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*: Evaluation Summary of a Distance-learning Astronomy Course for Secondary Science Teachers

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Posted: 04/28/03

The Astronomy Education Review, Issue 1, Volume 2:16-45, 2003

Abstract

This paper presents the evaluation summary for the Invisible Universe Online, an Internet-delivered distance-learning course for secondary science teachers, which focuses on astronomical origins and multiwavelength astronomy. Developed through support by the Stratospheric Observatory for Infrared Astronomy (SOFIA) and the Space Infrared Telescope Facility Education and Public Outreach (SIRTF EPO) programs, the course was implemented to test approaches to distance learning for use in future teacher flight training for SOFIA. This paper provides an overview of the strategy used for course evaluation, along with an extensive summary of the results of this evaluation and description of lessons learned through the development and implementation of the course. A related paper also appearing in AER (Keller & Slater 2003) provides a detailed overview of the course content and structure. The course Web site is http://btc.montana.edu/- ceres/origins/SP02/.

1. INTRODUCTION

This paper presents an evaluation summary 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 evaluated 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 and is open to any in- service teacher who wishes to enroll. The course is offered through the National Science Teachers Association (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 Montana State University Master of Science in Science Education (MSSE) 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/.

The course was first offered during the spring 2002 semester to a group of 24 science educators, hereafter referred to as participants. The primary goals of the course were to provide an integrated perspective on the use of multiwavelength astronomy to understand astronomical origins. Participants accessed the course via WebCT, a Web browser-based software platform designed for Web courses. The substantive elements of the course included highly structured weekly reading and homework assignments, weekly discussions regarding both content issues and pedagogy and 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. A related paper appearing in AER, "The *Invisible Universe Online*: Design of a Distance-learning Astronomy Course for Secondary Science Teachers" (Keller & Slater 2003), provides a detailed overview of the structure and nature of the course.

This paper provides an evaluation summary and description of lessons learned through design and implementation of this distance-learning course. Many of the insights gained from both summative and formative evaluation of the course can be generalized to any distance-learning experience. It is our hope that the results of this evaluation will prove useful both to individuals developing Internet-delivered courses and to EPO managers interested in the use of online learning as a means to reach science educators in a sustained and effective manner.

2. COURSE EVALUATION STRATEGY

A substantive effort in the development of the course focused on evaluation--evaluation of both student learning and the course design. Evaluation of student learning included evaluation of weekly homework assignments and four curriculum design projects, a midterm and final examination, and pre- and post-course concept maps completed by participants. The results of this student evaluation are presented in a related paper (Keller & Slater 2003). The remainder of the work presented here focuses on the structure and implementation of the course, with an evaluation of results and insights gained through weekly course surveys and a final course survey completed by course participants.

Two types of weekly course surveys were used in formative evaluation of the course. The first consisted of 16 Likert scale questions and 4 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, 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 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. All surveys were anonymous and conducted under the guidelines adopted by Montana State University. Participants were informed at the beginning of the course that their qualitative and quantitative responses would be used in evaluating and improving the course for future offerings.

Due to the discrete nature of Likert scale responses, we present here median results, along with graphical representations of survey responses. It should be emphasized that the results presented below come from a relatively small sample (n=24). While we have pooled formative evaluation results across the multiple weeks of the course for a combined total of 169 surveys, these surveys are not independent and represent multiple responses from the same small group of students. The final course evaluation was only administered once and represents the entire class sample (n=24). Because this was the first offering of the course, we can base our results only upon the responses of this first pilot course. As the course continues to be taught, we will continue to gather additional survey responses that will allow for both semester-to-semester comparisons and improved statistics for understanding the overall effectiveness of the course. The course will be re-offered during the fall 2002 semester and again in the spring 2003 semester.

Feedback from both the formative surveys and the summative survey provided valuable information for modification and further development of the course. Additionally, these surveys provided insight into the implementation of online courses in general. A summary of this data is provided in the remaining sections of this paper, with a focus on homework, reading, discussions, and the course overall.

3. IMPORTANCE OF FORMATIVE EVALUATION

Formative evaluation strategies used in online courses provide instructors the opportunity to adjust and modify the content, delivery, and balance of assignments and activities throughout the semester (Andriole 1997). We found this to be true with the information we gained from weekly evaluations. The data from these evaluations are also valuable for future modification of the course. Many participants provided comments similar to the quote below regarding the importance of the formative evaluation component.

> "I am really glad to see an ongoing survey-evaluation in this class. What a great way to obtain feedback on a week-to-week basis. This class has been fun so far and I am looking forward to really getting into it." (Week 2)

Formative evaluation results allowed instructors to gauge the amount of time spent by participants on the various components of the course. Results showed that participants were overwhelmed initially in the first few weeks by the presentation and amount of course responsibilities. Through both adjustments to course assignments and participant acclimatization to the course format, these time requirements were maintained at average to high levels throughout the course. As Table 1 shows, the mode and median amount of time spent on the course per week was 8-10 hours, a reasonable amount for a three-unit course. Table 2 shows that participants strongly agreed that the work requirement for the course was reasonable for the credit given. The authors attribute the utilization of formative assessment questions as one important factor in

achieving the proper balance of course assignments.

Table 1. Summative survey results regarding average amount of time spent on course each week (n=24)

How much time, on average, did you spend on this course per week?	**Number of respondents**
Less than 2 hours	0
2-4 hours	0
4-6 hours	4
6-8 hours	6
8-10 hours	9
10-12 hours	3
12-14 hours	0
More than 14 hours	2

Table 2. Summative survey results regarding course expectations and workload (n=24)

Category	**Question**	**Median Value**
Course Credit	The course work requirements were realistic for the amount of credit earned. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1* *strongly agree*

However, formative evaluation also involves inherent challenges. Throughout the course, participants provided conflicting comments and requests regarding course homework. Participants asked for more and less math, higher level questions and more basic questions, more textbook questions and more Web-based activities, and more and less collaborative activities. The following two quotes, provided during the same week of the course, highlight this issue of conflicting feedback.

> "Many of the questions from [the] book can be answered by simply looking at the chapter summaries. Many of the questions are interesting but more in depth questions with no clear answer would also be interesting." (Week 13)

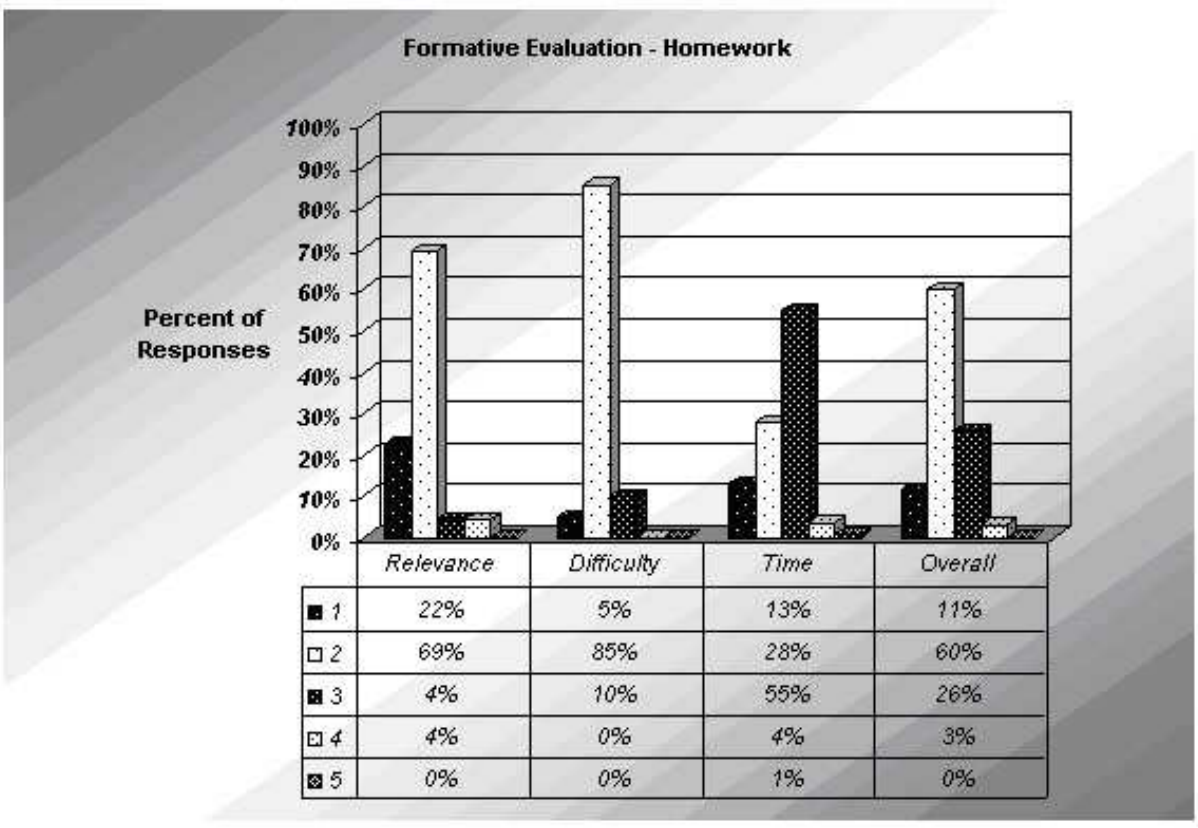
"It was good but a few questions did not have a clear answer as far as the text went." (Week 13)

