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

Astronomy Education Review

Volume 2, Feb 2003 - Dec 2003
Issue 1

The *Invisible Universe Online*: Design of a Distance-learning Astronomy Course for Secondary Science Teachers

by **John M. Keller**
University of Arizona
Timothy F. Slater
University of Arizona
Posted: 04/28/03

The Astronomy Education Review, Issue 1, Volume 2:1-15, 2003

Abstract

This paper presents the course structure for the Invisible Universe Online, an Internet-delivered distance-learning course for secondary science teachers that focuses on astronomical origins and multiwavelength astronomy. Developed through support by the Stratospheric Observatory for Infrared Astronomy (SOFIA) and the Space Infrared Telescope Facility (SIRTF) Education and Public Outreach programs, the course was implemented to test approaches to distance learning for use in future teacher flight training for SOFIA. The paper provides an overview and details of the structure of the course, with the intent of providing a model for astronomy and science educators interested in developing online courses for science teachers. A related paper appearing in the AER (Keller & Slater 2003) provides a preliminary evaluation of the course and describes several lessons learned through its design and implementation. The course Web site is http://btc.montana.edu/ceres/origin- s/SP02/.

1. INTRODUCTION

1.1 Overview

Many scientists and science educators target teacher enhancement as one of the highest leverage points for making significant impacts on the quality of science education. A secondary school earth and space science teacher will often interact directly with more than 150 students every day, and upwards of 5,000 students over an entire teaching career. It seemingly follows that if a scientist provides a Saturday workshop to 50 new science teachers, then nearly a quarter-million students could benefit. Such a scenario has been written repeatedly in many grant proposals by well-meaning scientists interested in science education.

Unfortunately, it is becoming clear that single-intervention, one-day workshops are highly limited in their long-term impact on science education. To be truly effective, scientists must develop long-term relationships with teachers that nurture both teachers' scientific content knowledge and their pedagogical content knowledge. In other words, providing either expert lectures or high-quality curriculum materials in isolation is insufficient; rather, scientists who are committed to making a difference in classrooms by working with teachers must also provide the "gift of their time." Developing productive relationships with teachers takes a significant commitment of time; research by Edinger (1991) suggests that it takes a minimum of 40 hours to make any meaningful inroads. This perspective has motivated federal and state funding agencies to be more supportive of summer workshops spanning three to six weeks, with required reinforcement meetings throughout the academic year (NSF 2001).

For many teachers, however, the logistics and difficulties of traveling to and attending such workshops can be substantially limiting. Like many professionals, teachers have busy family and professional lives, and taking three to six weeks away to attend a workshop, even when all expenses are paid, can be difficult even in the best of personal circumstances. The Internet, however, provides an alternative. Computer-mediated communication, especially asynchronous conferencing, allows workshops to be organized and to function productively even though the participants and instructors are widely separated, never meet face-to-face, and have varying schedules (Mayadas 1997). In recent years it has become clear that busy classroom teachers want--and will enroll in--high-quality professional development courses if they are tailored to their needs as educators and are electronically accessible from their homes or workplaces (Prather & Slater 2002). These highly motivated, well-informed, computer literate teachers are looking for educational opportunities that meet the specific time and geographical constraints of their busy lives.

Scientists and science educators working with a distance-learning program offered through the National Science Teachers Association (NSTA) Professional Development Institute and hosted by the National Teachers Enhancement Network (NTEN) at Montana State University (MSU) have acquired wide experience in providing such distance-delivered academic offerings to science teachers (Slater et al. 2001). Since 1993, NTEN has reached more than 2,000 science teachers through the development and delivery of over 40 different courses that now can be sequenced to fulfill many of the requirements of a Master of Science in Science Education graduate degree from MSU. General information about this project is accessible online by selecting "Distance Learning" at http://btc.montana.edu. NTEN courses are developed and taught by teams of scientists, high school teachers, and science educators. Participants use a personal computer and modem to connect to their classes (Smith & Taylor 1995), interacting with each other and with the instructor through conferencing software that allows for both structured public discussions and private messaging. Many aspects of the courses are unsurprising; textbooks, homework exercises, computer software, and evaluation activities are still used, but there are no lectures. Instead, instructors and students work through the material together in a highly structured and scheduled format, which requires almost daily interaction by all involved. These are far from "independent study" or "correspondence" experiences--indeed, participants report that discussion and networking is a major factor in their learning (Obbink & Tuthill 1998). Nonetheless, the fact that the discussions are not conducted in real time means that teachers can participate in the class at times most convenient for their personal schedules.

