Learning Science Online:

A Descriptive Study of Online Science Courses for Teachers

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Report

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Abstract

Online education is a rapidly growing phenomenon for science teachers. Using a sample of 40 online science courses for teachers offered during the 2004-2005 academic year, the Learning Science Online (LSO) study asks: Who are the students are in these courses? Who are the instructors? and What does science teaching and learning looks like in these courses? This research is unique in that it is the first aggregate study of online science courses from a wide variety of educational programs. Descriptive analyses suggest the typical instructor of these courses mirrors the science professoriate in many ways. The typical student is representative of the majority of high-school science teachers, although more likely to be in the early stages of their careers than the average teacher. The science teaching and learning utilized in these courses included frequent use of online discussions, Web-based readings, and images, while the use of more common instructional methods varied across courses.

Introduction

Online education is a rapidly growing industry that not only is well suited to many teachers' lifestyles, but also offers interesting new opportunities for teaching and learning science. The growth rate of online education in 2003-2004 (18 percent) was a factor of ten greater than that projected by the National Center for Education Statistics for the U.S. postsecondary student population on the whole for the same period (NCES 2005) and has been projected to continue at similar rates (Sloan 2004). In Fall 2005, a total of 3.2 million post-secondary students in the US studied online, which represents 17 percent of the post-secondary population and a growth rate of 35 percent from the year before (Sloan 2006).

Scarafiolti (2006) notes that online education addresses issues of geographical remoteness, limited offerings by institutions, and the complex lives of students. The teacher professional development community discovered early that online programs could offer "anytime, anywhere" education for working teachers. In the early 1990s, programs such as National Teacher Enhancement Network and Project Datastream were using the Internet for science teacher professional development, and today there are entire master's degree programs online for science teachers. Teachers take these courses not only to improve their content knowledge, but also for professional certification and advancement, which is becoming an increasingly important aspect of a teaching career.

The role of online learning environments as a tool for science teacher professional development has expanded at such a rate that the dearth of even the most descriptive knowledge about these online environments is startling. There are relatively few studies examining online science learning (Scanlon 2004) and none to date that have examined more than a few courses. To begin addressing the gaps in research, the Learning Science Online project studied 40 online science courses for teachers, asking:

- Who are the students in online science courses for teachers?
- Who are the instructors in online science courses for teachers?
- What does science teaching and learning look like in these courses?

The emphasis in LSO is a description of all online science courses for teachers, rather than the evaluation of individual courses.

Who are the students in online science courses for teachers?

The rapid growth of online learning for teachers raises the question of whether or not there is equity and broad participation in this new phenomenon. Garrison and his colleagues (2004) point out that online learners have new responsibilities and privileges including knowledge about, skill with, and acceptance of the technology; new modes and amounts of communication with instructors and peers; increased levels of learner self-direction; and a new learning environment that is often without restriction on time and location. These adaptations may come more easily for some students than others.

Do students in online science courses for teachers reflect the broader teaching population, or are these courses reaching an audience of teachers different from the audience reached by other forms of professional development?

The demographics in online science courses for teachers are likely affected by the overall demographics of the teaching force itself and its members' participation in professional development. Two-thirds of all teachers in the U.S. work in elementary schools, two-thirds are white non-Hispanics, and half are females, with the percentage of minority and female teachers higher in elementary than in secondary and combined elementary/secondary schools (NCES 2005, 2006). When considering only high-school science teachers, only about 10-15 percent are non-white and 30-50 percent are women, depending on the specific discipline (CCSSO 2005). Minority teachers reported participating in more professional development designed to improve instruction than their white counterparts did, but both groups were equally likely to participate in professional development focused on building content knowledge (NEA 2003). Teachers take online science courses not only to improve their content knowledge, but also for professional certification and advancement. Professional development is becoming an increasingly important aspect of a teaching career. For example, as of 2004, all NY state teachers must complete 175 hours of professional development every 5 years in order to maintain certification (NYSDoE 2006). Many other states require a professional development plan from all teachers outlining their plans for coursework and workshops for multiple years in advance. Online learning is poised to become a vital component of these plans.

Who takes online professional development is partly influenced by who has ready access to the Internet. Surveys conducted by the Pew/Internet and the American Life project in April 2006 show that Internet penetration among adults in the U.S. has hit an all-time high of 73 percent of respondents, with 42 percent of those having broadband connections at home. Both of these figures show a marked increase since 2005. Because of the media-rich content often used, online courses are most practical with high-speed, broadband Internet. Horrigan (2006a) notes that the majority of people who have posted content online, which would be necessary in most online courses, are home broadband users.

The typical Internet user is 18-29 years old, but given all users it is only for those over 65 where the percentage of users drops significantly (Fox 2005). In relation to household income and education, it is the lowest-income adults with less than a high-school education who are much less likely to have Internet access. More than 80 percent of people with incomes greater than $30,000 go online, versus 53 percent of those whose income is below $30,000 (Madden 2006). Similarly, only 40 percent of adults who have less than a high-school education use the Internet, while at least 64 percent of their more-educated counterparts go online—and a college degree raises that to 91 percent. Because of the high education level of teachers, the digital divide in computer usage is less likely to be shaping participation in online courses.

Growth in broadband adoption has been very strong in middle-income households, and particularly fast for African-Americans and for those with low levels of education (Horrigan 2006a). While Internet access is still lower for people in rural areas, the gap between their Internet use and that of their urban counterparts narrowed by a factor of two since 2003. For broadband Internet, however, the gap is still at 15 percent (Horrigan 2006b).

Who are the instructors in online science courses for teachers?

Online courses also offer fresh opportunities for faculty that may lead to a new breed of instructor that diverges from traditional science or science education faculty. The same matters of convenience and proximity that are argued as an advantage for students apply for instructors as well, and online courses may attract instructors who would not ordinarily consider teaching in a traditional face-to-face setting. Online courses also offer new and interesting roles for instructors as instructional designers, content experts, and community builders.

Do instructors in online science courses for teachers represent the typical science professor, or are these courses tapping a different group of potential instructors?

The typical science professor in the U.S. is male, Caucasian, and has earned a Ph.D. in science (NCES 2005). The typical full-time faculty member at a postsecondary institution is 50 years old (AASCU 2006). Online science courses for teachers differ from traditional courses offered by university science faculty in two distinct ways—they are online, and they are for teachers. These factors may serve to diversify the field of instructors for online courses by increasing access to a broader population, or possibly may narrow the field if teaching online is not seen as attractive to many faculty.

Instructors may be reluctant to begin teaching an online course for several reasons. In their survey of faculty and division chairs at a community college, O'Quinn and Corry (O'Quinn 2002) identified factors that may deter faculty from teaching online, including lack of professional prestige, delivery method used, change in faculty role, and lack of monetary support. If online courses are not considered part of the regular teaching load, or do not attract potential graduate students, it is possible that tenure-track professors will not see them as a priority. The perceived learning curve for online course environments may pose a barrier for some faculty, as could concern about the possible need to develop a large block of new materials. Online course materials are often designed en masse and then handed over to a Web developer to upload into the course environment system. This may appear a larger burden than "on-the-fly" preparation often associated with face-to-face courses. Interacting online may be seen to increase the workload, particularly with asynchronous discussions, which can seem to be a task without boundaries. Some instructors may feel that they must respond to every post or use the information provided in students' posts to understand student thinking in ways that would not typically be accessible in face-to-face courses. Finally, the compensation for teaching online courses may not be deemed commensurate with the amount of effort instructors believe they will spend teaching the course.

Instructors in a science course for K-12 teachers have a different task from instructors of a graduate course in their scientific degree program. Students of the former are not necessarily future researchers in the field and need a more general understanding of the subject matter. Teachers' understanding must be conceptually sound so that they not only deliver accurate information to students, but also build a framework within which students construct ideas. Science teachers must be taught how to model ways of inquiry, reasoning, and discussion that are consistent with scientific behavior, but that do not require the expertise of a specialist. This is a demanding task and requires a combination of talents, including not only science content expertise, but also an understanding of the K-12 classroom and of how children and adults learn, as well as a general ability to communicate and model their scientific ways of thinking. This may be of less interest to some faculty, particularly if it is not rewarded by their departments.

Palloff and Pratt (1999) note that online instructors must be trained to use the technology and also the methods of content delivery that are suitable for the new learning environment. In a synthesis of best online practices, the Sloan consortium reported a number of programs preparing faculty for designing and teaching in online learning environments (Allen 2005). These programs ranged from self-contained tutorials to interactive face-to-face and online seminars and courses. Even though the actual Web development may be done by support staff, instructors need to identify and recognize the strength and weakness of technologies, and use the new medium to its fullest potential to promote learning. Instructors need to build community and deliver content without many of the traditional modes of face-to-face lecture or discussion, a capacity identified in online communities of inquiry as "establishing a teaching presence" (Garrison 2000).

What does science teaching and learning look like in these courses?

Online learning can take many forms. Perhaps the simplest is the placement of teacher notes, readings, or video on the Web to replace a classroom lecture. Added to that may be many supplements: assignments, interaction through synchronous or asynchronous communication tools, interaction with computer animations and simulations, and offline activities such as reading, field work, and hands-on experimentation, to name a few. Online learning may be used to replicate a traditional face-to-face classroom, or it may be used to employ unique opportunities presented by the new environment.

What types of instructional methods are used in online science courses for teachers, and how do they compare to the types of practices called for by research and national standards?

A large body of literature describes online learning environments as potentially conducive to learning models that foster critical thinking, reflection, knowledge construction, and active participation (Dede 2002; Bullen 1998; Collis 2001; Harasim 1995). Many facets of these environments support a learning model of social constructivism, where learners work in a community to co-construct knowledge. This community of practice is made up of members of a novice-expert continuum. All learners can have a legitimate role no matter where on the novice-expert continuum they lie (Lave 1988) so that all can be included in a manner suited to their own abilities. Through interaction and exchange of ideas, individual learners are challenged to reflect on their own and others' perspectives, through which they advance their own thinking. Science teachers have a unique position in a novice-expert continuum in science learning. They are not typically the experts that scientists would be, and often they can be novices in certain domains of science. However, when they are back in the classroom, they are expected to model and coach their students (who are then the novices) along the continuum.

The National Science Education Professional Development Standards promotes science teacher professional development that immerses teachers as students within a scientific community of practice. The standards stipulate that "science learning experiences for teachers must:

- Involve teachers in actively investigating phenomena that can be studied scientifically, interpreting results, and making sense of findings consistent with currently accepted scientific understanding.
- Address issues, events, problems, or topics significant in science and of interest to participants.
- Introduce teachers to scientific literature, media, and technological resources that expand their science knowledge and their ability to access further knowledge.
- Build on the teacher's current science understanding, ability, and attitudes.
- Incorporate ongoing reflection on the process and outcomes of understanding science through inquiry.
- Encourage and support teachers in efforts to collaborate." (NRC 1996 p. 59)

In a community of practice, the role of the instructor is changed from more traditional lecture-oriented teaching to a guiding or mentoring role (Paloff 1999). Instructors model ways of knowing, doing, and communicating for students, as they also coach students toward adopting these ways for their own. This approach is well suited for professional development courses for teachers, where the relationship between the instructor and students must shift to acknowledge the professional status of the teacher-learner.

Asynchronous discussion boards provide unique opportunities for community learning due to their text-based, asynchronous, and archivable nature. Written discussions force students to make their thinking visible to themselves and others by having them craft their ideas in writing. This inherently raises students' level of interaction with the content at hand. In addition, students' writing is typically available for review long after the time of posting, so it becomes a source of reflection or referral for the learner and others. The asynchronous nature of discussion boards builds in natural "wait-time." Learners can respond to questions or comments whenever they are comfortable in doing so and can pace themselves as they read other students' ideas before articulating their own.

The potential of online discussions for science learning are highlighted in Harlen and Altobello's (Harlen 2003) study of an online master's program in science education created by TERC and Lesley University. They compared one online course to an analogous face-to-face course to study the frequency of students' reflections on their own learning process, teaching strategies, and the nature of the science content learned. The analysis of online asynchronous discussions and videotape of analogous classroom discussions showed that the online participants demonstrated more reflection and articulation about their own science learning and the process of inquiry than did their on-campus counterparts. This study also found a greater change in science understanding (as measured through pre- and post- thought experiments) in the online participants, and they were shown to have more confidence in teaching inquiry than the on-campus participants did.

Methodology

Learning Science Online (LSO) is a mixed-method longitudinal study of online science courses for K-12 teachers offered during the 2004-2005 academic year.

Participants

Four nested units of analysis are included in this study—institutions, courses, instructors, and students. Participants at all levels were informed that the purpose of this study was to learn about the nature of all online science courses for teachers rather than the evaluation of their specific course. The participation rates and characteristics of each unit of analysis are described below.

Institutions

Six programs hosted the online courses in this study. Of the six programs, Programs 1-3 were administered by educational nonprofit institutions and Programs 4-6 were administered by universities. Among the university programs, academic departments offered these courses—one program was based in a science department, one in a continuing education program, and one in a distance education program. Table 1 provides a profile of each program in terms of the number of courses participating in this study, whether the program is affiliated with a master's program, the amount of credit offered for the course, the target audience of teachers, and the duration of the courses.

The university-based programs accounted for 28 of the 40 courses in this study (70 percent), with 43 percent from Program 6 alone. Two of the three university-based programs and none of the nonprofit education programs were affiliated with a master's degree program. Courses in these programs could count toward a master's degree. The courses in this study could be taken for a maximum of 1-4 credits, depending upon the program and specific course. All of the courses in the nonprofit programs were offered for varying amounts of credit, whereas the courses offered by universities were not. The programs reported half of the courses (21 of 40 courses) as targeted toward teachers at all grade levels. The remaining courses were targeted toward middle and high school science teachers. Finally, the courses offered by nonprofit education institutions tended to be of shorter duration than courses offered by universities.