As with all courses, a diversity of backgrounds and interests requires multiple approaches and a balance of activities and topics to provide the most complete educational experience. Weekly surveys provided an effective means of gauging participant reactions to course activities, allowing fine adjustments to be made throughout the course (Stevens, Lawrenz, & Sharp 1996).

4. HOMEWORK EVALUATION SUMMARY

Four Likert scale questions were posed in weekly evaluations regarding the relevance to classroom teaching, difficulty level, amount of time required, and overall rating of homework activities in the course. Compiled results, totaling 169 surveys from 11 weeks, are presented in Table 3.

Table 3. Formative survey results regarding homework (n=169)



	Relevance	Difficulty	Time	Overall
1	22%	5%	13%	11%
2	69%	85%	28%	60%
3	4%	10%	55%	26%
4	4%	0%	4%	3%
5	0%	0%	1%	0%

Category	Question	Median Value
Relevance	The homework activities this week were relevant and applicable to my classroom teaching experience (either past, present, or future). *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*2* *agree*
Difficulty	The difficulty level of the homework activities this week was: *1-too challenging, 2-challenging, 3-unchallenging*	*2* *challenging*
Time	The time required for the homework activities this week was: *1-significantly high, 2-high, 3-average, 4-low, 5-signficantly low*	*3* *average*
Overall	Overall, I would rank the homework activities this week as: *1-excellent, 2-good, 3-satisfactory, 4-poor, 5-disappointing*	*2* *good*

The time required for homework completion was high to average, and the difficulty level was rated as challenging, but not too challenging or unchallenging. Overall, participants agreed that the homework assignments were relevant to their classroom teaching and rated the activities as good.

These quantitative trends were echoed in qualitative responses. The following participant comment emphasizes the importance of making homework relevant to teaching.

> "I really liked the homework. It took a lot of time. I was a little concerned about the amount of time I spent and whether I was going to be able to complete the course. However, I found that everything I did led to creating something I could use in my own classes. That makes it all worthwhile--and I'm okay with the amount of time I spent." (Week 2)

A summary of participant suggestions regarding important homework issues is provided below for consideration by online course developers.

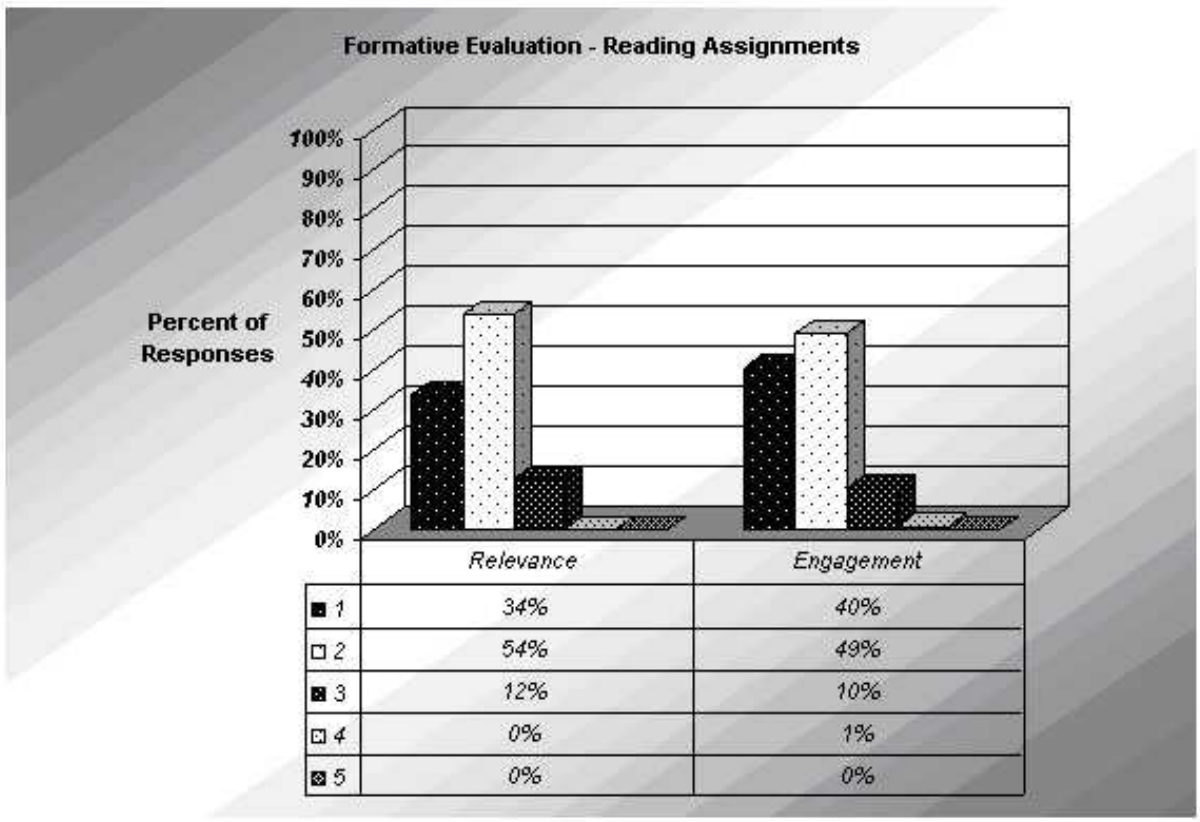
- *Alternative assignments:* Although most participants agreed that the homework activities were interesting and engaging, several participants requested that instructors provide additional activities at both more and less challenging levels. These additional activities would be optional but allow for participants to either challenge themselves more or provide a more solid background in the basics of the topic for that week.
- *Homework descriptions:* Many comments referred to the importance of making homework assignment instructions and expectations clear and concise. This included providing warnings of upcoming projects, making URLs available to participants, and streamlining and standardizing the format of the homework description. Requests were also made for more descriptive background explanations and expectations for use of unfamiliar Web sites.
- *Homework feedback:* Feedback on homework assignments was noted as an essential part of the learning process. As discussed above, instructors addressed this request by posting weekly solution sets and providing personalized feedback to participants who appeared to be struggling. Several participants also requested the opportunity to view projects completed by their peers as a means of sharing curriculum ideas.