This paper presents an overview of the course structure for a highly effective distance-learning course. The course, the *Invisible Universe Online*, was developed and implemented during the 2001-2002 academic year through co-sponsorship by NASA Education and Public Outreach (EPO) programs of the Space Infrared Telescope Facility (SIRTF) and the Stratospheric Observatory for Infrared Astronomy (SOFIA). Both of these planned infrared astronomy missions have aggressive EPO portfolios that include the development of user-friendly Web sites, numerous presentations at professional conferences, distribution of curriculum materials aligned with NRC National Science Education Standards, and face-to-face professional workshops for teachers. In addition, through the development of the course described in this paper, these programs are pursuing the effective use of distance learning as a means to promote the type of sustained teacher development described above. The 15-week course carries graduate university credit from the physics department and is open to any in-service teacher who wishes to enroll. The course is offered through the NSTA Professional Development Institute (http://ecommerce.nsta.org/institute/courses_web.asp) and serves as one of the required core courses for an astronomy education emphasis in the MSU Master of Science in Science Education program. Furthermore, the course serves as a test-bed for developing and testing various approaches to distance learning that will inform the extent to which flexible SOFIA flight training workshops can be delivered via the Internet for secondary teachers selected to fly on SOFIA missions. The course's public Web site is http://btc.montana.edu/ceres/origins/SP02/.

1.2 Class Demographics

Twenty-four science educators, hereafter referred to as participants, completed the *Invisible Universe Online* course during the spring 2002 semester. Of these, most were teaching either high school science (thirteen participants) or middle school science (eight participants). The three other participants were teaching in an alternative setting, on sabbatical, and retired, respectively. In terms of teaching environments, eighteen of the participants taught in traditional public schools, one taught in a traditional private school, and five were in other educational settings. In terms of subject area, eight taught physics or physical science courses, three taught earth science courses, one taught chemistry, eleven taught some combination of the above (including some life science courses), and one taught in a completely integrated curriculum program. Table 1 provides a cumulative distribution of the subjects taught by participants. All totaled, the participants were working directly with approximately 1,100 high school students and 900 middle school students at the time of the initial course offering.

Table 1. Cumulative distribution of subjects taught as reported by participants

Subject Taught	Number of Participants
Biology	9
Chemistry	17
Physics	13
Astronomy	12
Earth Science	15
Integrated Science	4
Other	4

Participants were spread geographically throughout 16 states and abroad. The most remote participants were taking the course from Alaska and Thailand. Participants in the course had a strong degree of comfort with computers, with 20 of 24 reporting that they found working with computers easy or somewhat easy, and only four reporting computer use to be moderate to somewhat difficult. This group also had substantial distance-learning experience; this was the first distance-learning course for only five of the participants, while fifteen participants had taken between one and five previous distance-learning courses, and four had taken more than five distance learning courses (see Table 2). Additionally, this group consisted of mostly veteran educators, with twenty of the participants having over five years of experience in the classroom (see Table 3).

Table 2. Online experience as reported by participants

Number of Online Classes	Number of Participants
0	5
1-2	7
3-5	8
6-10	2
10+	2

Table 3. Years of teaching experience as reported by participants

Years in Classroom	Number of Participants
1-5	4
6-10	6
11-20	8
20+	6

When asked about publicity, 12 participants reported finding out about the course through the National Teacher Enhancement Network Web site (http://btc.montana.edu/nten), two from Montana State University MSSE program fliers, two from friends, and seven from NSTA and MSU mailed advertisements.

