions before the instructor does?
8. Have issues of plagiarism, civility, and ethics been presented? (Although probably covered in official university documents, this bears reinforcement because electronic information is so easy to copy and paste.)
Astro 101 Content
1. Do course requirements correspond to institutional or departmental guidelines? *A 3-credit class is about 90 hours of student work. This includes class time, required reading, studying, homework questions and problems on current astronomy content, observing projects, two to three exams, and one or two short activities, such as reading about astronomical current events online or in the newspaper (Bobrowsky 1999).*

2. Do course materials and discussions correct astronomical misconceptions, myths, and errors in a nonthreatening manner? *Common misconceptions are associated with the causes of seasons, black holes, and moon phases.*
3. Are course materials (complexity and quantity) appropriate for beginning undergraduate non–science majors? (Astro 101 students won’t be expecting calculus-based astrophysics problems.)
Technical Issues
1. Are all links--both internally to course Web pages and externally to astronomy sites--working correctly, and is the whole site active? *Hint: Log in as a student to check this out.*
2. In case of main server failure, do students have alternative ways to communicate with the instructor? *Hint: Give out address, e-mail address, and phone and fax numbers to students in the first week of class.*
3. Is the URL clearly visible for each link, so that if a student prints out a page, the actual Web address will appear? *This is often not automatic because titles or labels often replace URLs; talk to tech support about this.*
4. Does the course take advantage of the ability to hyperlink to relevant sites so that students can get more in-depth explanations of the more difficult astronomical topics? *Check to see if technical and content-based tutorials are available at the university, and at your favorite science education Web sites.*
5. Is the technical hotline phone number next to the computer? *This is good advice for the students and for the instructor.*
Course Materials
1. Are syllabi, course requirements and texts, assignments, announcements, study groups, and so on, posted in a timely manner? *For example, at least 48 hours before astronomical events, and a week before assignments are due.*
2. Are there alternatives to content materials in case of mail delivery problems for textbooks, or in case of temporary inaccessibility to the Internet? *Downloadable astronomical software, faxed or e-mailed copies of astronomy lessons or activities for in-class use.*
3. Are there supplementary astronomy readings, resources, or activities for slower or more talented students? (Not necessarily for extra credit, but to ensure that all students are appropriately challenged)

4. Are class materials posted visibly in the appropriate places under legible headings? Hint: Imagine you are a new student in online courses, and log in to check this out. For Astro 101, materials are likely to include more than just a textbook--for example, a star chart, software, or a calculator.
5. Is the lesson pedagogically sound, interesting, and appropriate for the online environment, or is it merely an uploaded lecture? *Just posting lecture notes does not help students (Barnett 2003); they need to actively participate in their own learning.*
6. Are there multiple ways of assessing the students' work and progress? *Observation logs or journals, discussion of specific astronomical topics, group projects, homework, portfolios, and so on.*
Interactions
1. Do conference or discussion areas stay open to allow for ideas to be added at any time in multiple ongoing conversations during the semester? *This allows students to make connections between astronomical topics from different parts of the course.*
2. Does the classroom establish a sense of community for the students? *Students can be encouraged to help one another, which also can reduce some of the instructor's burden.*
3. Do the instructor's biography and photo or introductory comments (including interesting nuggets of astronomical experiences) convey enough personality to the students so that they can get to know him or her?
4. Is it clear to the students that personal comments can be read by everyone in the class, and that it is more appropriate to conduct personal discussions offline? *The online discussions are for astronomy, except perhaps in the virtual student lounge (see item 9 below).*
5. Is there a plan to handle verbose, nonparticipating, or troublemaking students?
6. Has a reasonable percentage of class time been allocated for faculty-to-student, student-to-student, and student-to-faculty communication? *There can be astronomy "conversations," not just one-way (instructor-to-student) communication.*
7. Are group projects or chances for collaborative learning included to encourage student-to-student communication about the astronomical content?

8. Are students notified as to when they can typically expect a reply from an instructor (e.g., within 24 hours)?
9. Is there a casual "meeting area" for the students to hang out (e.g., a virtual student lounge) to discuss peripheral or noncourse topics?

Table A.2. Resources for the Online Instructor

Articles of Specific Interest to Astronomy Instructors
Bobrowsky, M. 1999, "News Clippings for Introductory Astronomy," *The Physics Teacher*, 37, 374.
Bobrowsky, M. 2000, "Teaching Evolutionary Processes to Skeptical Students," *The Physics Teacher*, 38, 565.
Bobrowsky, M. submitted 2005, "Dealing with Disbelieving Students on Issues of Evolutionary Processes and Long Time Scales," *Astronomy Education Review*.
Keller, J., & Slater, T. 2003, "The Invisible Universe Online: Evaluation Summary of a Distance-Learning Astronomy Course for Secondary Science Teachers," *Astronomy Education Review*, 2(1), 16.
Lundeberg, M., Bergland, M., Klyczek, K., & Hoffman, D. 2003, "Windows to the World: Perspectives on Case-Based Multimedia Web Projects in Science," *Journal of Interactive Online Learning*, 1(3). National Center for Online Learning Research. http://www.ncolr.org/jiol/archives/2003/winter/4/index.asp
Slater, T., & Jones, L. 2004, "Assessment of an Internet-Delivered Interactive Approach to Introductory Astronomy for Non–Science Majors," *Astronomy Education Review*, 3(1), 17.
Lists of Astronomical Resources
Astronomical Society of the Pacific, Web Sites for College Astronomy Instructors. http://www.astrosociety.org/education/resources/educsites.html
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