- *Curriculum projects:* Several participants commented on difficulties completing homework assignments during weeks that also involved project completion. The request was made to reduce the amount of assigned homework on these weeks. This concern was not addressed during the first course offering, but may be addressed in future offerings. In addition, we found that each project required at least two weeks of development for participant success.
- *"Classroom-ready" activities:* Finally, participants commented on the benefit of "classroom- ready" curriculum materials. These requests were counterbalanced by comments that homework activities should be more "graduate level" in difficulty. Attempts were made whenever possible to provide both types of resources: both classroom-ready materials that participants could use with their students, and higher-level homework assignments appropriate to a graduate level course.

5. READING EVALUATION SUMMARY

Two Likert scale questions were posed each week regarding the relevance and engagement of reading assignments. Results from 11 weeks are presented in Table 4.

Table 4. Formative survey results regarding reading materials (n=169)

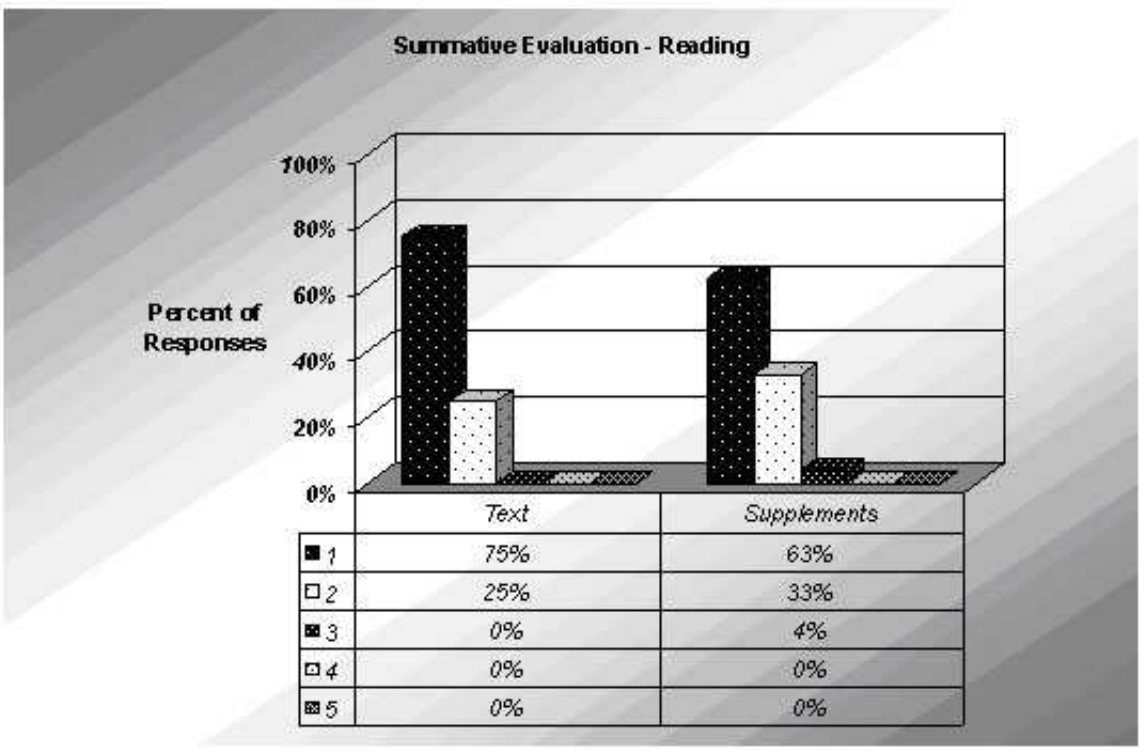


	Relevance	Engagement
1	34%	40%
2	54%	49%
3	12%	10%
4	0%	1%
5	0%	0%

Category	Question	Median Value
Relevance	How would you rate the reading assignments this week in terms of relevance to your teaching? *1-excellent, 2-good, 3-satisfactory, 4-poor, 5-disappointing*	*2 good*
Engagement	How would you rate this week's reading assignment in terms of interest and engagement? *1-excellent, 2-good, 3-satisfactory, 4-poor, 5-disappointing*	*2 good*

Note that 88% and 89% of the responses above are "favorable" regarding the relevance and engagement of the reading assignments, respectively. Qualitative questions asked regarding reading assignments reflected positive attitudes toward both the *Universe* textbook by Freedman & Kaufmann (2002) and readings from the Internet. In the final course evaluation, participants were asked to rate both the course text and supplemental (Internet) materials used in the course. Table 5 provides evidence that participants strongly agreed that both the textbook and supplementary course materials were effective:

Table 5. Summative survey results regarding reading materials (n=24)



Category	Question	Median Value
Text	The textbook used in this course met my needs as a learner. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1 strongly agree*
Supplements	The supplement(s) (any additional materials, outlines, etc.) used in this course met my needs as a learner. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1 strongly agree*

Interestingly, several participants wished for a balance between Web-based readings and textbook readings.

> "A mixture of text and Internet site reading would be nice, because then the reading could be incorporated better in the distance-learning concept. Being able to do parts of the assignments away from the computer is a nice aspect for those of us with small children and who spend a lot of time away from the computer; then the work can be taken with us to be worked on in spare moments." (Week 2)

Several participants emphasized the importance of providing clear explanations of exactly which pages or sections on the Web needed to be read, descriptions of the context and background for the Web readings, and expectations of what participants should get out of Web readings because of the hyper-linked nature of Web pages.

6. DISCUSSION EVALUATION SUMMARY

As discussed at more length in a related paper (Keller & Slater 2003), participants were divided into three discussion groups of eight participants each. The groups were assigned randomly, with no attention given to grade levels or subject areas that participants taught. While participants were able to look at other groups' discussions the week after they occurred, they were only able to see their own group's discussion during a given week.

A detailed understanding of the depth, quality, and benefits of weekly discussions is difficult to fully obtain. However, we have gained several insights into the effectiveness of discussions in the online setting through both qualitative and quantitative measurements. During the 15 weeks of the course, a total of 2,891 messages were posted by the 24 participants and three instructors. The class was divided into three groups, and the participants in each group were rearranged during spring break in Week 8. Table 6 provides the distribution of total number of postings made by each group. The table also shows the total number of postings made to a general course information folder and to "informal discussions" folders described in the related paper (Keller & Slater 2003).

Table 6. Distribution of messages posted by groups

Category	Number of Posts	% of Posts
Group A -- Weeks 1-7	518	17.9%
Group B -- Weeks 1-7	403	13.9%
Group C -- Weeks 1-7	493	17.1%
Group A -- Weeks 9-15	375	13.0%
Group B -- Weeks 9-15	327	11.3%
Group C -- Weeks 9-15	369	12.8%
General Course Info and Assistance -- Weeks 1-15	389	13.5%
Informal Discussions (Middle/High School) -- Weeks 9-15	17	0.6%
Total	*2,891*	*100%*

In addition to tracking the number of posts made by each discussion group, we were able to use the WebCT "tracking function" to determine how many messages each participant read and how many messages he or she posted. Table 7 summarizes the mean number of discussion messages that were accessed and posted by participants over the entire course and during an average week. This computation includes posts made by participants to the "general course info" folder and "informal discussion" folders mentioned above.