1.3 Participant Motivation

Overall, this group of participants represents a population of learners with fair to strong distance- learning experience. These were veteran educators looking to improve their content knowledge, pedagogy skills, and awareness of curriculum materials. Primary motivations for taking the distance-learning course as reported by participants included interest in increasing content knowledge in astronomy for both personal and professional reasons; earning credits toward re-credentialing and professional development; and learning how to integrate computers into the curriculum. Several participants noted that the distance-learning environment provided a convenient and effective means for them to integrate professional development through graduate coursework into their already busy lives.

2. COURSE GOALS

The course was developed as an advanced-level astronomy course intended to emphasize how astronomers have used and are using data from multiple wavelengths of the electromagnetic spectrum to advance our understanding of "astronomical origins" as outlined in the NASA Origins Program, which sponsors both SIRTF and SOFIA. Spread over a 15-week semester (including a spring break), the course topics were divided roughly into three categories. The first five weeks of the course focused on the NASA *Origins Science Roadmap* (http://origins.jpl.nasa.gov) and an understanding of light and the electromagnetic spectrum. The next six weeks covered topics related to the formation and evolution of stellar and planetary systems. The final three weeks of content focused on cosmology and galactic formation and evolution. The last week was reserved for course wrap-up, a final examination, and post-course surveys. Table 4 provides additional detail on the weekly topics within each of these divisions.

Table 4. Course overview and weekly Internet-based reading assignments used to supplement readings from the course textbook.

Week/Topic	Internet-Based Reading Assignment URLs
Origins/EM Spectrum	
Week 1: Intro to Search for Origins	NASA Origins Roadmap: http://origins.jpl.nasa.gov/whatis/whatis.html
Week 2: What is Light?	http://imagers.gsfc.nasa.gov/ems/ http://www.ipac.caltech.edu/Outreach/Multiwave http://www.colorado.edu/physics/2000/waves_particles/index.html
Week 3: Color and Temperature	http://books.nap.edu/html/nses/html/ http://ipac.jpl.nasa.gov/webvideo/video_isdn.html
Week 4: Spectroscopy	http://www.colorado.edu/physics/2000/xray/making_xrays.html http://www.chem.uic.edu/web1/OCOL-II/WIN/SPEC/IR/IRF.HTM http://science.widener.edu/svb/ftir/intro_ir.html
Week 5: Collecting Photons	http://spaceplace.jpl.nasa.gov/teachers/adaptive_optics.pdf
Stellar/Planetary Formation	
Week 6: ISM and Molecular Clouds	
Week 7: Star System Formation	
Week 8: SPRING BREAK	
Week 9: Extrasolar Planets and Atmospheres	http://sirtf.caltech.edu/science/planets/index.shtml http://sirtf.caltech.edu/science/stars/index.shtml http://oposite.stsci.edu/pubinfo/pr/2001/38/
Week 10: Star Death @ Multiple Wavelengths	http://chandra.harvard.edu/xray_sources/supernovas.html

Week 11: High Energy Exotics	http://chandra.harvard.edu/xray_sources/grb.html
Galactic Formation/Cosmology	
Week 12: The Milky Way	http://adc.gsfc.nasa.gov/mw/mmw_images.html http://rsd-www.nrl.navy.mil/7213/lazio/GC/
Week 13: Galaxy Formation and Evolution	
Week 14: Formation and Evolution of Universe	
Week 15: Concept Maps, Final Exam, Evals	

Through this structure, we were trying to emphasize the following course goals:

1. Develop scientific background knowledge of astronomical objects and phenomena with peak emissions outside of the visible region of the electromagnetic spectrum
2. Understand contemporary scientific research questions related to understanding how stars and planetary systems form and evolve, how galaxies formed and evolve, and evidence relating to the formation of our universe
3. Describe strategies and technologies for using non-visible wavelengths of EM radiation to study various phenomena
4. Integrate the related issues of astronomical science, technology, societal issues, and science education
5. Develop specific strategies for implementing concepts in the National Science Education Standards related to "invisible" astronomy and the search for astronomical origins

Although a part of the NASA Origins research agenda, biological origins was not emphasized in this course because Montana State University offers a distance-learning course specifically on astrobiology (Prather & Slater 2002). The *Invisible Universe Online* focused specifically on topics of planetary, stellar, galactic, and cosmological origins.