Table 1: Description of program by number of courses, maximum number of credits, whether or not affiliated with a master's degree program, and the grade level and duration of the courses.

Program Characteristics	Program 1	Program 2	Program 3	Program 4	Program 5	Program 6
Number of courses in study	4	7	1	1	10	17
Maximum number of credits	4 credits	2 credits	3 credits	1 credit	2-3 credits	3 credits
Affiliated with Masters degree program	No	No	No	No	Yes	Yes
Audience of courses						
Elementary school teachers	Yes	Yes	No	No	Yes	No
Middle school teachers	Yes	Yes	Yes	Yes	Yes	No
High school teachers	Yes	Yes	No	Yes	Yes	Yes
Duration of courses in program	5-6 weeks	5 weeks	17 weeks	5 weeks	14-16 weeks	12 week

NOTE: *"Audience of course" refers to the grade level focused on as identified by the host institution. "Duration" calculations are based on the start and end dates provided by the host institution.*

Two programs, one university and one nonprofit, are no longer offering the courses in this study. The remaining four programs vary in their level of self-sustainability. The online programs at the nonprofit institutions depend upon the support of their parent organization. At the universities, one online program is completely self-sustainable and profitable while the other is still supported through grants.

Courses:

To ensure a sufficient level of uniformity, courses were sought that met the following criteria:

- At least one graduate credit is offered for the course;
- Science content is the primary focus of the course (as opposed to instructional methods);
- Course requires some interaction among students and between instructor and students, which occurs primarily, but not necessarily exclusively, online via discussion boards, e-mail, chat rooms, or other electronic media (excluding TV monitors).

We selected graduate-level courses due to the small number of online undergraduate science courses available for teachers. We selected courses that emphasized science content over instructional methods to ensure some similarity in the online learning being studied, although some courses included instructional methods. Finally, to distinguish the courses in this study from (a) hybrid courses with roughly equal proportions of face-to-face and online interaction and (b) other forms of distance education, we selected courses where the majority of the interaction occurs online.

We located 60 courses meeting these criteria. Eight courses were already participating in an in-depth evaluation. The sponsoring programs of these eight perceived participation in the LSO study as too great a burden for their instructors and students, and they were not contacted. The instructors of the remaining 52 courses were contacted for inclusion in this study and all agreed to participate. Forty-five courses (87 percent) have complete data. Of the 45 courses that completed the study, there were five courses that were offered more than once by the same instructor. To avoid giving those courses more weight in the analysis, the duplicate courses with the highest student response rates were retained. A total of 40 unique courses are included in these analyses.

Seven courses did not complete the study—three courses were dropped due to low enrollment, one instructor reported their workload was too heavy to continue, and three instructors did not respond to prompts to participate. The completion rate varied by program (see Table 2). At least 70 percent of all courses in every program except Program 4 completed the study. In Program 4, three of the four courses did not complete the study for the reasons described above.

Reflecting their distribution across programs, the typical course in this study most resembles courses in Program 6—three credits, 12 weeks duration, affiliated with a master's degree program, and targeting high-school teachers (see Table 3).

Table 2: Number of courses in study, not completing the study, and completion rates by program.

Program	Completing Study	Not Completing Study	Completion Rate
1	4	0	100%
2	7	2	78%
3	1	0	100%
4	1	3	25%
5	10	2	83%
6	17	0	100%
Total	**40**	**7**	**85%**

NOTE: *The number of courses not completing the study includes only those who agreed to participate and did not complete the study. It does not include those courses not contacted.*

Table 3: Number and percentage of courses by number of credits, affiliation with a master's degree program, content area, audience, and duration.

Course Characteristics	Number of Courses	Percentage of Courses
Maximum Number of Credits		
1 credits	1	3%
2 credits	9	23%
3 credits	26	65%
4 credits	4	10%
Affiliation with master's degree program		
Part of a master's degree program	26	65%
Independent of a master's degree program	14	35%
Content areas of course		
Astronomy	5	13%
Biology/Life Science	28	70%
Chemistry	5	13%
Earth/Space Science	14	35%
Environmental Science	13	33%
Physics	7	18%
Science Education	13	33%
Other	9	23%
Audience of course		
Elementary school	9	23%
Middle school	18	45%
High School	30	75%
Unidentified level	7	18%
Duration		
5 weeks	11	28%
6 weeks	2	5%
12 weeks	16	40%
14 weeks	9	23%
16 weeks	1	3%
17 weeks	1	3%

NOTE: *Percentages may not sum to 100 because participants were instructed to select all that apply. "Content areas of course" refers to any content area the instructor identified as being included in the course. "Audience of course" refers to the grade level focused on as identified by the host institution. "Duration" calculations are based on the start and end dates provided by the host institution.*

Instructors indicated the science content areas included in their courses. The most prevalent science content was biology/life sciences, represented in 70 percent of the courses. Approximately a third of the courses covered content in environmental science, Earth/space science, and science education. Fewer than 10 courses included content in astronomy, chemistry, and physics.

Instructors:

Forty-three instructors of the 52 courses were contacted for participation in this study. Six of the 40 courses were taught by two instructors—in four courses both instructors participated, and in two courses one instructor did so. Thirty-five of the 41 instructors (85 percent) completed the study. The percentage of instructors completing the study varied by program (see Table 4). Participation rates varied from 33 to 100 percent of the instructors offering courses in each program. In half of the programs, all instructors participated in the study. In the other programs, two instructors did not complete the study. Instructor demographics—gender, race-ethnicity, educational background, etc.—are described in the results section.

Students:

Instructors reported 795 students were enrolled in these courses at the beginning of the courses and 734 were enrolled at the end of the add/drop period. Sixty-one percent of the students enrolled at the end of the add/drop period completed the pre-questionnaire. Of those, 66 percent completed the post-questionnaire, giving an overall response rate of 40 percent. Across courses, the response rate ranged from 17 percent to 100 percent, with 40 percent of the courses having response rates of 70 percent or more. While this response rate is not ideal, it exceeds the response rate of other studies of online education (Sloan 2004). The low response rate suggests the perspectives of these students may be selective in unknown ways.

Among students enrolled at the end of the add/drop period, instructors reported 34 percent were male, 58 percent were female, and they could not determine the gender of 8 percent of their students (see Table 5). A third of those students completing the pre- and post-questionnaires were male and two thirds were female. There was no difference in the student participation rates by gender in the study.

Table 4: Number of instructors in study, not completing the study, and completion rates by program.

Program	Completing Study	Not Completing Study	Completion Rate
1	4	0	100%
2	4	2	67%
3	2	0	100%
4	1	2	33%
5	8	2	80%
6	16	0	100%
Total	**35**	**6**	**85%**

NOTE: *The number of instructors not completing the study includes only those who agreed to participate and then dropped out of the study. It does not include those in courses with two instructors where the other instructor participated.*

Table 5: Percentage of students enrolled at the start of class, enrolled at the end of the drop period, completed only the pre-questionnaire, and completed both the pre- and post-questionnaires by gender and performance.

Characteristic	Enrolled at Start of Class (n=795)	Enrolled at End of Drop Period (n=734)	Completed Pre-Questionnaire (n=451)	Completed Both Pre- and Post-Questionnaires (n=296)	Among all students students enrolled, percentage completing pre and post
Response Rate	~	92%	61%	40%	40%
Gender					
Male	34%	34%	33%	36%	43%
Female	58%	58%	66%	64%	45%
Unknown	8%	9%	0%	0%	--
Performance					
A	~	63%	64%	71%	45%
B	~	19%	18%	18%	39%
C	~	5%	3%	2%	17%
D	~	0%	0%	0%	100%
F/Fail	~	13%	8%	2%	7%
Not Reported	~	~	7%	6%	--
Program					
1	14%	14%	12%	13%	36%
2	20%	20%	17%	20%	41%
3	1%	1%	1%	1%	38%
4	0%	0%	0%	1%	100%
5	26%	26%	30%	25%	39%
6	38%	39%	39%	41%	42%

***NOTE:** One instructor did not provide the number of students enrolled at the start of the course nor at the end of the drop period. Five students in that course completed the questionnaires and are included in this table. "Unknown" gender refers to students who the instructor could not classify based on their names. "F/Fail" includes students who received an F, an Incomplete, or withdrew from the course. "Not Reported" refers to students who did not give consent for their grade to be released and who did not report a grade on their questionnaire.*

Table 6: Description of programs by number of courses, instructors, and students.

Number in Study	Program 1	Program 2	Program 3	Program 4	Program 5	Program 6	Total
Courses	4	7	1	1	10	17	**40**
Instructors	4	4	2	1	8	16	**35**
Students	37	59	3	2	75	120	**296**

***NOTE:** Includes only instructors and students who completed both questionnaires.*

Students who performed better in their courses were more likely to have participated in this study—45 percent of those who received A's completed pre- and post-questionnaires versus 39 percent of those receiving B's, 17 percent receiving C's, and 7 percent of those who failed, received an incomplete, or withdrew from the course after the add/drop period had ended. This suggests the data from students are more representative of those who performed well in the course than of those who did not. Both students from Program 4 completed the study, compared to approximately 40 percent from the other programs. Additional student demographics—race, educational background, teaching experience, etc.—are discussed below.

In summary, a total of 35 instructors and 296 students from 40 unique courses in 6 institutions participated in this study.

Data Sources

Instructors' and students' pre- and post-course questionnaires were developed and tested with focus groups and piloted in four online courses during the summer of 2004. All questionnaires were administered online. Instructor and student pre-questionnaires collected demographic information such as their highest degree earned, fields of study, teaching experience, experience with online courses, and their expectations about the course.

In order to measure instructional methods employed in online science courses for teachers, we developed a set of survey items based on the measure of reform-based instruction in K-12 science classrooms developed by Borko and her colleagues (Borko 2003). This measure utilized detailed rubrics in classroom observations with moderate to high levels of inter-rater agreement. Although Borko's constructs were developed to examine children's learning, many of their principles are compatible with the call for new methods of professional development for teachers and have many parallels to NSES standards (NRC 1996). Constructs particularly relevant for measuring reform-based science instruction in online courses for teachers include:

- **Hands-On:** The extent to which learners are interacting with physical materials or models to learn science.
- **Minds-On:** The extent to which learners participate in activities that engage them in wrestling with scientific issues and developing their own understanding of scientific ideas.
- **Collaborative Grouping:** The extent to which a series of lessons uses learner groups to promote learning.

Questions about the use of common instructional materials for science (e.g., completing problem sets, reading textbooks) as well as those unique to online courses (e.g., online discussion boards, simulations) were also included so as to cover the potential range of instructional materials used in these courses. In addition to questions about instructional methods and materials, instructor and student post-questionnaires focused on overall course characteristics such as:

- perceived level of **technological and intellectual difficulty** of course materials
- frequency and nature of **assessment**

as well as the nature of communication and dynamics in the course, including:

- frequency and nature of **communication between instructor and students**
- frequency and nature of **communication among students**
- control and dynamics within **online discussions**
- perceived level of **support** from instructor, other students, and course design
- perceived **control over learning** by the student.

These pre- and post-questionnaires are the primary data sources reported here. Tables 7 and 8 summarize the items included in each course-level and student-level construct, respectively, and the internal consistency of each scale.

Instructor interviews were conducted to verify and enhance our understanding of their post-questionnaire responses. Interviews were also conducted with program coordinators to understand how instructors were recruited, hired, and compensated and the position of the programs within the larger institutions in terms of support provided and self-sustainability.

Data Analysis

The descriptive analyses presented in this paper require comparisons of means and distributions of responses. Standard statistical tests such as t-tests and chi-square tests were used. In cases when a large number of statistical tests were used on the same variables, a Scheffe test was employed to control the amount of Type I error across the t-tests. Cronbach's alpha, a measure of internal consistency of a set of items, is reported for each of the instructional methods and perceived support scales.

Results

The findings are organized around the central research questions about these online science courses for teachers:

- Who are the students in online science courses for teachers?
- Who are the instructors in online science courses for teachers?
- What does science teaching and learning look like in these courses?

Who are the students in online science courses for teachers?

Of the almost 800 students enrolled in the 40 online science courses in this study, 90 percent completed their courses. The demographic characteristics of students in our study are described in Table 9.

Table 7: Course Scales, Items, and Alpha Coefficients

Hands-On Instructional Activities (α=0.82)

1. Interacted with physical materials or models (e.g., mixing solutions, building circuits, scale models).
2. Carried out procedures of scientific investigations designed by instructors or course developers (e.g., lab exercises, kitchen experiments).
3. Designed their own scientific investigation(s) (e.g., developed hypothesis or question and procedures).
4. Carried out procedures of scientific investigations they designed (e.g. collected data, made observations).

Scale: 1=Not at all; 2=Once or twice in the course; 3=Once or twice a month; 4=Once or twice a week; 5=Three times a week or more.

Minds-On Instructional Activities (α=0.79)

1. Articulated their scientific ideas in an online discussion.
2. Reflected upon their earlier scientific ideas
3. Reflected upon the scientific ideas of other students.
4. Raised questions with other students about their scientific ideas.
5. Analyzed and drew conclusions from data, observations, and other forms of scientific evidence
6. Provided evidence to support their scientific ideas.

Scale: 1=Not at all; 2=Once or twice in the course; 3=Once or twice a month; 4=Once or twice a week; 5=Three times a week or more.

Collaborative Instructional Activities (α=0.87)

1. Worked as part of a team on group projects or assignment.
2. Worked as part of a small student group created to discuss course content.
3. Worked as part of a small student group created to complete assignments or activities.
4. Worked as part of a small student group created to review each others' work.

Scale: 1=Not at all; 2=Once or twice in the course; 3=Once or twice a month; 4=Once or twice a week; 5=Three times a week or more.