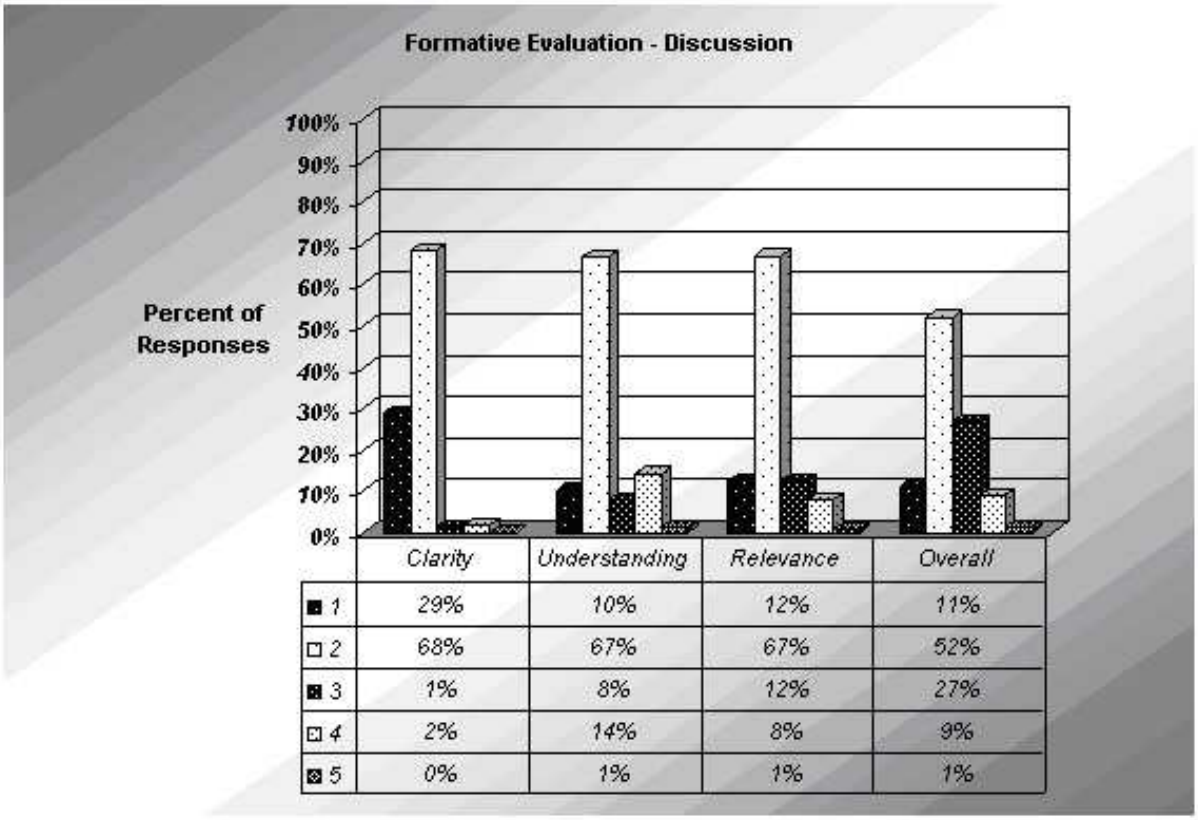
Table 7. Semester and weekly averages of messages accessed and posted by a typical course participant

Type of Action	Average number per participant during semester	Std Deviation	Average number per participant per week	Std Deviation
Messages Accessed	1,123	416	80	30
Messages Posted	121	39	9	3

In addition to these asynchronous message postings, participants indicated that a large volume of intra-course e-mail was exchanged throughout the course. The instructors did not have access to the numbers and content of e-mails sent between participants, but the lead instructor for the course accumulated a total of 455 e-mail messages from others in the course throughout the semester, an average of 33 messages per week.

Based upon the above numbers, it is obvious that a very large volume of messages, posts, and interactions occurred throughout the course. Of course, these numbers reflect only the quantity of messages that were shared, not the quality or contents of the interactions. To gain deeper insight into the quality and effectiveness of these student-to-student and teacher-to-student interactions, quantitative and qualitative data were obtained through the weekly course surveys. Each week, participants were asked four Likert scale items to evaluate the nature of that week's discussion. Table 8 provides a summary of those results compiled from weekly surveys over the entire semester.

Table 8. Formative survey results regarding discussion (n=169)



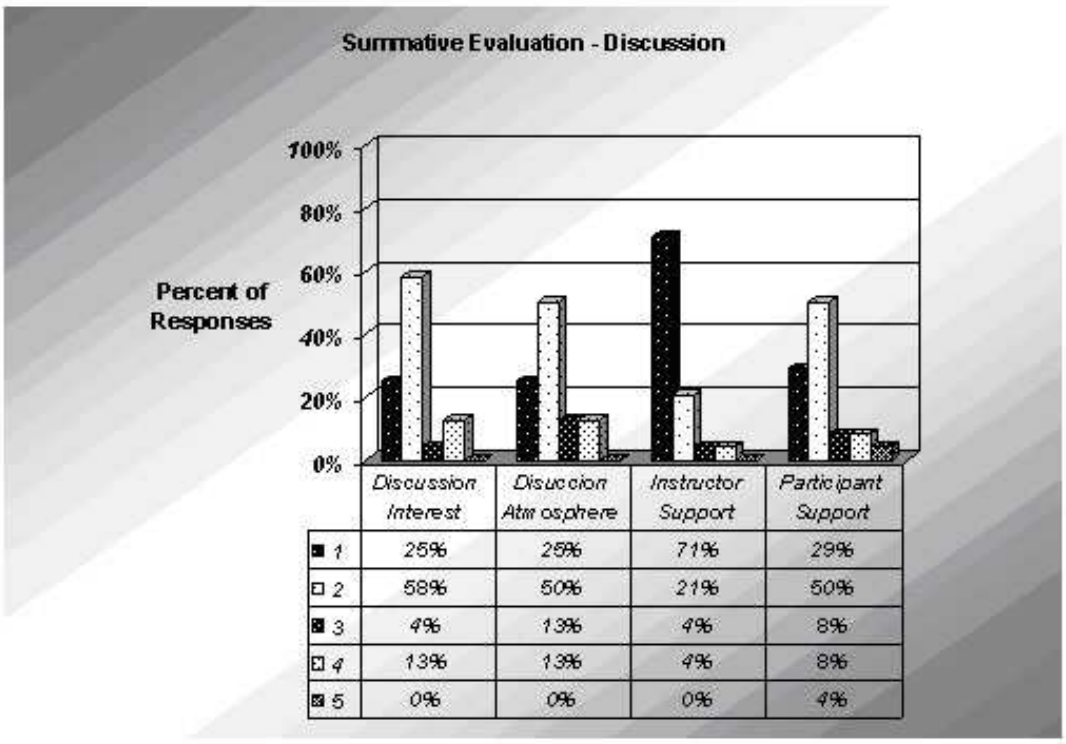
	Clarity	Understanding	Relevance	Overall
1	29%	10%	12%	11%
2	68%	67%	67%	52%
3	1%	8%	12%	27%
4	2%	14%	8%	9%
5	0%	1%	1%	1%

Category	Question	Median Value
Clarity	The discussion questions and expectations were clear this week. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*2* *agree*
Understanding	The discussion this week helped me to understand the topic at hand. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*2* *agree*
Relevance	The discussion this week was relevant and applicable to my classroom teaching experience. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*2* *agree*
Overall	Overall, I would rank the discussion this week as: *1-excellent, 2-good, 3-satisfactory, 4-poor, 5-disappointing*	*2* *good*

In comparing these survey results of Table 8 with those presented earlier regarding homework (Table 3) and reading (Tables 4 and 5), these discussion-related responses rank lower in terms of overall participant satisfaction. The rankings above are still positive, with 97% favorable responses regarding clarity, ~80% favorable responses regarding understanding and relevance, and 63% ranking the discussion overall as either excellent or good.

Evaluation data regarding discussions were also obtained from the final course survey. Table 9 provides responses to four Likert scale questions posed in the summative evaluation at the end of the semester.