3. COURSE STRUCTURE

The course was delivered using WebCT, a Web browser-based software platform specially designed for Web courses. This platform allowed for asynchronous discussion postings, online chatting, intra-course e-mail, course news dissemination, homework collection, secure gradebook, and exam and survey distribution. The primary foundations of the course were highly structured weekly reading and homework assignments, weekly discussions regarding both content issues and pedagogy/curriculum issues related to that content, and four two-week collaborative and individual projects involving implementation of course material into participants' teaching situations. This course structure was assessed through homework and project grades, weekly course surveys, midterm and final examinations, a pre-course and post-course concept map evaluation, and a final course survey. Participant grades were calculated using the scale provided in Table 5.

Table 5. Percentage of grade assigned to various course components

Assignment	Percentage of Grade
Weekly Homework Assignments	30%
Weekly Discussion Participation	20%
Four Course Projects	25%
Midterm Exam	10%
Final Exam	15%

3.1 Weekly Readings

Weekly reading and homework assignments were developed to integrate technology with the teaching of course material. Weekly readings were assigned from the text *Universe: Stars and Galaxies* by Freedman & Kaufmann (2002), and from selected Internet sites that provided relevant background information. These included Web sites on the NASA Origins Program, the NRC National Science Education Standards, the electromagnetic spectrum, infrared spectroscopy, X-ray production, adaptive optics, the interstellar medium, extrasolar planets, supernovae, X-ray detectors, gamma-ray bursts, the multiwavelength Milky Way, and more. Table 4 provides the primary Web addresses for the Internet-based reading assignments, along with an overview of the course topics.

The primary purposes of these reading assignments were to develop foundational knowledge for all participants, to serve as a springboard for more in-depth weekly discussions and homework assignments, and to demonstrate the integration of Web materials into a curriculum. Typical weekly assignments involved between 20 and 40 pages of reading. Participants were held accountable for these readings through weekly homework, weekly discussions, and course examinations.

3.2 Weekly Homework Assignments

Weekly homework assignments were submitted as typed responses to questions, scenarios, and laboratory activities. These questions and assignments came from end-of-the-chapter questions in the Universe textbook or were created by the course instructors. Attempts were made to blend textbook questions, lab activities, and Internet-based educational resources into the weekly course assignments. Specific details on these weekly assignments can be found on the *Invisible Universe Online* Web site (http://btc.montana.edu/ceres/origins/SP02/). A representative sample of homework activities is outlined briefly below.

- Infrared detection activity involving off-the-shelf digital cameras sensitive to near-infrared radiation from television remote controls (Pompea & Gould 2002)
- Utilization of several Java applets dealing with but not limited to the following topics:
  - radiation (http://csep10.phys.utk.edu/guidry/java/blackbody/blackbody.html)
  - Planck's Law (http://csep10.phys.utk.edu/guidry/java/planck/planck.html)
  - spectroscopy (http://mo-www.harvard.edu/Java/MiniSpectroscopy.html)
  - atmospheric windows (http://solarsystem.colorado.edu/navigation/lowRes.html)
  - electromagnetic scattering (http://zebu.uoregon.edu/textbook/ism.html)
  - pulsars (http://chandra.harvard.edu/xray_sources/pulsar_javav2.html)
- Review of several curriculum project materials, including a spectroscopy activity (http://www.as.utexas.edu/stardate/spectroscopy/sp.html) by Armosky & Hemenway (2001), activities on supernovae, and activities from Pompea & Gould (2002)
- Questions from the end-of-chapter reviews of the *Universe: Stars and Galaxies* text (Freedman & Kaufmann 2002)

3.3 Weekly Discussions

Experience has demonstrated the importance of frequent and structured discussions as a means of transforming a correspondence course into a collaborative exchange between course participants. Benefits of this transformation include stronger rates of participant retention, higher levels of topic coverage and participant involvement, and collaborative exchange on content, curriculum, and pedagogy issues between participants from a diverse range of educational settings.