Importance of Student Control over Their Learning (α =0.80)

1. Questioned the way they're being taught in this course.
2. Asked for clarification about activities that were confusing.
3. Expressed concern about anything that got in the way of their learning.
4. Helped plan what they were going to learn.
5. Helped decide which activities worked best for them.
6. Let the instructor(s) know if they needed more/less time to complete an activity.
7. Encouraged to provide feedback to their instructors about their questions and concerns about the course.

Scale= 1=Not at all important, 2=Somewhat important, 3=Important, 4=Very important.

Table 8: Course Scales, Items, and Alpha Coefficients

Hands-On Instructional Activities (α =0.84)

1. Interacted with physical materials or models (e.g., mixing solutions, building circuits, scale models).
2. Carried out procedures of scientific investigations designed by instructors or course developers (e.g., lab exercises, kitchen experiments).
3. Designed my own scientific investigation(s) (e.g., developed hypothesis or question and procedures).
4. Carried out procedures of scientific investigations I designed (e.g., collected data, made observations).

Scale: 1=Not at all; 2=Once or twice in the course; 3=Once or twice a month; 4=Once or twice a week; 5=Three times a week or more.

Minds-On Instructional Activities (α =0.65)

1. Articulated my scientific ideas in an online discussion.
2. Reflected upon my earlier scientific ideas
3. Reflected upon the scientific ideas of other students.
4. Raised questions with other students about their scientific ideas.
5. Analyzed and drew conclusions from data, observations, and other forms of scientific evidence
6. Provided evidence to support my scientific ideas.

Scale: 1=Not at all; 2=Once or twice in the course; 3=Once or twice a month; 4=Once or twice a week; 5=Three times a week or more.

Collaborative Instructional Activities (α =0.74)

1. Worked as part of a team on group projects or assignment.
2. Worked as part of a small student group created to discuss course content.
3. Worked as part of a small student group created to complete assignments or activities.
4. Worked as part of a small student group created to review each others' work.

Scale: 1=Not at all; 2=Once or twice in the course; 3=Once or twice a month; 4=Once or twice a week; 5=Three times a week or more.

Perceived Control over Learning (α=0.55)

1. Questioned the way I was being taught in this course.
2. Asked for clarification about activities that were confusing.
3. Expressed concern about anything that got in the way of my learning.
4. Helped plan what I was going to learn.
5. Helped decide which activities worked best for me.
6. Let the instructor(s) know if I needed more/less time to complete an activity.

Scale: 1=Not at all; 2=Once or twice in the course; 3=Once or twice a month; 4=Once or twice a week; 5=Three times a week or more.

Perceived Instructor Support (α=0.88)

1. Interactions with the instructor helped me understand the course material better.
2. I felt supported by the instructor(s) as I developed my understanding of the course material.
3. I felt my contributions to the online discussions were valued by the instructor.
4. The instructor(s) was accessible to me.
5. I was encouraged to provide feedback to the instructor(s) about my questions and concerns about the course.

Scale: 1=Strongly Disagree; 2=Disagree: 3=Neutral; 4=Agree; 5=Strongly Agree

Perceived Student Support (α=0.80)

1. Interactions with the other students helped me understand the course material better.
2. I felt supported by other students as I developed my understanding of the course content.
3. I felt my contributions to the online discussions were valued by other students.
4. The class atmosphere encouraged me to make contributions to the online discussions.

Scale: 1=Strongly Disagree; 2=Disagree: 3=Neutral; 4=Agree; 5=Strongly Agree

Perceived Course Supports (α=0.77)

1. I usually understood the content being taught in the course.
2. The course seemed to be designed to address multiple learning styles.
3. I felt my learning style was well suited for this course.
4. Course materials were organized so that each new concept built upon previous learning.
5. Course materials were organized so it was clear how different concepts covered in this course fit together.

Scale: 1=Strongly Disagree; 2=Disagree: 3=Neutral; 4=Agree; 5=Strongly Agree

Social Learning Opportunities (α=0.80)

1. Articulated my scientific ideas in an on-line discussion.
2. Reflected upon my earlier scientific ideas
3. Reflected upon the scientific ideas of other students.
4. Read/listened to other students' posts
5. Responded to other students' posts
6. Raised questions with other students about their scientific ideas.
7. Worked as part of a team on group projects or assignment
8. Worked on problems based in contexts from my daily life
9. Provided evidence to support my scientific ideas.
10. Communicated with other students via email
11. Communicated with other students via discussion boards
12. Worked in student groups created to discuss course content

Social Learning Opportunities (α=0.80) continued

13. Worked in student groups created to complete assignments or activities
14. Worked in student groups created to review each other's work
15. Receive feedback (e.g., comments on assignments, remarks in discussion posts) on your science learning in the course from other students?
16. Interactions with the other students helped me understand the course material better.
17. I felt supported by other students as I developed my understanding of the course content.
18. I felt my contributions to the on-line discussions were valued by other students.
19. The class atmosphere encouraged me to make contributions to the on-line discussions.

Instructor Learning Opportunities (α=0.76)

1. Read/listened to instructor posts
2. Responded to instructor posts
3. Communicated with instructor via discussion boards
4. Received feedback (e.g. grading with comments, assessment reports) on your science learning in the course from your instructor.
5. Interactions with the instructor helped me understand the course material better.
6. I felt supported by the instructor(s) as I developed my understanding of the course material.
7. I felt my contributions to the on-line discussions were valued by the instructor.
8. The instructor(s) was accessible to me.
9. Asked for clarification about activities that were confusing.
10. Expressed concern about anything that got in the way of my learning.
11. Helped plan what I was going to learn.
12. Helped decide which activities worked best for me.
13. Let the instructor(s) know if I needed more/less time to complete an activity.

Individual Learning Opportunities (α=0.76)

1. Worked with pen and paper problem sets (e.g., problems from a textbook or worksheet)
2. Interacted with physical materials or models (e.g., mixing solutions, building circuits, scale models)
3. Used computer-based animations, games, or simulations (e.g., virtual dissection, SimEarth, flash interactives)
4. Carried out procedures of scientific investigations designed by instructors or course developers (e.g., lab exercises, kitchen experiments)
5. Carried out procedures of scientific investigations I designed (e.g. collected data, made observations)
6. Worked on problems based in contexts from my daily life
7. Analyzed and drew conclusions from data, observations, and other forms of scientific evidence
8. Provided evidence to support my scientific ideas.
9. Read professional scientific publications (e.g., journals, periodicals)

Table 9: Percentage of students by gender, race, program type, teacher status, and age.

Student Characteristics	All Students (n=250)	Female Students (n=161)	Male Students (n=89)	Students in nonprofit courses (n=94)	Students in university courses (n=156)
Gender					
Male	36%	--	--	29%	40%
Female	64%	--	--	71%	60%
Race					
American Indian or Alaskan Native	0%	0%	0%	0%	0%
Asian	1%	1%	2%	0%	2%
Black or African-American	4%	6%	1%	4%	4%
Hispanic or Latino	1%	2%	0%	2%	1%
Native Hawaiian or Other Pacific Islander	0%	0%	0%	0%	0%
White	91%	90%	92%	90%	91%
Not reported	2%	1%	3%	2%	1%
Program Type					
Nonprofit	38%	42%	30%	--	--
University	62%	58%	70%	--	--
Science Teachers					
Yes	93%	93%	93%	95%	92%
No	7%	7%	7%	5%	8%
Age					
25-35 years	25%	24%	27%	20%	28%
36-45 years	32%	32%	34%	34%	31%
46-55 years	24%	27%	19%	21%	26%
56-65 years	17%	16%	19%	21%	14%
65+ years	1%	1%	1%	**3%**	**0%**

NOTE: *Students who took more than one course are included once in this table with one exception--four students who took courses in two programs are counted twice.*

Almost two-thirds of the students in our study were women, comparable to the percentage of women enrolled in these courses (see Table 5 in Methods section). Women constituted seventy-two percent of the students in nonprofit courses versus sixty percent of the students in university courses (χ^2=3.1, 1 d.f., p=0.07). Nine out of ten students were white with no differences by gender or program type. More than 90 percent of the students (n=232) were or had ever been science teachers, with similar percentages of males and females and students in nonprofit and university courses. Half of the students were younger than 45 years old. Nonprofit courses tended to have larger percentages of students (24 percent) in the upper age brackets than university courses had (14 percent) (χ^2=8.99, 4 d.f., p=0.06). There was no significant difference in the distribution of ages by gender of the students (χ^2=2.28, 4 d.f., p>0.10).

Two-thirds of the students reported having earned bachelor's degree in a science field—with almost half of the students reporting a bachelor's degree in biology (see Table 10).

Table 10: Percentage of students earning bachelor's degrees in each field of study overall and by student gender and program type.

Fields of Study	All students (n=250)	Female students (n=161)	Male students (n=89)	Students in nonprofit (n=94)	Students in university courses (n=156)
Any science field	66%	64%	70%	57%	71%
Biology/Life Science	48%	48%	47%	41%	51%
Chemistry	10%	9%	12%	5%	13%
Earth/Space Science	5%	4%	6%	9%	3%
Physics	3%	1%	6%	2%	3%
Other Science	9%	10%	7%	7%	10%
Engineering (any discipline)	3%	2%	3%	3%	3
Mathematics	2%	2%	1%	3%	1%
Science Education (any science discipline)	20%	18%	22%	15%	22%
Mathematics Education	1%	1%	1%	1%	1%
Elementary Education	13%	17%	6%	24%	6%
Other Education field	7%	6%	8%	6%	7%
Other Non Science fields	9%	6%	16%	7%	10%

NOTE: *Percentages may not sum to 100, as participants were instructed to select all that apply. Number of students refers to those who completed both a pre- and post-questionnaire. Students who took more than one course are included once in this table.*

Students in university courses were significantly more likely to have earned a bachelor's degree in a science field than were students in nonprofit courses (χ^2=4.91, 1 d.f., p=0.0267). Twenty percent of the students reported having earned a bachelor's degree in science education. Women and students in nonprofit courses (70 percent of whom were women) were more likely to have a bachelor's degree in elementary education than men and students in university courses (gender χ^2=6.39, 1 d.f., p=0.0115; program type χ^2=18.37, 1 d.f., p<0.0001). This difference is a reflection of the different audiences targeted, with university programs targeting high school science teachers and nonprofit programs targeting teachers at all grade levels.

Ninety-three percent of the students in this study were teachers—90 percent of whom teach in public schools (see Table 11). Ten percent taught in private parochial schools or in private independent schools.

Table 11: Percentage of students earning bachelor's degrees in each field of study overall and by student gender and program type.

Student Characteristics	All students (n=250)	Students in nonprofit courses (n=156)	Students in university courses (n=94)
School Type			
Public	74%	79%	71%
Parochial	5%	3%	6%
Independent	5%	5%	5%
Not currently teaching	16%	13%	18%
Community Type			
Rural	11%	12%	11%
Small Town	20%	16%	22%
Large Town	12%	10%	13%
Mid-size City	9%	9%	10%
Suburb of mid-size city	8%	12%	6%
Large City	10%	16%	6%
Suburb of large city	14%	14%	14%
Not currently teaching	16%	13%	18%

NOTE: *Percentages may not sum to 100, as participants were instructed to select all that apply. Number of students refers to those who completed both a pre- and post- questionnaire. Students who took more than one course are included once in this table.*

Sixteen percent were not currently teaching (this includes 7 percent who have never taught). The remaining 74 percent taught in public schools. Half of the students reported teaching in a city or suburb. Eleven percent of the students reported teaching in a rural or farming community. A third reported teaching in a small or large town.

Sixty-two percent of the students reported between 1 and 10 years of science teaching experience at any grade level (see Table 12).

Over half were certified to teach secondary science. Almost a quarter of the students were certified to teach middle or junior high school. Students in nonprofit courses were significantly more likely than students in university courses to have K-8, ESL, early childhood, or "other" types of certification. Students in university courses, in contrast, were more likely than students in nonprofit courses to not be currently certified, either with no plans of becoming certified or having been certified in the past.

Table 12: Percentage of students by type and subject area of certification and years of science teaching experience overall and by student gender and program type.

Student Characteristics	All students (n=250)	Female students (n=161)	Male students (n=89)	Students in nonprofit (n=94)	Students in university courses (n=156)
Type of certification					
I have never been and do not plan to become certified	7%	7%	7%	3%	10%
I am not currently certified, but was certified in the past	3%	2%	4%	0%	4%
I am not currently certified, but am working to become certified	8%	7%	11%	11%	7%
Emergency, temporary, or provisional certification	5%	4%	6%	2%	6%
Elementary Grades (K-6) certification	6%	7%	3%	9%	4%
Elementary Grades (K-8) certification	14%	18%	6%	27%	6%
Junior High/Middle Grades certification	23%	23%	24%	24%	22%
Secondary (9-12) science certification	54%	52%	58%	48%	58%
Secondary (9-12) certification in a field other than science	9%	11%	7%	6%	11%
Teaching English as a Second Language certification	2%	2%	1%	4%	1%
Special Education certification	4%	4%	3%	4%	4%
Early Childhood certification	2%	3%	1%	5%	1%
Technology certification	4%	3%	4%	3%	4%
Other certification	8%	9%	6%	15%	3%
Years of K-12 science teaching experience					
I have never taught K-12 science	17%	17%	17%	15%	18%
1 year	6%	6%	7%	6%	6%
2 -5 years	33%	31%	37%	32%	34%
6-10 years	23%	23%	22%	24%	22%
11-15 years	10%	11%	7%	10%	10%
16-20 years	5%	6%	4%	3%	6%
20-25 years	3%	4%	1%	6%	1%
26+ years	3%	2%	4%	3%	3%

NOTE: *Percentages may not sum to 100 because participants were instructed to select all that apply. Number of students refers to those who completed both a pre- and post-questionnaire. Students who took more than one course are included once in this table.*

Reflecting the target audience of these courses, most students were currently teaching high-school science (see Table 13). Sixty percent of males versus 47 percent of females were currently teaching high-school science (χ^2=3.86, 1 d.f., p=0.0495). One in four students in nonprofit courses was teaching science at the middle-school level (grades 6-8), significantly higher than the one in ten students in university courses teaching science at that level (χ^2=12.58, 1 d.f., p=0.0004). Similarly, 60 percent of the students in university courses were currently teaching high-school science compared to 35 percent of the students in nonprofit courses (χ^2=15.62, 1 d.f., p<0.0001).