Table 9. Summative evaluation results regarding discussion (n=24)



Category	**Question**	**Median Value**
Discussion Interest	I found the online discussions interesting. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*2 agree*
Discussion Atmosphere	The class atmosphere encouraged me to make contributions to the online discussions. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*2 agree*
Instructor Support	I felt supported by the instructor(s) as I developed my understanding of the course material. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1 strongly agree*
Participant Support	I felt supported by other participants as I developed my understanding of the course material. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*2 agree*

While these results are still favorable (with all questions rating over 75% favorable), the scores are weaker than similar summative scores related to homework, readings, and other elements of the class. Thus, we identified the asynchronous discussion area of the course as the most critical area for experimentation and improvement in future offerings of the course. Four open-ended questions were posed each week regarding participants' impressions of and suggestions for weekly discussions. In addition, an open-ended question on the final course evaluation asked, "How could the discussions or discussion format of this course been improved?" In evaluating this qualitative data, we have identified four areas that elicited multiple responses from participants: 1) discussion group size, 2) homogeneous versus heterogeneous groups, 3) nature of discussion topics, 4) building a collaborative community, and 5) level of discussion guidance. Each of these is discussed further below. In the final section on discussion evaluation, we discuss the effectiveness of having instructors rotate through discussion groups as facilitators.

6.1 Discussion Group Size

Some participants commented that group sizes of eight participants each felt too small to allow for rich discussion. Suggestions were made throughout the semester that the class instead be divided into two groups of 12 participants each. Interestingly, the intent of the instructors in having three small groups of eight was to force participants to contribute more and not lurk unnoticed in the background. One participant comment regarding group size provided unique insight into this issue.

> "Three groups are fine but when people aren't jumping in with only 8 of us it is slow going. On the other hand during weeks when everyone was posting a lot then 8 was a great number in a group." (Week 10)

While there may be no "optimal" group size, the above and other related comments emphasize the importance of holding participants accountable for contributing to the discussion in a timely and meaningful manner. Participants were expected to participate early in discussions and to provide at least two meaningful posts per week. Based upon participant comments, an even stronger expectation may be appropriate. To address this issue in the next offering of the course (fall 2002), participants will be required to contribute two posts for each discussion question posed. If there are two discussion questions assigned, participants are required to post four times, twice on each question. A comparison of survey responses between these two course offerings should be instructive. Another interesting study for the future may be to offer two versions of the course--one with three discussion groups and a concomitant section with two discussion groups--and compare discussion interactions between the two versions.

6.2 Homogeneous vs. Heterogeneous Groups

Participants also debated the heterogeneous groupings used in the course. Middle school teacher participants commented that they often felt intimidated by the level of discussion in their groups and requested more homogeneous groupings by "grade level taught." The quote below reflects this frustration.

> "As one of two middle school teachers grouped with high school physics and chemistry teachers, it was frustrating to try to discuss curriculum projects. We live in different worlds. I was extremely concerned that I didn't have a clue about subjects and topics that they were bouncing around like yo-yos, and that the things I needed to think about doing were obviously inconsequential to them." (Week 4)

This concern was considered by the course instructors, who decided to maintain the heterogeneous grouping throughout the semester. The instructors were hesitant to separate discussions into high school level and middle school level groups and judged that the benefits of having teacher participants from different teaching levels interacting together outweighed frustrations with the level of discussion.

However, some targeted attempts to mitigate the frustrations regarding heterogeneous groupings were made. First, instructors made several posts to encourage participants to be aware of and sensitive to the heterogeneous nature of their groups. Participants were encouraged to respond sensitively to other posts and to ask for clarification if concepts or topics became confusing. It was emphasized that questions expressing confusion were equally valid to posts describing answers and thorough understanding. Also, two discussion folders were added during Week 8, providing a pair of "informal" groupings for middle school teacher participants and high school teacher participants. These groups did not replace the formal discussion groups of the course, but provided an additional forum for participants to interact informally with participants teaching similar grade levels. Interestingly, only 15 posts were made to the middle school group and two to the high school group during the seven weeks they were available in the course.

6.3 Nature of Discussion Topics

Beaudin (1999) identifies four primary strategies for maintaining a focused asynchronous discussion: 1) carefully designed questions, 2) guidelines for learners to prepare their responses, 3) rewording of discussion questions if things go off topic, and 4) providing discussion summaries. Several comments from participants in this study echoed these same thoughts. In particular, participants emphasized the importance of the initial discussion questions posed each week. If the discussion question was too nebulous or broadly posed, some expressed a lack of confidence in their ability to appropriately address the goals of the week's discussion. Several participants also emphasized the importance of asking questions that reached at higher levels of Bloom's taxonomy (Brissenden, Slater, & Mathieu 2002). The quote below reflects this sentiment regarding the Week 6 discussion questions on the nature and distribution of the interstellar medium and molecular clouds and processes of interstellar and atmospheric reddening.

> "The discussion questions (this week) were more low-level--just knowledge-comprehension types. More at the synthesis-evaluation levels might have sparked more discussion." (Week 6)

Participant comments also highlighted disagreement regarding the intended purpose of class discussions. Throughout the course, several participants suggested that discussion questions should focus primarily on implementation and application of content material to classroom teaching situations.

> "This week's discussion was better. There was a good connection between science content and science pedagogy." (Week 5)

Meanwhile, others suggested that the discussion component of the course should primarily serve as a place for participants to discuss their misconceptions and confusion about course content and homework assignments.

> "The discussion is now more focused on specific questions from homework. I think before it was uncertain whether this was OK. Anyway, this has been helpful." (Week 10)

The above comments reflect the importance and the challenges inherent in formulating effective discussion topics. Multiple layers of consideration are involved in articulating and balancing goals associated with given discussions in an online course. To address the issues described briefly above, we provide the following instructor reflections, along with our plans for future course offerings.

- *Stating discussion goals explicitly:* The initial weekly discussion description should emphasize and clearly state the ultimate goals of the discussion. Participants should be given thought-provoking questions that provide clear paths for launching and continuing the discussion. Facilitation following this initial posting is essential, but attention to the initial layout of discussion goals and structure can go a long way toward rich discussion throughout a given week. In the next offering of this course, discussion goals are stated explicitly as part of "Weekly Goals," and a weekly timeline is provided in the discussion description regarding expectations for participant posts. Both instructor and participant facilitators will then help guide the discussion toward these specific goals.
- *Use of Bloom's taxonomy:* Bloom's taxonomy can be used to ensure multiple layers of questioning throughout weekly discussions. Kinzie et al. (2002) discuss the use of Bloom's taxonomy as part of discussion facilitation and provide an online tutorial for helping online course developers integrate this taxonomy into course discussions (http://onlinelearn.edschool.virginia.edu/discuss/). Specific attention will be directed in the fall 2002 course offering of the *Invisible Universe Online* to address this issue. As part of the course, participants will be introduced formally to Bloom's taxonomy and evaluated based upon where participant responses lie on this continuum.
- *Integration of content knowledge and pedagogical knowledge:* In offering enhancement programs for teachers, it is important to integrate both content knowledge and pedagogical knowledge through a balance of discussion topics addressing both of these essential elements of effective teaching. Attempts were made throughout the first offering of the course to diversify discussion topics to include both science content and pedagogy and instructional issues to address participant interest in both of these elements. A colleague, Dr. Edward Prather, plans to focus his current offering of an online astrobiology course around the integration of science content, pedagogical knowledge, and contextual knowledge into Pedagogical Content Knowledge (PCK) (Gess-Newsome 1999) centered on astrobiology. Attention to both science content and pedagogy issues is essential in the development of teacher enrichment programs.

6.4 Building a Collaborative Community

Specific attempts were made in the course to build a community within the discussion groups (Schrum 2002; Weisenberg & Hutton 1996). Several previous studies have emphasized the importance of community building in the online environment. In addition to helping increase participant retention rates, building a sense of community can motivate participants through feelings that they are part of a group to which they need to contribute. Specific examples of this included assigning collaborative group projects, limiting discussion group sizes to create stronger group interaction, asking participants to post biographies, and attempting an ice-breaker activity titled "Two Truths and a Lie." In this activity, participants provided three statements about themselves, two of which were truthful and one of which was false. The other group members then guessed which of the three items was the "lie."