The course participants were divided into three separate discussion sections, each with eight course participants. The three course instructors facilitated these groups using a rotation strategy in which each instructor monitored a different group each week. The motivation, benefits, and drawbacks of this facilitator rotation strategy are discussed further in the evaluation section of this paper.

Discussion participants were only able to interact directly with the eight members of their discussion group during each week, but were provided with an archive of discussion postings from other groups in the week following each discussion. The primary goal of reducing group sizes was to provide a more focused and engaged discussion group where participants had to take more ownership and responsibility for moving the discussion forward. In a sense, participants were taking a seminar with eight students rather than with a class of 24. Participants were given a weekly discussion grade based upon a three point rubric system emphasizing frequent and meaningful discussion postings. A description of the rubric is provided in Table 6.

Table 6. Group discussion scoring rubric

SCORE	QUALITY	DESCRIPTION
2 to 3	Meeting and Exceeding Expectations	Student participated early in the discussion and at least two times in a meaningful manner. By his or her interaction, through both questions posed and answers proposed, the student attempted to move the discussion forward. It was clear that the student took time to think about comments or questions posed and responded in a way that was respectful, articulate, thought-provoking, and on time. Strong effort and investment in the discussion was evident.
1 to 2	Working Toward Expectations	Student participated in the discussion at least once in a meaningful manner and by his or her interaction moved the discussion forward. Student took some time to think about comments or questions posed, but there is room for improvement. Responses seem rushed, with only some depth or thought-provoking comments. Some effort and investment in the discussion was evident.
0 to 1	Work was Not Done or is Not Meeting Expectations	There was little to no participation in the discussion, or the student participated in some of the discussion but responses were clearly rushed, were late in the week, or had little thought put into them. Responses may not have been respectful, articulate, thought-provoking, or on time. Clearly more effort or investment in the discussion is needed.

To earn full credit, participants were required to contribute to the discussion group on at least two separate occasions each week. Full credit was not granted to students who checked in only once per week or who tried to contribute all of their posts at the same time. Credit was given to posts that were thoughtful and significantly contributed to developing and expanding on the discussion topics at hand. This included stating and supporting thoughts and opinions on the topic, asking questions that propelled the discussion forward, and responding to questions posed by group members. Discussion facilitators looked for evidence that participants had read the contributions of others in their group and added their own input to help advance the group's understanding. Questions asked to clarify confusion or doubts about topics were just as essential as responses to those questions, and participants were encouraged to ask other group members to clarify and defend their points.

Discussion topics included content-specific issues related to weekly reading and assignments, pedagogical questions related to science teaching and NRC National Science Education Standards, curriculum design critiques from participants, and discussion of community building activities to encourage richer discourse within each discussion group. Specific details of weekly discussion topics can be found at the course Web site (http://btc.montana.edu/ceres/origins/SP02/). Three sample discussion topics are provided below to give a sense of the format and content of discussion topics.

- Describe how the concepts of star color, redshift, interstellar reddening, and atmospheric reddening can be confusing; as a group, explain the fundamental physics behind each of these processes and how important distinctions can be made between the four. Finally, do your students even notice color in the sky? Is the night sky red, white, blue, or black? What do your students think? What do astronomers think? What do you think?

- Black holes, and more recently, gamma ray bursts (GRBs), seem to be topics that often capture the interest and attention of many students. What are some of the common misconceptions about black holes and GRBs held by your students and by the public? Feel free to describe any misconception you had prior to this week's reading. Also, what central questions did this week's reading spark regarding these bizarre astronomical objects? Finally, how can you address these questions and misconceptions in your teaching?
- This week's reading included a kinesthetic lesson on adaptive optics and an optional reading on orbital motion. These are just two examples of "kinesthetic" or "dramatic" activities to teach science concepts:
  - in biology, students can act out cellular respiration and protein synthesis
  - in chemistry, students can play electrons filling up the energy levels of an atom (carefully arranged desks in the classroom)
  - in physics, students can role play diffusion or laser light
  - in earth science, students can demonstrate the difference between seismic waves (compressional p-waves and transverse s-waves)

  What is your expert opinion of this type of "kinesthetic" lesson? If you have experience, describe to your group a kinesthetic lesson that you have taught. What is the value or benefit of presenting a science concept kinesthetically? What are the drawbacks or pitfalls? Wherever appropriate, back up your opinions with examples, personal experiences, and/or pedagogical theory.