Students were asked the number of online courses they had previously taken, as well as their reasons for enrolling in their current course (see Table 14). This was the first online course for a quarter of the students, with this being true for 37 percent of the students in nonprofit courses and 18 percent of the students in university courses (χ^2=13.76, 1 d.f., p<0.001). Given their affiliation with master's degree programs, it is not surprising that students in university courses reported having taken a larger number of online courses than students in nonprofit courses had (χ^2=21.09, 6 d.f., p=0.0018). The number of courses varies by gender, with women reporting having taken fewer courses than men (χ^2=17.98, 6 d.f,. p=0.0063).

The majority of students are taking these courses for personal learning (89 percent) and professional advancement (82 percent). Forty-four percent of the students reported taking their online course because it is convenient in terms of time, location, and/or cost. Men were more likely than women to report taking the course for professional advancement (t=1.82, 149 d.f., p=0.07) while women were more likely to base their decision on the reputation of the program (t=-2.081, 294 d.f., p=0.04). There were no significant differences between the reasons students in university and nonprofit programs gave for enrolling in their respective courses.

Table 13: Percentage of students by type and subject area of certification and years of science teaching experience overall and by student gender and program type.

Student Teaching Experience	All students (n=250)	Female students (n=161)	Male students (n=89)	Students in nonprofit (n=94)	Students in university courses (n=156)
Not currently teaching science in a K-12 classroom	16%	17%	15%	13%	18
Grade level(s) at which currently teaching science					
Kindergarten	1%	1%	0%	1%	1%
1st grade	1%	2%	0%	2%	1%
2nd grade	1%	2%	0%	2%	1%
3rd grade	1%	1%	1%	2%	1%
4th grade	2%	2%	3%	4%	1%
5th grade	4%	4%	2%	6%	2%
6th grade	8%	9%	7%	14%	4%
7th grade	11%	13%	8%	19%	6%
8th grade	13%	13%	12%	19%	9%
9th grade	28%	22%	39%	22%	32%
10th grade	40%	39%	43%	27%	48%
11th grade	39%	32%	52%	26%	47%
12th grade	36%	31%	45%	26%	42%

NOTE: *Percentages may not sum to 100 because participants were instructed to select all that apply. Number of students refers to those who completed both a pre- and post-questionnaire. Students who took more than one course are included once in this table.*

Table 14: Percentage of students by number of online courses they have taken and their reasons for taking courses overall and by student gender and program type.

Student Characteristics	All students (n=296)	Female students (n=189)	Male students (n=107)	Students in nonprofit (n=99)	Students in university courses (n=197)
Number of online courses taken prior to current course					
0 courses	24%	28%	19%	37%	18%
1 course	17%	17%	16%	20%	15%
2 courses	16%	17%	13%	9%	19%
3 courses	10%	7%	15%	6%	12%
4 courses	9%	5%	17%	9%	10%
5 courses	4%	4%	5%	4%	5%
6 or more courses	17%	19%	14%	11%	20%
Missing	3%	3%	2%	3%	3%
Reason for taking course					
Professional Advancement	82%	79%	87%	81%	82%
Personal Learning	89%	88%	90%	87%	89%
Convenience	44%	43%	44%	39%	46%
Reputation of program	13%	16%	7%	12%	13%
Something else	1%	1%	2%	2%	1%

NOTE: *Percentages may not sum to 100 because participants were instructed to select all that apply. Number of students refers to those who completed both a pre- and post-questionnaire.*

Table 15: Percentage of students planning to access the course through specific venues overall and by student gender and program type.

Plan to access course	Students (n=288)	Female students (n=189)	Male students (n=107)	Nonprofit courses (n=96)	University courses (n=192)
Through a computer at home	93%	93%	94%	89%	96%
Through a computer in my classroom	58%	56%	63%	58%	58%
Through a computer in the school media center	10%	10%	9%	17%	6%
Through a computer at a local college or university	6%	4%	8%	7%	5%
Through a computer at a local library	2%	4%	0%	6%	1%
Through a computer at an Internet café or other retail establishment	2%	2%	2%	3%	2%

NOTE: *Percentages may not sum to 100 because participants were instructed to select all that apply.*

Nine out of ten students planned to access the online portion of their course through a computer in their home, with 93 percent of students in university courses versus 86 percent of students in nonprofit courses planning to do so (t=-1.91, 149 d.f., p=0.06) (see Table 15). Fifty-eight percent of the students report they planned to access the course from their classroom. Fewer than 10 percent report accessing the course from public computers in libraries, a local university, or Internet cafes.

Who are the instructors in these online science courses for teachers?

Program coordinators identified the following criteria when selecting instructors for their courses: strong science background; K-12 teaching experience; teacher professional development experience; university teaching experience; and, to a lesser extent, publication record, schedule flexibility, and online teaching experience. Most instructors were selected from a pool of current and retired colleagues. None of the programs reported a formal recruitment process, although most said they had turned away unsolicited requests to teach online courses.

A total of 35 unique instructors participated in this study. Eighty percent (n=28) of the instructors taught one course in this study and seventeen percent (n=6) taught two courses. One instructor contributed three discrete courses. The likelihood that instructors contributed more than one course to this study did not differ significantly by instructor gender or program type.

Table 16 describes the gender, race, and age of the instructors. A little more than one third of the instructors were female and all except one were white. In terms of gender and race-ethnicity, these instructors mirror the demographics of the broader science professoriate—predominantly white and male.

Twenty-four instructors (69 percent) worked for a university and eleven (31 percent) worked for a nonprofit education institution. In nonprofit institutions, 60 percent of the instructors of online science courses for teachers were women, whereas in universities 28 percent of the instructors were women (t=1.80, 33 d.f., p=0.0808). The average age of these instructors was 54 years old, with no significant differences in the ages of male and female instructors and instructors teaching courses through the different types of institutions.

Table 16: Percentage of instructors by gender, race, age, and number of courses taught in this study overall and by instructor gender and program type.

Instructor Characteristics	All Instructors (n=35)	Female Instructors (n=13)	Male Instructors (n=22)	Nonprofit Instructors (n=10)	University Instructors (n=25)
Gender					
Male	63%	--	--	40%	72%
Female	37%	--	--	60%	28%
Type of Institution					
Nonprofit	31%	46%	18%	--	--
University	69%	54%	82%	--	--
Race					
American Indian or Alaskan Native	0%	0%	0%	0%	0%
Asian	0%	0%	0%	0%	0%
Black or African-American	0%	0%	0%	0%	0%
Hispanic or Latino/a	0%	0%	0%	0%	0%
Native Hawaiian or other Pacific Islander	0%	0%	0%	0%	0%
White	97%	92%	100%	90%	100%
Other race	0%	0%	0%	0%	0%
Multi-racial	3%	8%	0%	10%	0%
Age					
Less than 30 years old	3%	8%	0%	0%	4%
30-39 years old	14%	23%	9%	30%	8%
40-49 years old	11%	15%	9%	10%	12%
50-59 years old	40%	23%	50%	20%	48%
60-69 years old	23%	15%	27%	20%	24%
70-79 years old	9%	15%	5%	20%	4%
Number of courses taught by this instructor that are in the study					
1 course	80%	77%	77%	70%	76%
2 courses	17%	15%	18%	20%	20%
3 courses	3%	8%	0%	10%	4%

Instructors were asked to select in which of the following fields they had earned a bachelor's, master's, and doctorate: (a) biology/life science; (b) chemistry; (c) Earth/space science; (d) physics; (e) other STEM field; (f) science education; (g) other education; and (h) other fields. Sixty-nine percent of the instructors had earned a doctorate—88 percent of the doctorates were in a science field, 13 percent in science education (see Table 17).

A master's degree was the highest degree earned for a quarter of the instructors, and a bachelor's degree was the highest degree for less than 10 percent of the instructors. The majority of instructors with a bachelor's or master's degree as their highest degree were graduate students working toward higher degrees. Eighty-three percent of the instructors had earned a science degree at some level.

Half of the bachelor's degrees, 31 percent of the master's degrees, and 40 percent of the doctorates earned by these instructors were in the biological and life sciences (see Table 18). The next most common degrees were in chemistry or science education.

Table 17: Percentage of all instructors by highest degree earned overall and by instructor gender and program type.

Educational Background	All Instructors (n=35)	Female Instructors (n=13)	Male Instructors (n=22)	Nonprofit Instructors (n=10)	University Instructors (n=25)
Highest Degree Earned					
Bachelor's	9%	23%	0%	10%	8%
Master's	23%	23%	23%	60%	8%
Doctorate	69%	54%	77%	30%	84%
Field of Doctorate*					
Science	88%	71%	94%	67%	90%
Non-science	13%	29%	6%	33%	10%
Ever earned a science degree (any level)	83%	62%	95%	60%	92%

Calculated from number completing a doctorate.* ***NOTE:* *Percentages may not sum to 100 due to rounding.*

Table 18: Percentage of instructors earning bachelors, masters, and doctorates in each field of study.

Field of Study	Bachelors	Masters	Doctorate
Biology/Life Science	54%	31%	40%
Chemistry/Physical Science	26%	11%	17%
Earth/Space Science	11%	6%	11%
Physics	6%	6%	0%
Other STEM field*	11%	6%	0%
Science Education	29%	20%	9%
Other Education	9%	3%	3%
Other Fields	11%	0%	3%
No degree at this level	0%	37%	31%

N=35
STEM=Science, technology, engineering, and mathematics* ***NOTE:* *Percentages may not sum to 100 because participants were instructed to select all that apply. Several instructors completed a bachelor's degree and doctorate but no master's degree.*

Table 19: Number and percentage of instructor's degees by content area of the course(s) they are teaching in the study.

Content areas included in course	Number of Courses	Bachelors	Masters	Doctorate	No Degree in Content Area
Biology/Life Science	31	65%	45%	45%	19%
Earth/Space Science	15	20%	7%	20%	73%
Physics	7	14%	14%	0%	86%

NOTE: *Percentages may not sum to 100 because participants were instructed to select all that apply. Biology/Life Science includes courses with content in biology/life science and environmental sciences. Earth/Space Science includes courses with content in astronomy and Earth/space science.*

Instructors were asked to identify which of the following content areas were included in their course: (a) astronomy; (b) biological/life sciences; (c) Earth/space science; (d) environmental science; (e) physics; (f) science education; and (g) other science or education. Of interest here is the match between the educational background of the instructors and the science content of the courses they are teaching (see Table 19).

Instructors reported that biological and life sciences content was included in 31 of the 40 courses (78 percent). Four out of five instructors teaching these courses had a degree in the biological sciences. The remaining 20 percent of instructors had degrees in chemistry, Earth/space sciences, or science education. Earth and space science content was included in 15 of the 40 courses (38 percent) with only one quarter of those courses taught by an instructor with a degree in that content area. Instructors with degrees in biological and life sciences taught seven of those other eleven courses. Seven courses with physics content were offered, with one instructor reporting a bachelor's and master's degree in physics. Half of the instructors of these courses had degrees in other science fields and half had degrees in science education.

Instructors were asked to identify (a) the type of appointment they held at the institution; (b) in what department they were appointed, if any; and (c) the amount of time they have taught at the college or university level (see Table 20). Twice as many instructors do not have regular faculty appointments (assistant, associate, or full professor) as do have them, with male instructors and instructors at universities significantly more likely to have regular faculty appointments than women and instructors at nonprofit institutions (instructor sex $t=5.02$, 21 d.f., $p<0.001$; program type $t=-4.71$, 24 d.f., $p<0.001$). Half of the instructors were appointed in a science department, with instructors at universities three times as likely as instructors at non-profits to have this type of appointment ($t=-2.49$, 33 d.f., $p=0.0180$). Forty percent of the instructors had 10 or fewer years and 40 percent had 21 or more years of experience teaching science at the postsecondary level. Male instructors had taught a greater number of years than female instructors (males=21 years; females=8 years; $t=3.61$, 33 d.f., $p=0.001$). Instructors at universities had taught science at that level for a longer time than instructors at nonprofits (university instructors=21 years; nonprofit instructors=5 years; $t=-4.72$, 30 d.f., $p<0.0001$).

Table 20: Percentage of all instructors by type of appointment, department of appointment, and number of years of college/university science teaching by instructor gender and program type.

Instructor Characteristics	All Instructors (n=35)	Female Instructors (n=13)	Male Instructors (n=22)	Nonprofit Instructors (n=10)	University Instructors (n=25)
Type of appointment					
No appointment at this institution	23%	38%	14%	50%	12%
Instructor/Lecturer	26%	46%	14%	40%	20%
Adjunct professor	11%	15%	9%	10%	12%
Assistant professor	0%	0%	0%	0%	0%
Associate professor	17%	0%	27%	0%	24%
Full professor	9%	0%	14%	0%	12%
Professor emeritus	9%	0%	14%	0%	12%
Other appointment	6%	0%	9%	0%	8%
Regular faculty appointment					
Yes	26%	0%	41%	0%	36%
No	74%	100%	59%	100%	64%
Department appointed					
No appointment at this institution	23%	38%	14%	50%	12%
Science Department	46%	31%	59%	20%	60%
Education Department	17%	31%	14%	10%	20%
Other Department	9%	8%	14%	20%	8%
Number of years taught science at college/university level					
0-1 year	11%	23%	5%	30%	4%
2-5 years	20%	23%	18%	50%	8%
6-10 years	11%	23%	14%	0%	16%
11-15 years	9%	15%	5%	10%	8%
16-20 years	9%	8%	9%	10%	8%
21+ years	40%	8%	50%	0%	56%

NOTE: *Percentages may not sum to 100 because participants were instructed to select all that apply. Tenure-track appointments are the assistant, associate, full, and emeritus positions.*

Because these are online courses for science teachers, instructors were also asked about their K-12 science teaching experience. Half of the instructors had some K-12 teaching experience, primarily at the middle- and high-school levels (see Table 21). Two-thirds of female instructors and one-third of male instructors had taught science at the K-12 level. Female instructors were significantly more likely to have taught science at the elementary level than male instructors (t=-2.76, 14 d.f., p=0.0151). Nine of the ten instructors at nonprofit education institutions had K-12 science teaching experience, compared to only a quarter of the 25 instructors at universities who had such experience (χ^2=11.06, 1 d.f., p=0.0009). Nonprofit instructors were significantly more likely than university instructors to have middle school (t=3.11, 33 d.f., p=0.0039) and high school (t=2.74, 33 d.f., p=0.0099) science teaching experience.