Despite these purposeful acts to build community, open-ended survey responses reflected a sentiment that there was still a desire for even more interaction and connectivity among group members. Although the sentiment was not pervasive, comments and suggestions like the following did appear occasionally on weekly evaluations throughout the course.

> "I also do not feel that we have gotten to really know the people in our groups. I liked the study buddy idea from other classes where you are assigned people to meet in your group during the week and they are the ones that you can seek help from. This gave a little tighter feeling to the group and you did get to meet and talk with others on a more personal level." (Week 7)

In addition, analysis data from the summative course evaluation presented in Table 10 above reveal that participants felt more supported by the course instructors than they did by other participants and the class atmosphere. In an ideal collaborative community, we imagine that participants would feel as much or more support from their fellow participants as they would from the instructors. The foregoing discussion regarding homogenous and heterogeneous grouping may have factored into these sentiments. Brown (2001) identifies commonality as one of the first requirements for participants to begin interacting. More opportunities to help participants recognize their commonalities despite differing teaching environments may have been advantageous. She also acknowledges that while an instructor can facilitate opportunities for community building, "community did not happen unless the participants wanted it to happen." Following her suggestions, specific attention will be given in the future offerings of the *Invisible Universe Online* to an explicit discussion of the elements of a strong online community.

Suggestions are presented below for consideration by other online course developers attempting to address the important issues centered around creating a collaborative community.

- *Assigning initial collaborative groups:* For the first collaborative project, participants were instructed to form their own collaborative groups. Expressing that it was frustrating and inefficient to have to find partners for the project early on in the course, participants suggested that instructors should have assigned collaborative groups for this first project.
- *Starting weekly discussions midweek instead of Monday morning:* Some participants felt that starting discussions on or before the weekend would provide more active involvement and engagement, instead of participants waiting until the end of their busy weekend to contribute posts to the discussion. Course instructors will experiment with this idea during the fall 2002 offering of the course by running each week from Thursday morning through Wednesday evening.
- *Making discussion topics two weeks long instead of one week long:* This suggestion was based upon attitudes that participants were just getting at the heart of a discussion topic when they had to drop the topic and pick up on a new discussion. Experimentation with the duration of discussion topics will be attempted in future course offerings.
- *Carefully structuring and implementing ice-breaker activities:* Participant comments regarding the "Two Truths and a Lie" activity described above expressed their support of the ice-breaker idea but criticized its implementation. The instructors spread the activity out over too long of a period; participants were still guessing about their peers' lies into Week 6 of the course. Many participants felt that the activity should have been concentrated in the first two weeks of the course. This suggestion is being implemented in the next offering of the course.

6.5 Levels of Discussion Guidance

A final issue related to the discussion component of the course involves the level of instructor facilitation and discussion guidance. Written comments, similar to the quote below, expressed satisfaction with the level of instructor participation and leadership within discussions.

> "I enjoy the discussions very much. It's good to get the input from other teachers and to offer my own input. I think the instructors are getting in at just the right time and to the right extent." (Week 2)

A question that online discussion leaders continually grapple with is when and how much to contribute to participants' discussion versus how much to allow the discussion to flow on its own. Participants expressed opinions spanning the spectrum of opinions related to this issue. Some participants felt that an instructor should only enter into conversations if they are going significantly off-track or if misinformation is propagated. Others felt that there could never be enough instructor involvement, and "the more instructor input, the better."

Participant comments seemed to reflect an interest in more guided discussion with more prodding, questioning, and probing by both instructors and participants. Participants also expressed a need for confirmation that instructors would clarify or point out blatant content errors or misinformation, as expressed in the following comment.

> "I believe we need instructor input as to what was correct and to answer questions that went unanswered." (Week 6)

Several suggestions made throughout the semester regarding ways to provide additional guidance to discussion are summarized below.

- *Weekly discussion summaries:* Several participants suggested that some type of wrap-up activity for each discussion topic would be valuable in alleviating the feeling that some topics dropped out of conversation due to attrition. One suggestion to deal with this was for different participants to be assigned each week to wrap up and summarize that week's discussion. This strategy will be implemented and studied in the fall 2002 offering of the course.
- *Participant discussion facilitators:* Another suggestion was for various participants to be assigned as discussion leaders throughout the course. These discussion leaders would be responsible for researching their topic ahead of time and helping to guide the discussion for that week. This participant involvement would potentially free up the instructor to serve as a sounding board and as an expert who could reflect meaningfully on a topic without having to "lead" the discussion. As the participant comment below suggests, participants may also feel compelled to be more involved to support participant facilitators.

  > "I think that rotating the role of discussion moderator would have encouraged more participation in the discussion each week. It was very easy to put this part of the course off. By rotating the discussion leaders, each participant will gain empathy of the others and will take a more vested interest." (Final Course Evaluation)

  It is important that good facilitation be modeled prior to assigning participants to take on this role, however. In the next offering of the *Invisible Universe Online*, course instructors will model facilitation techniques during the first weeks of the course. During the last eight weeks of the course, participants will each be assigned to lead one week of discussion. Participant facilitators will be given a detailed set of objectives and guidelines to aid them in guiding the discussion. In addition, course instructors will continue to participate in discussions and provide support and advice.

- *Stimulating discussion early in the week:* Several participants commented that several discussion topics often took time to get off the ground. One suggestion offered was to assign certain students each week to serve as "first responders" responsible for kicking off the conversation from the beginning.

  > "It would have been much more helpful to debate areas that we found troublesome. One way to do this is to assign first responders each week that must start the discussion rolling. This insures that the discussion topics are relevant to student needs." (Final Course Evaluation)

  While this suggestion is not being implemented in the next offering of the course, discussion guidelines have been implemented to emphasize that participants need to provide different "types" of discussion contributions. Type 1 responses involve initial responses and ideas related to the discussion topics posed. Type 2 responses involve thoughtful responses to contributions by other group members. Specific deadlines will be posed for Type 1 responses in an attempt to stimulate discussion earlier in each week.

- *Timing of discussion questions:* A final suggestion was that more focused discussion questions be fed out over the course of an entire week rather than posting broad questions at the very beginning of the week. Some felt that by asking all of the questions at the very beginning of the week, discussions became an "answer these two questions" written assignment rather than spawning new and engaging conversations. A corollary to this suggestion was the idea that multiple discussion topics for a given week could be introduced at different points throughout the week--the first discussion question being introduced at the beginning of each week, the next during the middle of the week, with a wrap-up question for the end of the week. These suggestions have been considered and will be experimented with in future offerings of the course.

6.6 Rotation of Course Instructors Through Discussion Groups

A structure of rotating instructors as discussion leaders through the three discussion groups from week to week was utilized during the first course offering. This strategy was implemented for two reasons: 1) to allow instructors to focus more coherently on the discussion of only eight participants rather than the confusing dialog of 24 participants; and 2) to ensure that all participants had an opportunity to interact with the different facilitation approaches of the three instructors.

A survey question was posed at the end of the course to address the effectiveness of this strategy. The question was posed as to whether participants felt that the rotation strategy "was an effective method for discussion group facilitation." Four participants strongly agreed, 14 agreed, 2 had no opinion, 3 disagreed, and 1 strongly disagreed. The mean value from this question was 2. Additionally, an attempt was made to group survey results by instructor to determine if the three facilitators scored significantly differently on survey questions regarding discussions. There was no significant difference in participant perceptions and attitudes toward discussion as reported on weekly surveys based upon which instructor was facilitating the discussion.