3.4 Curriculum Projects

The third instructional mode used in the course involved four curriculum development projects assigned throughout the semester. One of these required collaboration between two or three participants and the remaining three encouraged, but did not require, collaboration. Participants were allowed two weeks to complete each project. The primary focus of the projects was to promote the development of usable curriculum and lesson plan materials that participants could use directly in their teaching situations. It was thought that the projects would motivate reflection on course content and conceptual models being developed, and also provide useful products that participants would benefit from as they planned and taught their classes. Below is a brief summary of the four required projects.

- *Multiwavelength Project:* Participants were asked to form two- to three-person groups and to develop an electronic slideshow that could be used to emphasize the fundamental concept that viewing astronomical objects at different wavelengths provides essential perspectives for understanding these objects more fully. Participants were directed to the SIRTF Multiwavelength Gallery (http://sirtf.Caltech.edu/Education/Messier/gallery.html) as one potential site for accessing multiwavelength images.
- *Light Activity Project:* Participants were given the assignment of developing and submitting a lesson plan for a lab or activity dealing with a fundamental aspect relating to the nature of light. Participants were encouraged to choose activities that required significant additional development and improvement.
- *Current Events Project:* As part of the course, the developers maintained a "current events in invisible astronomy" page highlighting recent discoveries involving data collected beyond the visible range of the electromagnetic spectrum. Additionally, articles from a diverse level of literature sources

(from online news articles to NASA press releases to scientific papers) were presented for each topic. Participants were assigned to select one of these topics and write a one- to two-page page paper briefly summarizing the topic, critiquing the consistency and presentation of the topic between varying sources, and discussing the implementation of this current events piece into their classroom.

- *Origins Unit Plan Project:* Participants were assigned to provide a three- to seven-day unit plan addressing one of the many scientific "investigations" described in the NASA Origins Science Roadmap. This unit plan was to include an overview of the investigation, a summary of curriculum goals associated with the unit, a listing of day-to-day activities in the plan, and a description of how the lessons in the unit would support the primary lesson goals.

Completed projects were made available to all course participants so that they could review and use the wide and rich collection of ideas associated and packaged in each of these projects. These projects were designed to be flexible enough that participants could tailor them to their classroom situations while remaining focused on the content and scope of the topics covered in the course.

3.4 Course Evaluation

A substantive effort in the development of the course focused on evaluation--evaluation of both student learning and the course design. The following sections describe levels of assessment, both formative and summative, on both student learning and course design.

3.4.1 Evaluation of Student Learning

Homework assignments were graded each week by the course instructors. While time did not allow course instructors to provide detailed individual feedback for each and every submitted problem set, the instructors provided participants with answer keys and a summary of common difficulties for each of the assignments. The instructors also attempted to provide individual feedback to any students who appeared to have more serious problems with the homework assignments or curriculum projects.

The course included a midterm examination during Week 7 and a final exam during Week 15. These exams were essentially take-home exams. Participants were allowed to use their textbooks, class notes, and Web materials during the exam. They were not allowed to use input from any other individuals, and a three-hour time limit was imposed electronically on each exam. The exams involved a combination of multiple choice questions and open-ended questions and were delivered using testing functions within *WebCT*. Not surprisingly, these highly motivated learners performed well on both examinations. The mean score on the midterm exam was a 92%, with a standard deviation of 7%. The mean score on the final examination was 92%, with a standard deviation of 6%. Each evaluation provided an opportunity for instructors to judge the level of understanding and learning achieved by participants. In addition, the exams served as a progress check and, as one participant put it, "provided an excellent tool for consolidating all that we’ve done." (Week 7)