Table 21: Percentage of instructors by K-12 science teaching experience and by instructor gender and program type.

Instructor Characteristics	All Instructors (n=35)	Female Instructors (n=13)	Male Instructors (n=22)	Nonprofit Instructors (n=10)	University Instructors (n=25)
Ever taught in a K-12 science classroom?					
Yes	46%	62%	36%	90%	28%
No	54%	38%	64%	10%	72%
Grade levels taught					
Never taught K-12	54%	38%	64%	10%	72%
Elementary grades (K-5)	20%	46%	5%	40%	12%
Middle school (6-8)	34%	54%	23%	70%	20
High School (9-12)	37%	38%	36%	70%	24%

NOTE: *Percentages may not sum to 100 because participants were instructed to select all that apply.*

In addition to their overall amount of teaching experience, instructors' experience specifically teaching online could influence the nature and quality of their courses. Instructors were asked (a) the number of different online courses they have taught (not counting the one they were currently teaching); and (b) the number of times they had taught the course in the study.

A third of the instructors had taught only their current course online, and 18 percent had taught six or more different online courses (see Table 22). Ten percent of the courses in the study were being taught for the first time, while two thirds had been taught at least three other times. Instructors were almost evenly divided among those expecting to spend less than 8 hours per week, 8-10 hours per week, and more than 10 hours per week teaching their online course. There were no significant differences in the amount of time nonprofit and university instructors expected to spend.

Online courses can place requirements on instructors that are different from those experienced in face-to-face courses. The level of preparedness instructors feel they need for teaching these courses is potentially important for how the courses ultimately function. Instructors were asked to rate how prepared they felt in a range of course activities from teaching science content to providing technical support (see Table 23 for all of the course activities).

Over half of all instructors felt very well prepared for all course activities, with more than 85 percent feeling this way about accessing course materials and teaching science content. The instructors felt least prepared to provide technical support and meet the needs of students with multiple learning styles. There were no significant differences in the levels of preparedness reported by instructor gender or program type.

Table 22: Percentage of instructors by the number of different online courses they have taught, the number of times they have taught the online course in the study, and the amount of time they expect to spend teaching the course.

Instructor Characteristics	Instructors (n=40)	Nonprofit Instructors (n=12)	University Instructors (n=28)
Number of different online courses taught			
0 courses	35%	33%	36%
1 courses	13%	8%	14%
2 courses	15%	8%	18%
3 courses	18%	25%	14%
4 courses	0%	0%	0%
5 courses	3%	8%	0%
6 or more courses	18%	17%	18%
Number of times previously taught the online course in study			
0 times	10%	8%	11%
1 time	15%	17%	14%
2 times	13%	0%	18%
3 times	20%	25%	18%
4 times	13%	8%	14%
5 times	13%	8%	14%
6 or more times	18%	33%	11%
Amount of time expecting to spend teaching course			
Less than 2 hours per week	0%	0%	0%
2-4 hours per week	5%	0%	7%
4-6 hours per week	0%	0%	0%
6-8 hours per week	23%	8%	29%
8-10 hours per week	38%	50%	32%
More than 10 hours per week	35%	42%	32%

Online courses can place requirements on instructors that are different from those experienced in face-to-face courses. The level of preparedness instructors feel they need for teaching these courses is potentially important for how the courses ultimately function. Instructors were asked to rate how prepared they felt in a range of course activities from teaching science content to providing technical support (see Table 23 for all of the course activities).

Over half of all instructors felt very well prepared for all course activities, with more than 85 percent feeling this way about accessing course materials and teaching science content. The instructors felt least prepared to provide technical support and meet the needs of students with multiple learning styles. There were no significant differences in the levels of preparedness reported by instructor gender or program type.

Table 23: Percentage of instructors reporting their level of preparedness for specific components of the course.

Components of Course	Number of instructors responding	Not Applicable	Not Well Prepared	Somewhat Prepared	Well Prepared	Very Well Prepared	Mean (S.D.)
Access all pertinent course materials (e.g., readings, discussion prompts)	40	0% (0)	0% (0)	3% (1)	10% (4)	88% (35)	3.9 (0.43)
Navigate online environment	40	0% (0)	3% (1)	3% (1)	25% (10)	70% (28)	3.6 (0.67)
Provide technical support	40	3% (1)	10% (4)	35% (14)	28% (11)	25% (10)	2.7 (0.98)
Facilitate online discussions	40	0% (0)	0% (0)	8% (3)	35% (14)	58% (23)	3.5 (0.64)
Teach science content	40	0% (0)	0% (0)	0% (0)	15% (6)	85% (34)	3.9 (0.36)
Assess student understanding	40	0% (0)	0% (0)	13% (5)	38% (15)	50% (20)	3.4 (0.71)
Evaluate student participation	40	0% (0)	0% (0)	5% (2)	38% (15)	58% (23)	3.5 (0.60)
Meet the needs of multiple student learning styles	40	5% (2)	0% (0)	23% (9)	40% (16)	33% (13)	3.1 (0.76)
Encourage student participation	40	0% (0)	3% (1)	5% (2)	35% (14)	58% (23)	3.5 (0.72)
Teach science inquiry	40	0% (0)	0% (0)	3% (1)	40% (16)	58% (23)	3.6 (0.55)
Address students' misunderstandings	40	0% (0)	0% (0)	10% (4)	38% (15)	53% (21)	3.4 (0.68)
Identify relevant resources (online and elsewhere)	40	0% (0)	3% (1)	3% (1)	30% (12)	65% (26)	3.6 (0.68)

NOTE: *Scale goes from 1=not well prepared for this course to 4=very well prepared. 'Not Applicable' responses are not included in means.*

Table 24: Percentage of instructors by their training in facilitating online discussion overall and by program type.

Instructor Characteristics	Instructors (n=35)	Nonprofit Instructors (n=10)	University Instructors (n=25)
Ever had facilitation training?			
Yes	49%	100%	28%
No	51%	0%	72%
Type of facilitation training			
Face-to-face course	31%	50%	24%
Online course	26%	80%	4%

NOTE: *Percentages may not sum to 100 because participants could select all that apply.*

As noted above, facilitating online courses requires somewhat different skills from teaching face-to-face courses. Instructors were asked whether or not they had any formal training in facilitating online courses and, if so, whether the training was in the form of a face-to-face or online course. Half of the instructors reported some type of formal facilitation training, a third in a face-to-face course, and a quarter in an online course (see Table 24). All of the nonprofit instructors and a third of the university instructors reported some facilitation training (t=-7.14, 24 d.f., $p<0.0001$), with nonprofit instructors much more likely than university instructors to have taken an online course (χ^2=19.2, 1 d.f., $p<0.0001$).

Programs varied in how instructors are compensated and, in universities, whether online courses are considered part of their teaching load or as overload. Two nonprofit institutions paid instructors on a per-course basis, ranging from $1,600 to $2,000 per course, while the third non-profit budgeted for 0.20 FTE instructor out of grant funds. Two university programs paid on a per-course basis; one paid $700 per course while another paid $4000 per course (with an additional allotment of $2000 to provide for a TA if course enrollment exceeded 12 students). The third university program paid instructors approximately $400 per student enrolled in the course.

The evaluation of instructors varies by program, utilizing a combination of student evaluations, direct observation, and review of materials. All programs use student evaluations. Two program coordinators observed their instructors' courses. In three programs, curriculum managers or program directors observed instructors. Five of the six programs utilized external parties to review course materials, including external evaluators as well as accrediting institutions and agencies. The sixth program relied on program coordinators and other online instructors to review course materials. As part of their grant funding, three programs underwent formal external evaluations.

What does science teaching and learning look like in these courses?

The characteristics of these courses are discussed in three sections: (a) course environment; (b) instructional methods and materials; and (c) nature of communication. "Course environment" includes the course platform, the number of teaching assistants, who designed the course, technical support available, how students access the course, and how much time instructors and students spent engaged in the course. "Instructional methods and materials" includes instructor and student perceptions of the instructional strategies and materials used in the courses. Finally, "nature of communication" includes the tools used for communication among students and between the instructor and students, as well as student and instructor perceptions of the communication.

Course Environment

Five of these programs were developed with the support of grants, while the sixth was supported through university funds. Development costs ranged from a few thousand dollars to $150,000-$200,000 per course. Scientists, professional curriculum developers, K-12 teachers, programmers, and most of the instructors (78 percent) participated in the development process. The participation of instructors in the development process varied significantly by program type, with half of the nonprofit instructors helping design the courses they taught and 89 percent of the university instructors helping design their courses (χ^2=7.34, 1 d.f., p=0.006).

All except one course in this study was offered through a pre-existing online course platform—WebCT, Blackboard, or eCollege. Two-thirds of the courses had no teaching assistant, 30 percent had one teaching assistant, and two courses (6 percent) had two or more teaching assistants. In 78 percent of the courses, instructors helped design the course.

When asked where students were expected to go for technical support, 85 percent of the instructors reported they themselves were sources of technical support (see Table 25). Forty-five percent of the courses referred students to university information services. A third of the courses expected students to utilize department technical support, a teaching assistant, other students, or personal sources (e.g., spouse, friend).

Students were asked what percentage of their total course time was spent logged into the online course environment (e.g., submitting assignments, reading discussion posts, contributing to discussions) versus offline course activities (e.g., reading from books or material printed from the Web, hands-on activities, writing in a journal, etc.). Instructors were asked how they expected students to divide their course time between online and offline activities. Students and instructors reported considerable diversity in the percentage of online course time (see Table 26).

Table 25: Percentage and number of instructors reporting the types of technical support provided.

Types of Technical Support	Percentage of Instructors reporting:
University information services	45%
University department technical support	30%
Instructor	85%
Teaching assistant	30%
Other students in course	35%
Personal sources	33%
Other	23%

N=40 instructors
***NOTE:** Percentages may not sum to 100 because participants were instructed to select all that apply.*

Table 26: Percentage of instructors expecting and students reporting various percentages of total course time spent in online activities.

Percentage of Total Course Time Online	Instructors Expecting Students to Spend (n=40)	Students Reporting (n=296)
0%	0%	0%
1-9%	0%	1%
10-19%	3%	7%
20-29%	28%	12%
30-39%	10%	12%
40-49%	13%	17%
50-59%	13%	16%
60-69%	10%	11%
70-79%	10%	9%
80-89%	8%	9%
90-100%	8%	8%

***NOTE:** Percentage of instructors and students refers to those who completed both a pre- and post-questionnaire.*

Instructors were almost evenly divided among expecting their students to spend less than 30 percent, between 30 and 60 percent, and more than 60 percent of their course time online. Almost half of the students reported spending between 30 and 60 percent of their course time online. Among the other half of the students, most reported spending more than 60 percent of their course time online.

Students were asked to estimate the average amount of time they spent on course activities (online and offline) per week and how many times they visited the course Web site per week. Instructors were asked how much time they expected students to spend working on course activities. Students reported spending more time and visiting more often than instructors expected (see Tables 27 and 28). Half of the students reported spending more than 8 hours per week on course work, with thirty-one percent reporting more than 10 hours per week. Sixty-one percent of the students reported visiting the course site seven times or more per week.

Table 27: Percentage of instructors by the time they expected students to spend and percentage of students by the time they actually spent on the course.

Student Time	Instructors Expecting Students to Spend (n=40)	Students Actually Spent Spent (n=281)
0%	0%	0%
1-9%	0%	1%
10-19%	3%	7%
20-29%	28%	12%
30-39%	10%	12%
40-49%	13%	17%
50-59%	13%	16%
60-69%	10%	11%
70-79%	10%	9%
80-89%	8%	9%
90-100%	8%	8%

NOTE: *Percentage of students and instructors refers to those who completed both a pre- and post-questionnaire.*

Table 28: Percentage of instructors expecting and student reporting the number of times they visited a course per week.

Number of Visits to Course per week	Instructors Expecting Students to Visit (n=40)	Students Actually Visiting (n=296)
0 times	0%	0%
1 time	0%	0%
2 times	5%	2%
3 times	23%	5%
4 times	25%	13%
5 times	13%	10%
6 times	5%	9%
7 or more times	30%	61%

NOTE: *Number of students and instructors refers to those who completed both a pre- and post-questionnaire.*

At the end of the course, instructors were asked how much time per week they spent on various course activities from reading course materials to reading/listening to student posts. Reflecting that (a) all of the course materials are online from the beginning of the course and (b) most instructors had taught their courses before, they reported spending the least time on delivering course content and reading course materials (see Table 29). The most time-intensive part of these courses for most instructors was reading and listening to student posts, which took more than five hours a week for a third of the instructors. They spent a little less time responding to students and evaluating student work.

Table 29: Percentage and number of instructors reporting the amount of time per week they spent on specific course activities.