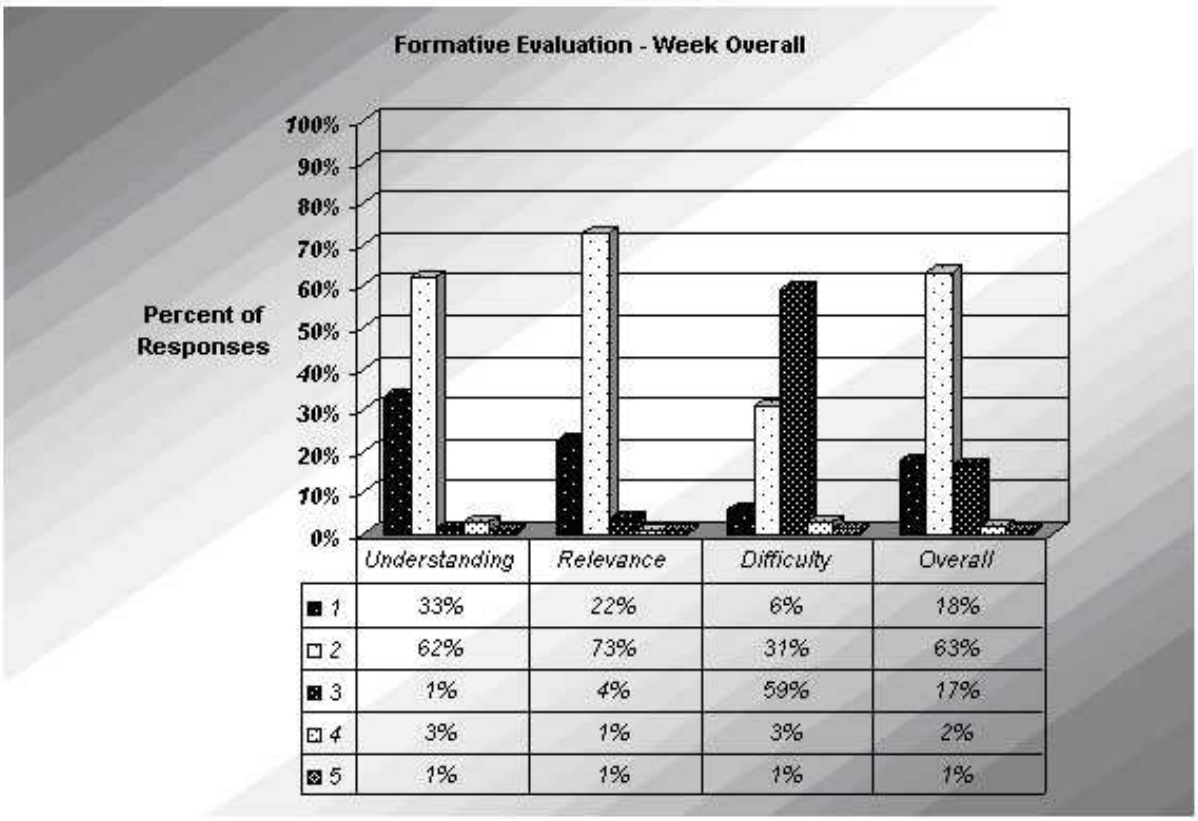
From an instructor perspective, monitoring only eight rather than 24 individuals each week was significantly less burdensome. Course instructors found it easier to concentrate and focus on the specific needs of the participants they were working with and to ensure that all questions and issues were being addressed within that group. Also, there was less confusion among instructors regarding who was responsible for which parts of discussion monitoring than there would have been if all three instructors

had tried to keep track of all 24 participants at once. If resources allow, we strongly encourage online instructors to experiment with this strategy of group facilitation.

7. COURSE EVALUATION SUMMARY

The above sections have discussed evaluation data from specific components of the course: homework, readings, and discussion. In addition, data were collected regarding attitudes and opinions of the course in general. These data were collected in the form of four weekly agree/disagree items on the overall course structure, several open-ended weekly questions regarding the course, and a final course evaluation. Table 10 provides the compiled data from the 11 administered weekly surveys and demonstrates that the course was highly successful.

Table 10. Formative survey results regarding the course (n=169)



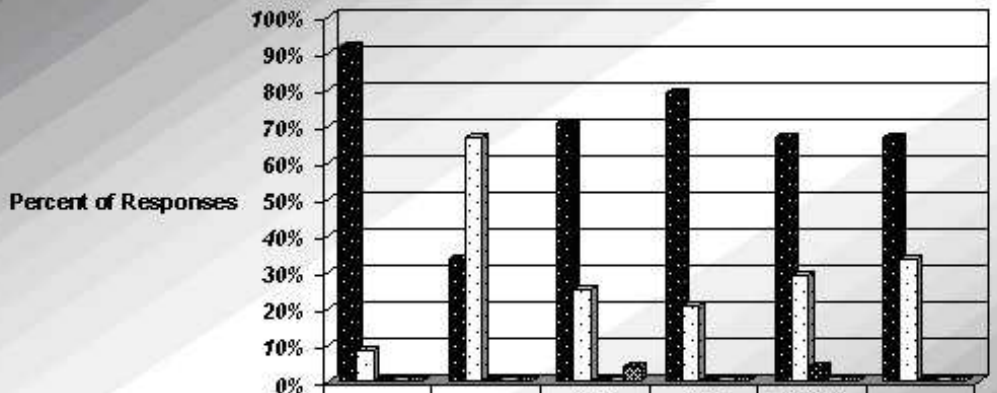
	Understanding	Relevance	Difficulty	Overall
1	33%	22%	6%	18%
2	62%	73%	31%	63%
3	1%	4%	59%	17%
4	3%	1%	3%	2%
5	1%	1%	1%	1%

Category	Question	Median Value
Understanding	Overall, this week helped me understand the topic at hand. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*2* *agree*
Relevance	Overall, this week was relevant and applicable to my classroom teaching experience. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*2* *agree*
Difficulty	The difficulty level of the course this week was: *1-significantly high, 2-high, 3-average, 4-low, 5-significantly low*	*3* *average*
Overall	Overall, I would rank this week as: *1-excellent, 2-good, 3-satisfactory, 4-poor, 5-disappointing*	*2* *good*

In addition, several summative questions were asked at the end of the semester regarding both participant learning and impact on their teaching. The results of these survey questions have been divided into two categories below. Table 11 provides responses regarding content knowledge increase and interest generated by the course. Table 12 shows responses regarding the impact of the course on participants' professional needs and teaching.

Table 11. Summative survey results course content (n=24)