A final assessment strategy implemented in this course involved the use of pre- and post-course concept maps. At the outset of the course, participants were asked to create three concept maps focused around the themes of : 1) electromagnetic radiation, 2) stellar and planetary evolution, and 3) cosmology and galactic evolution. In these "selected terms concept maps" (http://www.flaguide.org), participants were given a list of approximately 20 concepts for each map and asked to organize and link these based upon their current understanding of the topic using IMHC concept mapping software (http://cmap.coginst.uwf.edu/). At the end of the course, participants were given the same sets of concepts and asked to repeat the process. While a more thorough analysis of these concept maps is saved for future work, preliminary evaluation of these pre- and post-course concept maps shows improvement in all three topics, with more improvement in the latter two topics than the topic of electromagnetic radiation. One possible explanation for this trend is that participants' pre-course understanding of electromagnetic radiation was inherently stronger than their understanding of the latter two topics.

3.4.2 Evaluation of Course Design

In addition to evaluating student achievement in the course, the instructors also implemented an extensive formative evaluation plan to assess the design of the course through weekly course surveys. Two types of course surveys were utilized. The first consisted of 16 agree/disagree questions using a Likert scale and four open-ended questions. These questions were grouped into categories focusing on the following aspects of the course: discussion, homework, reading, and entire week. The second survey consisted of six open-ended questions asking for more extensive comments on the course, again focusing on discussion, homework, reading, entire week, and the course. Each week, two-thirds of the class took the multiple-choice survey, while the remaining third completed the open-ended survey. Thus, each participant completed two multiple-choice surveys and one open-ended survey every three weeks. This assessment strategy was used in order to minimize the amount of time required for participants to complete surveys while still providing useful amounts of both qualitative and quantitative data regarding the course design. All responses to the surveys were anonymous. In addition, all participants completed a final course survey during the final week of the course. This summative survey consisted of 25 Likert scale items and 14 open-ended questions.

Feedback from both the formative surveys and the summative survey provided valuable feedback for modification and further development of this course. Additionally, these surveys provided insight into the implementation of online courses in general. A summary of this data is provided in a related paper also appearing in the AER (Keller & Slater 2003).

4. CONCLUSIONS

This paper has provided an overview of an online, distance-learning course developed for secondary science teachers. The course was successfully piloted with 24 participants during the spring 2002 semester through Montana State University. Through a combination of Internet- and text-based readings, weekly homework assignments, curriculum design projects, examinations, and online, asynchronous discussions, participants were provided with a comprehensive and integrated study of the use of multiwavelength astronomy to understand astronomical origins. Discussions between participants were facilitated by three course instructors and provided an essential interactive component to the course, transforming it from a correspondence course to a collaborative learning experience. Particular attention was dedicated to providing learning experiences and activities that provided an integrated perspective of astronomy and that were relevant to participants' classroom teaching situations.

The *Invisible Universe Online* is an attempt by astronomy educators to research effective uses of distance learning as a means of enhancing teacher understanding and the integration of current astronomy into classroom science teaching. The primary focus of the course involved our understanding of astronomical origins and the importance of multiwavelength astronomy as a basis for this understanding.

This effort was sponsored and supported by EPO efforts of both the SIRTF and SOFIA missions. Both projects are centrally concerned with reaching teachers through creative and diverse avenues, including distance learning. When SOFIA starts involving over 200 teachers per year in education efforts revolving around airborne infrared astronomy, distance learning will provide just one means of reaching teachers all around the country to provide the background and understanding central to the goals and objectives of the program. It is our hope that this paper has provided a useful model of an online course that will be valuable for astronomy and science educators interested in distance learning. The results and lessons learned from this particular study are provided in a related paper (Keller & Slater 2003). We encourage those interested in the course evaluation results to continue reading this accompanying piece.