Course Activity	Number of instructors responding	None	Less than an hour	1-2 hours	2-5 hours	More than 5 hours	Mean (S.D.)
Delivering course content	40	15% (6)	15% (6)	40% (16)	25% (10)	5% (2)	2.9 (1.10)
Reading course materials	40	10% (4)	28% (11)	33% (13)	23% (9)	8% (3)	2.9 (1.10)
Reading/listening to student posts	40	0% (0)	0% (0)	15% (6)	53% (21)	33% (13)	4.2 (0.68)
Corresponding with students	40	0% (0)	5% (2)	40% (16)	45% (18)	10% (4)	3.6 (0.74)
Evaluating student work	40	0% (0)	8% (3)	28% (11)	43% (17)	23% (9)	3.8 (0.88)

NOTE: *Scale goes from 1=None for this course to 5=More than 5 hours per week.*

Instructional Methods and Materials

To examine the instructional goals of the course, instructors and students were asked about the emphasis of the science content in the course—breadth vs. depth. Their responses have implications for the selection of instructional activities. Almost two thirds of the courses focused on breadth and depth equally (see Table 30). According to instructors, 20 percent of the courses were designed to emphasize depth over breadth, and 18 percent were designed to emphasize breadth over depth.

Based on work by Borko and her colleagues (2003), a list of 23 instructional activities likely in online learning environments was created. Instructors were asked how frequently they expected students to engage in each activity (see Table 31).

Table 30: Percentage and number of students reporting on the emphasis of science content.

Characteristics of Science Content	Instructors (n=40)	Students (n=296)
Breadth of content covered was emphasized over depth.	18%	15%
Breadth and depth of content covered were equally emphasized.	63%	72%
Depth of content covered was emphasized over breadth.	20%	13%

NOTE: *All calculations are based upon participants who responded to Q24 of the instructor post-survey and Q28 of the student post-survey.*

Table 31: Percentage and number of instructors reporting on their expectations for student participation in specific course activities.

Content Activities	Not at All	Once or Twice During the Course	Once or Twice a Month	Once or Twice a Week	Three Times a Week or More
Worked with pen and paper problem sets (e.g., problems from a textbook or worksheet)	53% (21)	23% (9)	10% (4)	15% (6)	3% (1)
Interacted with physical materials or models (e.g., mixing solutions, building circuits, scale models)	63% (25)	15% (6)	10% (4)	13% (5)	0% (0)
Used computer-based animations, games, or simulations (e.g., virtual dissection, SimEarth, flash interactives)	53% (21)	23% (9)	5% (2)	13% (5)	8% (3)
Articulated their scientific ideas in an online discussion.	0% (0)	5% (2)	0% (0)	40% (16)	55% (22)
Articulated their scientific ideas in a journal.	85% (34)	5% (2)	3% (1)	3% (1)	5% (2)
Reflected upon their earlier scientific ideas	0% (0)	10% (4)	33% (13)	43% (17)	15% (6)
Reflected upon the scientific ideas of other students.	0% (0)	3% (1)	10% (4)	53% (21)	35% (14)

Table 31(cont): Percentage and number of instructors reporting on their expectations for student participation in specific course activities.

Content Activities	Not at All	Once or Twice During the Course	Once or Twice a Month	Once or Twice a Week	Three Times a Week or More
Read/listened to other students' posts	0% (0)	3% (1)	0% (0)	40% (16)	58% (23)
Responded to other students' posts	0% (0)	3% (1)	5% (2)	50% (20)	43% (17)
Read/listened to instructor posts	0% (0)	3% (1)	3% (1)	63% (25)	33% (13)
Responded to instructor posts	3% (1)	5% (2)	13% (5)	63% (25)	18% (7)
Raised questions with other students about their scientific ideas.	0% (0)	8% (3)	15% (6)	53% (21)	25% (10)
Worked as part of a team on group projects or assignment	43% (17)	13% (5)	13% (5)	15% (6)	18% (7)
Carried out procedures of scientific investigations designed by instructors or course developers (e.g., lab exercises, kitchen experiments)	60% (24)	15% (6)	10% (4)	10% (4)	5% (2)
Designed their own scientific investigation(s) (e.g., developed hypothesis or question and procedure	45% (18)	33% (13)	13% (5)	10% (4)	0% (0)
Carried out procedures of scientific investigations they designed (e.g., collected data, made observations)	63% (25)	25% (10)	8% (3)	5% (2)	0% (0)
Worked on problems based in contexts from their daily life	20% (8)	28% (11)	33% (13)	13% (5)	8% (3)
Analyzed and drew conclusions from data, observations, and other forms of scientific evidence	13% (5)	25% (10)	25% (10)	25% (10)	13% (5)
Provided evidence to support their scientific ideas.	8% (3)	10% (4)	20% (8)	50% (20)	13% (5)
Read professional scientific publications (e.g., journals, periodicals)	15% (6)	18% (7)	23% (9)	35% (14)	10% (4)

Table 31(cont): Percentage and number of instructors reporting on their expectations for student participation in specific course activities.

Content Activities	Not at All	Once or Twice During the Course	Once or Twice a Month	Once or Twice a Week	Three Times a Week or More
Participated in on-site fieldwork (e.g., water testing, species counting in a natural setting, astronomical observations of the night sky)	83% (33)	13% (5)	13% (2)	0% (0)	0% (0)
Visited professional scientific environments (e.g., labs)	100% (40)	0% (0)	0% (0)	0% (0)	0% (0)
Interacted with professional scientists (site visits)	88% (35)	10% (4)	3% (1)	0% (0)	0% (0)

N=40 instructors.
NOTE: Scale goes from 1=not at all to 5=three times a week or more in this course. All calculations are based upon participants who responded to Q13 of the instructor post-survey.

Instructors in at least half of the courses reported that at least once a week, students were expected to:

- Articulate their scientific ideas in an online discussion
- Reflect upon their earlier scientific ideas
- Reflect upon the scientific ideas of other students
- Read/listen to other students' posts
- Respond to other students' posts
- Read/listen to instructor posts
- Respond to instructor posts
- Raise questions with other students about their scientific ideas
- Provide evidence to support their scientific ideas.

On the opposite end of the frequency continuum, at least half of the instructors reported that their students were never expected to:

- Work with pen and paper problem sets (e.g., problems from a textbook or worksheet)
- Interact with physical materials or models (e.g., mixing solutions, building circuits, scale models)
- Use computer-based animations, games, or simulations (e.g., virtual dissection, SimEarth, flash interactives)
- Articulate their scientific ideas in a journal
- Carry out procedures of scientific investigations designed by instructors or course developers (e.g., lab exercises, kitchen experiments)
- Carry out procedures of scientific investigations they designed (e.g., collected data, made observations)
- Participate in on-site fieldwork (e.g., water testing, species counting in a natural setting, astronomical observations of the night sky)
- Visit professional scientific environments (e.g., labs)
- Interact with professional scientists.

Instructional activities that varied in their use across courses include:

- Worked as part of a team on group projects or assignment
- Designed their own scientific investigation(s) (e.g., developed hypothesis or question and procedure)
- Worked on problems based in contexts from their daily life
- Analyzed and drew conclusions from data, observations, and other forms of scientific evidence
- Read professional scientific publications (e.g., journals, periodicals)

Combined, these results paint a picture of online courses with frequent online discussions (55 percent expecting students to do so three times a week or more) and relatively infrequent interaction with real-world phenomena or scientists. The use of other science education methods such as pen and paper problems, use of authentic contexts, and review of scientific literature varied among the courses.

Comparing the mean frequencies of these activities by program type revealed a few differences (see Table 32).

Table 32: Mean frequency of specific course activities reported by instructors overall and by program type.

Course Activities	All courses (n=40)	Nonprofit courses (n=12)	University courses (n=28)
Worked with pen and paper problem sets (e.g., problems from a textbook or worksheet)	1.9 (1.21)	1.1 (0.29)	2.3* (1.27)
Interacted with physical materials or models (e.g., mixing solutions, building circuits, scale models)	1.7 (1.09)	1.8 (1.14)	1.7 (1.08)
Used computer-based animations, games, or simulations (e.g., virtual dissection, SimEarth, flash interactives)	2.0 (1.34)	2.6 (1.56)	1.8 (1.17)
Articulated their scientific ideas in an online discussion.	4.5 (0.75)	4.6 (0.90)	4.4 (0.69)
Articulated their scientific ideas in a journal.	1.4 (1.03)	2.0 (1.54)	1.1* (0.57)
Reflected upon their earlier scientific ideas	3.6 (0.87)	3.9 (0.79)	3.5 (0.88)
Reflected upon the scientific ideas of other students.	4.2 (0.72)	4.4 (0.52)	4.1 (0.79)
Read/listened to other students' posts	4.5 (0.64)	4.8 (0.45)	4.4 (0.69)
Responded to other students' posts	4.3 (0.69)	4.5 (0.67)	4.3 (0.70)
Read/listened to instructor posts	4.3 (0.63)	4.4 (0.52)	4.2 (0.67)
Responded to instructor posts	3.9 (0.85)	4.3 (0.49)	3.7* (0.91)
Raised questions with other students about their scientific ideas.	4.0 (0.85)	4.1 (0.90)	3.9 (0.83)
Worked as part of a team on group projects or assignment	2.5 (1.58)	1.5 (1.17)	3.0* (1.55)
Carried out procedures of scientific investigations designed by instructors or course developers (e.g., lab exercises, kitchen experiments)	1.9 (1.25)	1.8 (0.94)	1.9 (1.38)
Designed their own scientific investigation(s) (e.g., developed hypothesis or question and procedure	1.9 0..992	1.7 (0.89)	2.0 (1.04)
Carried out procedures of scientific investigations they designed (e.g., collected data, made observations)	1.6 (0.85)	1.7 (0.89)	1.5 (0.84)

Table 32 (cont): Mean frequency of specific course activities reported by instructors overall and by program type.

Course Activities	All courses (n=40)	Nonprofit courses (n=12)	University courses (n=28)
Worked on problems based in contexts from their daily life	2.6 (1.17)	2.4 (1.24)	2.7 (1.16)
Analyzed and drew conclusions from data, observations, and other forms of scientific evidence	3.0 (1.24)	2.5 (0.91)	3.2 (1.32)
Provided evidence to support their scientific ideas.	3.5 (1.09)	3.1 (1.16)	3.7 (1.02)
Read professional scientific publications (e.g., journals, periodicals)	3.1 (1.25)	3.3 (1.24)	2.5 (1.19)
Participated in on-site fieldwork (e.g., water testing, species counting in a natural setting, astronomical observations of the night sky)	1.3 (0.72)	1.3 (0.45)	1.3 (0.81)
Visited professional scientific environments (e.g., labs)	1.0 (0.00)	1.0 (0.00)	1.0 (0.00)
Interacted with professional scientists (site visits)	1.2 (0.69)	1.4 (1.31)	1.1 (1.01)

**Statistically significant at the $p<0.01$ level.*
NOTE: *Scale goes from 1=not at all to 5=three times a week or more in this course. All calculations are based upon participants who responded to Q13 of the instructor post-survey. Standard deviations are in parentheses.*

Instructors of nonprofit courses reported higher frequencies of students articulating their scientific ideas in a journal (t=1.76, 164 d.f., p=0.08) and responding to instructor posts than did instructors of university courses (t=3.62, 294 d.f., p<0.001). Instructors of university courses, in comparison to instructors of nonprofit courses, expected students to work more frequently on problem sets (t=-6.89, 268 d.f., p<0.001) and to work as part of a team on group projects or activities (t=-11.88, 293 d.f., p<0.001).

Instructors were asked the frequency with which student groups were expected to meet for specific purposes—discussing course content, completing assignments or tasks, reviewing for tests, and reviewing each others' work. Half of the instructors reported that students were expected to interact at least once a week to discuss course content (see Tables 33 and 34).

A quarter of the instructors expected student groups to interact at least once a week to complete assignments or tasks. Instructors of university courses expected student groups to interact more frequently for these purposes than instructors of nonprofit courses (discuss content t=-8.80, 287 d.f., p<0.001; complete assignments t=-6.81, 268 d.f., p<0.001). The majority of instructors did not expect student groups to review each other's work, possibly because exams and peer review were relatively rare evaluation strategies.

Another window into the instructional activities of these courses is the materials students are expected to use. Instructors were asked to report the frequency with which students were expected to use 11 different materials, and students reported how often they did so (see Table 35 for specific materials).

More than half of the instructors reported that students were expected to use (a) books; (b) Web-based readings; and (c) images at least once or twice a week. Half of the instructors reported that students were never expected to use the following technologies (a) calculators; (b) physical materials; (c) presentation software; (d) spreadsheets; (e) audio files; (f) graphing and data analysis tools; (g) video files; and (h) interactive computer modules.

Potentially more important than their frequency of use are instructor and student perceptions of the course materials. Of interest in this study are perceptions of the ease of technological access, intellectual difficulty, the extent to which concepts built upon students' prior learning, and the extent to which different concepts fit together. At the end of each course, instructors and students were asked about these perceptions (see Table 36).

Three-quarters of the instructors and almost 9 out of 10 students found the course materials "generally easy to access." A quarter of the instructors and 11 percent of the students reported that the materials were "sometimes easy to access." A few students reported the course materials were generally difficult to access.

Nine out of ten instructors and students reported that the course materials were at an appropriate level of difficulty. None of the instructors felt the course materials were too easy for the students, while 5 percent of the students felt they were. Five percent of instructors and students felt the course materials were too difficult.

Table 33: Percentage and number of instructors reporting on the frequency and purpose of student groups

Purpose of Student Groups	Not at All	Once or Twice During the Course	Once or Twice a Month	Once or Twice a Week	Three Times a Week or More
Student groups created to discuss course content	33% (13)	13% (5)	3% (1)	23% (9)	30% (12)
Student groups created to complete assignments or activities	38% (15)	18% (7)	18% (7)	10% (4)	18% (7)
Studied to prepare for tests	93% (37)	3% (1)	5% (2)	0% (0)	0% (0)
Student groups created to review each other's work	58% (23)	13% (5)	13% (5)	10% (4)	8% (3)

N=40 instructors;
***NOTE:** Scale goes from 1=not at all to 5=three times a week or more in this course. All calculations are based upon participants who responded to Q 20A and Q20B of the instructor post-survey.*

Table 34: Mean frequency of each purpose of student groups reported by instructors by program type.