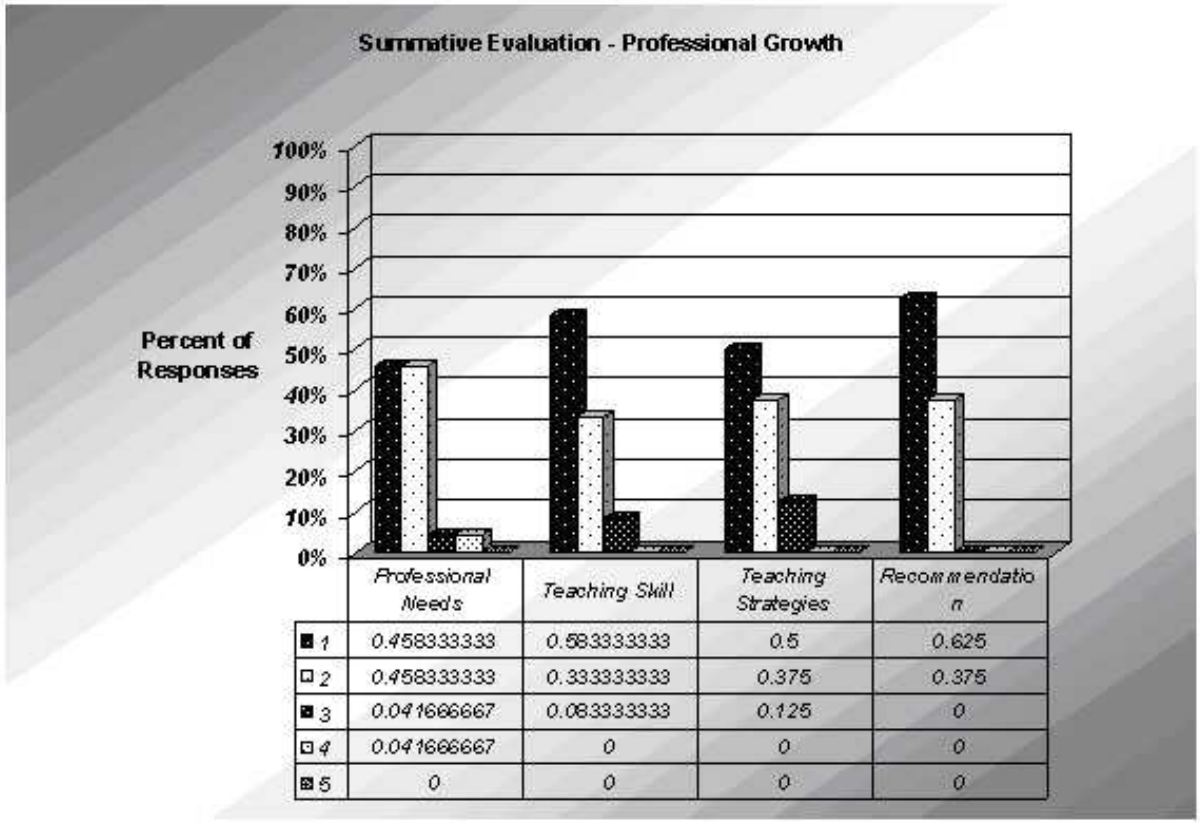
Summative Evaluation - Content



	Interesting Content	Understanding	EM Knowledge	MW Astronomy Knowledge	Origins Knowledge	Resources
1	92%	33%	71%	79%	67%	67%
2	8%	67%	25%	21%	29%	33%
3	0%	0%	0%	0%	4%	0%
4	0%	0%	0%	0%	0%	0%
5	0%	0%	4%	0%	0%	0%

Category	Question	Median Value
Interesting Content	The content of the course was interesting to me. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1* *strongly agree*
Understanding	I usually understood the content being taught in the course. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*2* *agree*
EM Knowledge	This course increased my content knowledge of light and EM radiation. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1* *strongly agree*
MW Astronomy Knowledge	This course increased my content knowledge of multiwavelength astronomy. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1* *strongly agree*
Origins Knowledge	This course increased my content knowledge of astronomical origins. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1* *strongly agree*
Resources	This course furthered my knowledge of resources in the subject area. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1* *strongly agree*

Table 12. Summative survey results regarding professional development (n=24)



	Professional Needs	Teaching Skill	Teaching Strategies	Recommendation
1	0.458333333	0.583333333	0.5	0.625
2	0.458333333	0.333333333	0.375	0.375
3	0.041666667	0.083333333	0.125	0
4	0.041666667	0	0	0
5	0	0	0	0

Category	Question	Median Value
Professional Needs	The course seemed to be designed with my professional needs in mind. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*2 agree*
Teaching Skill	This course improved my professional skills in this subject area. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1 strongly agree*
Teaching Strategies	This course taught me new strategies for educating others about this subject area. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1.5 agree – strongly agree*
Recommend-ation	I would recommend this course to my colleagues. *1-strongly agree, 2-agree, 3-no opinion, 4-disagree, 5-strongly disagree*	*1 strongly agree*

For all of these questions, participants primarily agreed or strongly agreed that the course was interesting, understandable, instructive, and beneficial to participant teaching. Finally, all participants either strongly agreed (15 participants) or agreed (9 participants) that they would recommend the course to their colleagues.

7.1 Professional Development and Classroom Impact

In addition to results presented in Table 11, several open-ended questions were posed in the summative evaluation at the end of the semester. Two of these questions surveyed specific ways in which the course directly impacted participants' teaching and what participants gained from the course in terms of overall professional development. Responses to these questions were particularly enlightening in terms of what participants felt they gained most from this distance-learning experience.

With regard to the question about what participants gained from the course, the majority of respondents identified the increased content knowledge in astronomy, electromagnetic radiation, and multiwavelength astronomy as the most direct impact on their teaching. Two additional benefits of the course were: 1) the relevance of course assignments and activities to their teaching; and 2) the strong integration of additional Web resources into the online class. These results are summarized in Table 13.

Table 13. Summary of responses to survey question regarding impact of course on teaching

Ways course will impact participant teaching	Number of Respondents
Increased content knowledge	14
Projects and activities applicable to classroom teaching	8
Use of additional Web sites	5
Increased confidence and interest in lesson planning	1
State curriculum will limit impact	1

The sample responses provided below from this question regarding teaching impact demonstrate the importance of including both strong science content and pedagogy, and curriculum and instruction issues in the course.

> "I am using many of the activities and resources in my classes. Often, we would discuss something one week in this course and it would fit in very nicely with what I was currently teaching. I am using one of the lab activities in the physics course I teach now. I am working on ways to integrate this content into the chemistry classes I teach too." (Final Course Evaluation)

> "I have gained so many ideas and resources, I am already teaching my group at a level far beyond what I was before." (Final Course Evaluation)

> "Setting up each of the projects has given me lesson ideas. I have gained an abundance of resources to use in my science classes." (Final Course Evaluation)

Similar results were obtained from an evaluation question targeting what participants gained from the course in terms of overall professional development. The question posed to elicit these responses was: "In terms of your overall professional development, what have you gained from this course?" Again, the majority of respondents commented on increased content knowledge as the primary benefit. Other responses included credit gained toward re-credentialing, additional online resources, additional teaching resources, confidence in lesson planning, experience with distance learning, stronger familiarity with the NRC National Science Education Standards, increased appreciation for the integration of multiple scientific disciplines in astronomy, and increased appreciation for "invisible astronomy." The selected quotes below from this open-ended question illustrate some of these responses.

> "A better understanding about how we detect, measure and thus create current theories." (Final Course Evaluation)

> "A HUGE LOT! The depth of my content knowledge has greatly increased. This is so important in adding to the general class conversation. But, I’ve also walked away with some very specific lesson ideas or teaching techniques." (Final Course Evaluation)

"I have learned how to integrate Internet resources into the curriculum. I have also learned how to develop activities and material that will allow the students to really apply the information that they learn." (Final Course Evaluation)

8. CONCLUSIONS

As presented in this paper, the development and implementation of this course has provided valuable insights and implications for the astronomy education and distance-learning communities at large. We have attempted to emphasize the following "lessons learned" through our efforts with this course:

1. Including both formative and summative evaluation components to distance-learning courses
2. Providing both traditional textbook-based activities and interactive Web resources for course readings and assignments
3. Including curriculum projects, "classroom ready" activities, and other elements to the course that challenge participants to integrate their learning into their teaching situations
4. Experimenting with various group sizes and attributes for group discussion
5. Rotating instructor facilitators through different groups on a weekly basis
6. Posing concise yet rich discussion questions that allow participants to engage at multiple levels of thinking
7. Continuing to create and study ways of forming and enhancing collaborative communities within online learning groups
8. Exploring strategies for guiding and facilitating online discussions

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 background and understanding central to the goals and objectives of the program. The following participant comment reflects the potential for success in this venture; when asked, "Is there anything else we should know in evaluating this course?", the participant responded:

"Only that this course was much better than many face-to-face courses that I have taken, and truly illustrated the strength of online discussion and work among educators scattered around the country (and could just as well be from around the world). Thanks for the great effort and great resources!" (Final Course Evaluation)

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 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.

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