Resources

Invisible Universe Online Course Web site -- http://btc.montana.edu/ceres/origins/SP02/

NSTA Professional Development Institute -- http://ecommerce.nsta.org/institute/courses_web.asp

Montana State University National Teacher Enhancement Network and Masters of Science in Science Education Program -- http://btc.montana.edu

NASA Origins Science Roadmap -- http://origins.jpl.nasa.gov

NRC National Science Education Standards -- http://books.nap.edu/html/nses/html/index.html

Designing Online: Asynchronous Discussions -- http://onlinelearn.edschool.virginia.edu/discuss

Field-tested Learning Assessment Guide -- http://www.flaguide.org

IMHC Concept Mapping Software -- http://cmap.coginst.uwf.edu/

Acknowledgments

We would like to extend our appreciation to the following individuals for their invaluable contributions to the development and completion of this work: Michael Bennett, Edna DeVore, Michelle Thaller, and the NASA EPO programs of the Space Infrared Telescope Facility (SIRTF) and the Stratospheric Observatory for Infrared Astronomy (SOFIA) for supporting and guiding the implementation of the *Invisible Universe Online* course; Sanlyn Buxner at the University of Colorado-Boulder, for her involvement in instructing and continually improving the course; John Usher, Kelly Boyce, Ritchie Boyd, and the Burns Telecommunications Center at Montana State University-Bozeman for providing the infrastructure and technical support that made the course possible; Janelle Bailey, Erika Offerdahl, Delphine Perrodin, and Ed Prather, members of the Conceptual Astronomy and Physics Education Research (CAPER) group at the University of Arizona, for their editorial contributions to this work; Adrienne Gauthier for her editorial contributions and for making the fall 2002 offering of the course even better; and the 24 teacher participants of the spring 2002 *Invisible Universe Online* course for their 2,800+ discussion postings, 250+ course evaluations, and the patience, understanding, and motivation they provided to the development team.

References

Armosky, B., & Hemenway, M. K. 2001, *Decoding Starlight with Spectroscopy*, Austin: University of Texas at Austin McDonald Observatory, http://www.as.utexas.edu/stardate/spectroscopy/sp.html.

Edinger, P. F. 1991, The Use of Earth Science Teacher Inservice Time for Local Field Trips and Laboratory Workshops and its Relationship to Teacher Attitudes, Columbia: University of South Carolina. Ph.D. dissertation.

Freedman, R., & Kaufmann, W. 2002, *Universe: Stars and Galaxies*, New York: W. H. Freeman & Company.

Keller, J., & Slater, T. F. 2003, The Invisible Universe Online: Evaluation Summary of a Distance-Learning Astronomy Course for Secondary Science Teachers, *Astronomy Education Review*,

Mayadas, F. 1997, Asynchronous Learning Networks: A Sloan Foundation Perspective, *Journal of Asynchronous Learning Networks*, 1(1), 1.

National Research Council. 1995, *National Science Education Standards*, Washington, D.C.: National Academy of Sciences Press, http://books.nap.edu/html/nses/html/index.html.

National Science Foundation. 2001, *Elementary, Secondary, and Informal Education: Program Solicitation and Guidelines*, Arlington, VA: National Science Foundation, NSF 01-060.

Obbink, K., & Tuthill, G. 1998, Taking the Distance out of Distance Learning: Lessons Learned, *A Faculty Development Workshop on Best Practices in Distributed Learning*, Bozeman: Montana State University, http://btc.montana.edu/nten.

Pompea, S., & Gould, A. 2002, *Invisible Universe--GEMS Teacher Guide*, Berkeley: Regents of the University of California.

Prather, E. E., & Slater, T. F. 2002, An Online Astrobiology Course for Teachers, *Astrobiology*, 2(2).

Slater, T. F., Beaudrie, B., Cadtiz, D. M., Governor, D., Roettger, E. R., Stevenson, S., & Tuthill, G. F. 2001, A Systemic Approach to Improving K-12 Astronomy Education Using NASA's, *Journal of Computers in Mathematics and Science Teaching*, 20(2), 163.

Smith, R. C., & Taylor, E. F. 1995, Teaching Physics Online, *American Journal of Physics*, 63, 1090.