Purpose of Student Groups	Nonprofit courses (n=40)	University courses (n=296)
Student groups created to discuss course content	2.0 (1.48)	3.5 (1.62)
Student groups created to complete assignments or activities	1.5 (1.00)	3.0 (1.50)
Whole class discussions	3.3 (1.78)	3.1 (1.51)
Studied to prepare for tests	1.0 (0.00)	1.2 (0.55)
Student groups created to review each other's work	1.6 (0.90)	2.1 (1.48)

***NOTE:** Scale goes from 1=not at all to 5=three times a week or more in this course. All calculations are based upon participants who responded to Q 20A and Q20B of the instructor post-survey. Standard deviations are in parentheses.*

Table 35: Percentage and number of instructors reporting on their expectations for student use of specific materials.

Types of Materials	Not at All	Once or Twice During the Course	Once or Twice a Month	Once or Twice a Week	Three Times a Week or More
Books	33% (13)	10% (4)	3% (1)	35% (14)	20% (8)
Web-based readings	0% (0)	3% (1)	8% (3)	33% (13)	58% (23)
Calculators	80% (32)	13% (5)	5% (2)	3% (1)	0% (0)
Physical materials	63% (25)	23% (9)	3% (1)	13% (5)	0% (0)
Presentation software	50% (20)	35% (14)	13% (5)	3% (1)	0% (0)
Spreadsheets	80% (32)	18% (7)	3% (1)	0% (0)	0% (0)
Audio files	88% (35)	5% (2)	5% (2)	3% (1)	0% (0)
Images	5% (2)	8% (3)	5% (2)	38% (15)	45% (18)
Graphing and data analysis tools	70% (28)	20% (8)	8% (3)	3% (1)	0% (0)
Video files	50% (20)	20% (8)	10% (4)	10% (4)	10% (4)
Interactive computer modules	68% (27)	15% (6)	13% (5)	3% (1)	3% (1)

N=40 instructors
NOTE: *Scale goes from1=Not at all to 5=three times a week or more in this course. All calculations are based upon participants who responded to Q5 of the instructor post-survey.*

Table 36: Number and percentage of courses by number of credits, affiliation with a master's degree program, content area, audience, and duration.

Characteristics of Course Materials	Instructors (n=40)	Students (n=296)
Technological access		
Generally easy to access	75%	88%
Sometimes easy to access, at other times difficult	23%	11%
Generally difficult to access	0%	1%
Don't know	3%	--
Intellectual difficulty		
Too easy	0%	6%
Just right	95%	89%
Too difficult	5%	5%
Don't know	0%	--
Each new concept built upon previous learning.		
Strongly disagree	0%	1%
Disagree	3%	5%
Neutral	3%	14%
Agree	75%	60%
Strongly agree	20%	20%
It was clear how different concepts fit together.		
Strongly disagree	0%	1%
Disagree	0%	4%
Neutral	10%	12%
Agree	70%	62%
Strongly agree	20%	21%

NOTE: *Percentage of instructors and students refers to those who completed both a pre- and post-questionnaire. Question wording varies between two instruments.*

Instructors and students were asked the extent to which they agreed with two statements: "Each new concept built upon previous learning," and "It was clear how different concepts fit together." There were high levels of agreement with both statements. Students were more likely than the instructors to disagree or be neutral about these statements. Gender and program type differences in student's perceptions were examined (see Table 37).

Male and female students generally shared the same perceptions of the course materials with one exception—males were more likely than females to report that the course materials were too easy for them (χ^2=6.81, 2 d.f., p=0.03). Students in nonprofit and university courses had similar perceptions of the ease of technological access and intellectual difficulty of the course materials. They differed in the other two perceptions, with students in nonprofit courses reporting higher levels of agreement with the statements than students in university courses (prior learning t=2.33, 294 d.f., p=0.02; concepts fit t=2.11, 294 d.f., p=0.04).

Table 37: Percentage of students reporting on the characteristics of course materials by student gender and program type.

Characteristics of Course Materials	Female students (n=189)	Male students (n=107)	Students in nonprofit courses (n=99)	Students in university courses (n=197)
Technological access				
Generally easy to access	87%	90%	89%	87%
Sometimes easy to access, at other times difficult	13%	9%	11%	12%
Generally difficult to access	1%	1%	0%	1%
Intellectual difficulty				
Too easy for me	4%	10%	10%	5%
Just right for me	89%	88%	86%	90%
Too difficult for me	6%	2%	4%	5%
Each new concept built upon previous learning.				
Strongly disagree	1%	1%	0%	1%
Disagree	7%	2%	2%	7%
Neutral	13%	15%	15%	13%
Agree	62%	56%	56%	62%
Strongly agree	16%	26%	27%	16%
It was clear how different concepts fit together.				
Strongly disagree	1%	0%	1%	1%
Disagree	5%	3%	2%	5%
Neutral	11%	13%	11%	12%
Agree	65%	57%	56%	65%
Strongly agree	18%	27%	30%	17%

NOTE: *Number of students refers to those who completed both a pre- and post-questionnaire.*

Nature of Communication

None of the courses in this study met face-to-face. If they are not communicating in person, what technologies are the students using to communicate with instructors and each other? More important than the technologies used is the content of this communication and the climate it creates in the course. Students and instructors were asked about their perceptions of this climate. Specifically of interest were (a) who initiated topics during online discussions; (b) who contributed to the online discussions; (c) the frequency and perceived helpfulness of instructor and student feedback; and (d) perceptions of the course climate including support for and value given to students' contributions to the online discussion and the extent to which the climate encouraged their participation.

To understand the media used for communication in these courses, instructors were asked how often they expected students to communicate with them and each other via eight communication media (see Tables 38 and 39).

Table 38: Percentage and number of instructors reporting how frequently and with what format students communicated with them.

Communication with Instructor	Not at All	Once or Twice During the Course	Once or Twice a Month	Once or Twice a Week	Three Times a Week or More
Paper mail	100% (40)	0% (0)	0% (0)	0% (0)	0% (0)
Telephone	100% (40)	0% (0)	0% (0)	0% (0)	0% (0)
Email	23% (9)	25% (10)	35% (14)	18% (7)	0% (0)
Classroom meetings (i.e. face-to-face)	100% (40)	0% (0)	0% (0)	0% (0)	0% (0)
Discussion boards	13% (5)	5% (2)	23% (9)	60% (24)	0% (0)
Synchronous chat	78% (31)	5% (2)	15% (6)	3% (1)	0% (0)
Video conferencing	100% (40)	0% (0)	0% (0)	0% (0)	0% (0)
White boarding	100% (40)	0% (0)	0% (0)	0% (0)	0% (0)

N=40 instructors

NOTE: *Scale goes from 1=not familiar to 5=three times a week or more in this course. All calculations are based upon participants who responded to Q13B of the instructor post-survey. 'Not at all' responses include instructors who reported students were not required to communicate using that format.*

Table 39: The percentage and number of instructors reporting how frequently they expected students to communicate with each other via each format.

Communication Between Students	Not at All	Once or Twice During the Course	Once or Twice a Month	Once or Twice a Week	Three Times a Week or More
Paper mail	100% (40)	0% (0)	0% (0)	0% (0)	0% (0)
Telephone	100% (40)	0% (0)	0% (0)	0% (0)	0% (0)
Email	40% (16)	0% (8)	13% (5)	20% (8)	8% (3)
Classroom meetings (i.e. face-to-face)	100% (40)	0% (0)	0% (0)	0% (0)	0% (0)
Discussion boards	5% (2)	5% (2)	0% (0)	33% (13)	58% (23)
Synchronous chat	48% (19)	25% (10)	13% (5)	15% (6)	0% (0)
Video conferencing	100% (40)	0% (0)	0% (0)	0% (0)	0% (0)
White boarding	100% (40)	0% (0)	0% (0)	0% (0)	0% (0)

N=40 instructors
NOTE: *Scale goes from 1=not familiar to 5=three times a week or more in this course. All calculations are based upon participants who responded to Q14 of the instructor post-survey.*

Instructors expected students to use one of three media to communicate in these courses: (1) e-mail, (2) discussion boards, and (3) synchronous chat. Discussions boards were the sites of the most frequent instructor-student and student-student communication, with 60 percent of instructors expecting students to contact them via this medium at least once a week and 58 percent expecting students to contact each other via this medium three times a week or more. No instructors expected students to communicate with them or each other via paper mail, telephone, video conferencing, or white board.

Attesting to the significance of online discussions in these courses is the percentage of the course grade determined by students' performance in these discussions, with online discussions accounting for between 0 and 60 percent of the course grade (see Table 40). Online discussions accounted for 20 percent or less of the course grade in a third of the courses, between 21 and 30 percent of the course grade in 37 percent of the courses, and more than 30 percent of the final grade in 27 percent of the courses.

In half of the courses, instructors chose most if not all of the topics in the online discussions (see Table 41). Students and instructors were equally likely to have chosen new topics in 20 percent of the courses. In the remaining courses, instructors chose most if not all of the new topics for discussion. Two-thirds of instructors and students reported that nearly all students contributed to these discussions, with some students contributing more than others.

Table 40: Percentage of overall grade given to online discussions

Percent of Overall Grade	Courses
0%	3%
1-10% of grade	16%
11-20% of grade	18%
21-30% of grade	37%
31-40% of grade	16%
41-50% of grade	8%
51-60% of grade	3%
61-70% of grade	0%
71-80% of grade	0%
81-90% of grade	0%
91-100% of grade	0%

N=38 instructors
***NOTE:** All calculations are based upon instructors who responded to Q2 on the student information sheet. Two instructors did not report this information.*

Table 41: Percentage of students and instructors who initiated and contributed to online discussions

Aspects of Online Discussion	Students (n=289)	Instructors (n=40)
Who chose new topics within the online discussions		
Students chose nearly all of the new topics in the online discussions.	8%	3%
Students chose most of the new topics in the online discussions. Instructors chose a few of the new topics in the online discussions.	14%	25%
Students and instructors were equally likely to have chosen new topics in the online discussions.	15%	20%
Instructors chose most new topics in the online discussions. Students chose a few of the new topics in the online discussions.	24%	20%
Instructors chose nearly all new topics in the online discussions.	39%	33%
No response	0%	0%
Who contributed to online discussions		
A small group of students were the main contributors to discussions in this course. Most students did not contribute to discussions.	7%	0%
Over half of the students contributed to discussions, but some students contributed more than others.	15%	18%
Over half of the students contributed equally to discussions.	3%	3%
Nearly all students contributed to discussions, but some students contributed more than others.	63%	68%
Nearly all students contributed equally to discussions.	12%	13%
No response	0%	0%

***NOTE:** All calculations are based upon participants who responded to Q16 and Q17 of the instructor post-survey and Q23 and Q24 of the student post-survey.*

There were no significant differences in these perceptions by student gender (see Table 42). Students in university courses, however, were more likely than students in nonprofit courses to report that instructors chose nearly all of the topics for online discussion (χ^2=24.4, 5 d.f., p<0.001). This pattern matches that reported by instructors, where 36 percent of university instructors and 25 percent of nonprofit instructors reported that they chose nearly all of the new topics in the online discussions.

Table 42: Percentage of students reporting who initiated and contributed to online discussions by student gender and program type.

Aspects of Online Discussion	Female Students (n=184)	Male Students (n=105)	Students in nonprofit courses (n=96)	Students in university courses (n=193)
Who chose new topics within the online discussions				
Students chose nearly all of the new topics in the online discussions.	8%	8%	9%	7%
Students chose most of the new topics in the online discussions. Instructors chose a few of the new topics in the online discussions.	17%	10%	14%	15%
Students and instructors were equally likely to have chosen new topics in the online discussions.	15%	13%	25%	9%
Instructors chose most new topics in the online discussions. Students chose a few of the new topics in the online discussions.	21%	30%	30%	21%
Instructors chose nearly all new topics in the online discussions.	39%	39%	22%	47%
No response	1%	0%	0%	1%
Who contributed to online discussions				
A small group of students were the main contributors to discussions in this course. Most students did not contribute to discussions.	9%	4%	11%	5%
Over half of the students contributed to discussions, but some students contributed more than others.	15%	14%	24%	10%
Over half of the students contributed equally to discussions.	4%	2%	6%	2%
Nearly all students contributed to discussions, but some students contributed more than others.	58%	70%	58%	65%
Nearly all students contributed equally to discussions.	14%	10%	9%	14%
No response	1%	0%	0%	1%

NOTE: *All calculations are based upon participants who responded to Q23 and Q24 of the student post-questionnaire.*

In addition to discussing science content, other potential roles of communication are empowering students and providing feedback. Instructors were asked with what frequency they expected students to engage in empowering instructional behaviors such as asking for clarification and helping to plan what they were going to learn (see Table 43 for all behaviors). The most common student behaviors were students asking for clarification about activities they found confusing and letting the instructor know if they needed more or less time to complete an activity. Least common were questioning the way they were taught, helping to plan what they were going to learn, and deciding what activities worked best for them, with at least half of the instructors reporting these behaviors never occurred.

Table 43: The percentage and number of instructors reporting how frequently they expected students to communicate with each other via each format.

Students Behaviors	Not at All	Once or Twice During the Course	Once or Twice a Month	Once or Twice a Week	Three Times a Week or More	Mean (S.D.)
Questioning the way they were taught in this course.	50% (20)	45% (18)	5% (2)	0% (0)	0% (0)	1.6 (0.60)
Asking for clarification about activities that they found confusing.	3% (1)	43% (17)	28% (11)	28% (11)	0% (0)	2.8 (0.88)
Expressing concern about anything that got in the way of their learning.	10% (4)	43% (17)	38% (15)	10% (4)	0% (0)	2.5 (0.82)
Helping to plan what they were going to learn.	58% (23)	25% (10)	15% (6)	3% (1)	0% (0)	1.7 (0.92)
Helping to decide which activities worked best for them.	48% (19)	30% (12)	8% (3)	13% (5)	3% (1)	1.9 (1.14)
Letting the instructor(s) know if they needed more/less time to complete an activity.	5% (2)	53% (21)	33% (13)	10% (4)	0% (0)	2.5 (0.75)

N=40 instructors

NOTE: *Scale goes from 1=not at all to 5=three or more times a week. All calculations based upon participants who responded to Q27 of the instructor post-survey.*

Students were asked about the frequency with which they received feedback from instructors and other students on their science learning in the course (see Table 44).

Seven out of ten students reported receiving feedback from instructors and students at least once a week, but they reported the feedback from instructors as significantly more helpful than feedback from other students ($t=5.40$, 288 d.f., $p<0.001$). Twice as many students reported feedback from instructors as "very helpful" as said that about feedback from other students.

Students and instructors were asked their perceptions about the course climate (see Table 45 for specific perceptions).

Table 44: Percentage and number of students reporting on frequency and helpfulness of feedback from the instructor and other students.

Characteristics of Feedback	Instructor Feedback	Student Feedback
Frequency of feedback		
Not at all	2%	4%
Once or twice during the course	7%	9%
Once or twice a month	15%	16%
Once or twice a week	67%	47%
Three times a week or more	9%	21%
Helpfulness of feedback		
No response	0%	1%
Not helpful	8%	10%
Somewhat helpful	20%	28%
Helpful	28%	37%
Very helpful	44%	22%

N=296 students who completed pre- and post-questionnaires.
***NOTE:** All calculations are based upon participants who responded to Q16 and Q17 in the student post-questionnaire.*

Table 45: Percentage and number of students reporting their level of agreement with specific statements about the course climate.

Group	Aspects of Course Climate	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean (S.D.)	Significantly different from items in group(s):
1	8. The instructor was accessible to me.	1% (3)	1% (3)	5% (14)	47% (140)	46% (136)	4.4 (0.71)	3 to 6
2	3. I felt supported by the instructor(s) as I developed my understanding of the course material.	2% (6)	5% (15)	10% (29)	50% (148)	33% (98)	4.1 (0.90)	1, 4 to 6
	14. I was encouraged to provide feedback to the instructors about my questions and concerns about the course.	1% (3)	4% (13)	14% (40)	49% (146)	32% (94)	4.1 (0.85)	
3	5. I felt my contributions to the online discussions were valued by the instructor.	1% (4)	3% (9)	16% (48)	55% (162)	25% (73)	4.0 (0.81)	1, 5, and 6
	7. The class atmosphere encouraged me to make contributions to the online discussions.	0% (0)	5% (16)	15% (45)	54% (160)	25% (75)	4.0 (0.79)	
	11. I felt my learning style was well suited for this course.	1% (2)	5% (14)	15% (43)	54% (159)	26% (78)	4.0 (0.81)	
4	1. Interactions with the instructor helped me understand the course material better.	2% (7)	7% (21)	16% (47)	47% (140)	27% (81)	3.9 (0.96)	1, 2, and 6
	2. Interactions with the other students helped me understand the course material better.	1% (4)	6% (18)	18% (54)	49% (145)	25% (75)	3.9 (0.89)	
	6. I felt my contributions to the online discussions were valued by other students.	0% (0)	4% (13)	21% (63)	56% (165)	19% (55)	3.9 (0.75)	
5	4. I felt supported by other students as I developed my understanding of the course content.	0% (1)	6% (17)	24% (70)	50% (147)	21% (61)	3.8 (0.83)	1 to 3, 6
6	10. The course seemed to be designed to address multiple learning styles.	2% (6)	20% (60)	29% (86)	36% (106)	13% (38)	3.4 (1.01)	1 to 5

N=296 students who completed pre- and post-questionnaires.
NOTE: *Scale goes from 1=strongly disagree to 5=strongly agree. All calculations are based upon participants who responded to Q30 of the student post-questionnaire. A probability level of 0.05 was used to consider a difference statistically significant.*

Overall, there was a high level of agreement with all of the statements. Over 90 percent of the students agreed or strongly agreed that their instructor was accessible to them, a level of agreement significantly higher than most other perceptions. The lowest level of agreement was with the statement "This course was designed to address multiple learning styles," with 49 percent of the students agreeing or strongly agreeing despite three-quarters of the students agreeing that the course was well suited to their own learning style. Gender and program differences in the perceptions are examined in Table 46.

Table 46: Mean level of student agreement with specific statements about the course climate by student gender and program type.

Aspects of Course Climate	Female Students (n=189)	Male Students (n=107)	Students in nonprofit courses (n=99)	Students in university courses (n=197)
Interactions with the instructor helped me understand the course material better.	3.9 (0.95)	3.9 (0.98)	3.9 (0.95)	3.9 (0.97)
Interactions with the other students helped me understand the course material better.	3.9 (0.86)	4.0 (0.94)	3.9 (0.92)	3.9 (0.88)
I felt supported by the instructor(s) as I developed my understanding of the course material.	4.0 (0.91)	4.1 (0.88)	4.1 (0.82)	4.0 (0.94)
I felt supported by other students as I developed my understanding of the course content.	3.8 (0.83)	4.0 (0.81)	3.7 (0.85)	3.9 (0.81)
I felt my contributions to the online discussions were valued by the instructor.	4.0 (0.79)	4.0 (0.83)	4.0 (0.74)	4.0 (0.84)
I felt my contributions to the online discussions were valued by other students.	3.8 (0.78)	4.0 (0.69)	3.7 (0.75)	4.0 (0.74)
The class atmosphere encouraged me to make contributions to the online discussions.	4.0 (0.78)	4.1 (0.80)	3.9 (0.80)	4.0 (0.75)
The instructor was accessible to me.	4.3 (0.68)	4.4 (0.77)	4.4 (0.64)	4.3 (0.75)
The course seemed to be designed to address multiple learning styles.	3.3 (0.97)	3.5 (1.06)	3.5 (0.97)	3.3 (1.02)
I felt my learning style was well suited for this course.	4.0 (0.82)	4.1 (0.80)	4.1 (0.77)	3.9 (0.83)
I was encouraged to provide feedback to the instructors about my questions and concerns about the course.	4.0 (0.92)	4.2 (0.69)	4.3 (0.70)	4.0 (0.90)

NOTE: *Scale goes from 1=strongly disagree to 5=strongly agree. All calculations are based upon participants who responded to Q30 of the student post-survey. Standard deviations are in parentheses.*

Male students reported higher levels of agreement than female students did with the "this course is designed to address multiple learning styles" question (t=2.08, 294 d.f., p=0.04). Males also reported feeling slightly more encouraged than females to provide feedback to instructors (t=2.19, 270 d.f., p=0.03). Students in university courses reported higher levels of agreement that their contributions to the online discussions were valued by other students than students in nonprofit courses (t=-2.93, 294 d.f., p<0.01). Students in nonprofit courses were more likely than students in university courses to agree that their learning style was well suited for the course (t=1.74, 294 d.f., p=0.08) and that they were encouraged to provide feedback to the instructors (t=2.08, 2 d4.f., p=0.04).

Instructor perceptions of the course climate were similar to those of the students, except they tended to report a higher level of agreement (see Table 47). Seventy percent of the instructors "strongly agreed" that they were accessible to their students. The lowest level of agreement was with the statement "This course was designed to address multiple learning styles," with 78 percent of the instructors agreeing or strongly agreeing with that statement.

Table 47: Percentage and number of instructors reporting their level of agreement with specific statements about the course climate.

Aspects of Course Climate	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean (S.D.)
The class atmosphere encouraged students to interact with each other.	0% (0)	0% (0)	3% (1)	33% (13)	65% (26)	4.6 (0.54)
I was accessible to students.	0% (0)	0% (0)	3% (1)	28% (11)	70% (28)	4.7 (0.53)
The course was designed to address multiple learning styles.	0% (0)	8% (3)	15% (6)	60% (24)	18% (7)	3.9 (0.79)
Students were provided regular feedback on their progress in the course.	0% (0)	3% (1)	8% (3)	50% (20)	40% (16)	4.3 (0.81)
Students were encouraged to provide feedback to their instructors about their questions and concerns about the course.	0% (0)	0% (0)	8% (3)	43% (17)	50% (20)	4.4 (0.64)

N=40 instructors
NOTE: *Scale goes from 1=strongly disagree to 5=strongly agree. All calculations are based upon participants who responded to Q30 of the instructor post-survey.*

Discussion

Building on research in science teacher professional development, online learning, and general demographics of the science professoriate and Internet users, Learning Science Online posed a series of questions about who teaches online science courses for teachers, who the instructors of these courses are, and what science learning and teaching looks like in the courses.

Do students in online science courses for teachers reflect the broader teaching population, or are these courses reaching an audience of teachers different from the audiences reached by other forms of professional development?

In terms of school type, students in online science courses for teachers were similar to the general teaching population—90 percent work in public schools; 10 percent work in private, independent or parochial schools. Students taking online science courses for teachers differed from the general teaching population in all other characteristics examined—gender, race-ethnicity, grade levels taught, years of teaching experience, and school community type. When considering only high-school science teachers, however, the LSO students were more representative in race-ethnicity to the broader population.

Students in online science courses for teachers were more likely to be female than the general teaching population. This is particularly striking given the overrepresentation of high-school science teachers where women represent even a lower percentage of the population (CCSSO 2005). This could be explained by the "third shift" phenomenon (Kramarae 2001), where women are fitting their education in among their regular work and home duties—the "anytime, anyplace" nature of online suits their needs for flexibility.

The majority of teachers in the U.S. are white, but with nearly 40 percent minority. Among high school science teachers, however, only 10-15 percent are minority (CCSSO 2005). This latter figure is similar to the percentage of minority respondents in online science courses for teachers (10 percent).

Students in online science courses for teachers were more likely to have less than 10 years of teaching experience (60 percent) relative to the general teaching population (40 percent) (NCES 2005). Given that the majority of the students in these courses were seeking professional development (most often through a master's degree), it is reasonable that they would be more likely to be in the early stages of their teaching careers.

Students in online science courses for teachers were more likely than teachers in the general teaching population to be teaching in schools in rural communities and small towns (31 percent in online courses vs. 17 percent in the general teaching population). These online programs may be reaching teachers in more remote areas that would not ordinarily have access to similar professional development programs. Interestingly, though, only 44 percent of LSO students reported "convenience" as a reason for taking the course.

All of these findings must be tempered with limitations of the sample. First, only half of the students in these courses completed the pre- and post-questionnaires, with better-performing students more likely to participate than students with poorer performance. Second, a substantial number of elementary science courses we located were not able to participate in this study due to their own ongoing evaluation. As reported above, the demographics of elementary versus secondary teachers differ substantially and could have influenced the demographics of our study. For example, secondary teachers are more likely than elementary teachers to have bachelor degrees in science. Also, we do not know the percentage of minority students in the courses, so it is possible that minority students were willing to enroll in online science courses for teachers, but were less likely to participate in this study.

Do instructors in online science courses for teachers represent the typical science professor, or are these courses tapping a different group of potential instructors?

The answer to this question depends on whether instructors are situated in a university or nonprofit program. In university programs, instructors of online science courses for teachers resemble the broader science professoriate—predominantly male, mid-fifties, a Ph.D. in science, little K-12 teaching experience. There is one notable difference between the online instructors in university programs and typical university science professors—no instructor of an online course was actively pursuing tenure. They were either graduate students, adjunct faculty, already tenured, or retired. In nonprofit programs, instructors of online science courses for teachers did not resemble the broader science professoriate in other ways as well—they were predominantly female, were less likely to have earned a Ph.D. in science, and had considerable K-12 teaching experience. The lack of courses targeting elementary teachers in this study could have shaped the demographics of the instructors who participated and perhaps if elementary teacher courses had been included, the instructors in this study may not have as closely resembled the science professoriate.

Instructor salaries range from approximately $700-$8000 per course. Most courses were conducted with one instructor, typically a scientist. Other courses employed a team of scientists, or a scientist teamed with an educator. These instructors were generally selected from a group of known colleagues, some with decades of face-to-face science teaching experience. There was no formal recruitment of instructors for the courses in this study. This is in contrast to the typical rigorous recruitment and selection process for new faculty, but is not dissimilar to the recruitment of part-time faculty and lecturers. Program coordinators reported feeling fortunate to be able to draw from an excellent pool of candidates who, because of geographical or time considerations, may not ordinarily teach these courses face to face. They do not feel the need to spend time and money recruiting more broadly because they are confident of the talents of their colleagues, but without a more open process it is impossible to know if there are other highly qualified candidates who are not being considered.

Instructors of online science courses for teachers reported feeling prepared both technologically and scientifically, but they reported feeling least prepared in dealing with students' different learning styles. These perceptions did not vary with program or gender of instructor. Only one-third of university instructors had any training for teaching online, but most instructors at nonprofit organizations had either some face-to-face or online training for online facilitation. Most of these instructors had taught the course of study previously which may help explain their general feeling of preparedness. Consistent with other research on instructors in online courses (Palloff 1999), the majority of LSO instructors' time was spent on reading and responding to student posts on the discussion boards, which is quite a different process from delivering a typical lecture and even responding to occasional questions from the class. They also reported spending significant time on evaluating student work.

What types of instructional methods are used in online science courses for teachers and how do they compare to the types of practices called for by research and national standards?

Online science courses for teachers ranged from 5 weeks (1 credit) to 13 weeks (1-3 credits) in duration. The majority of students and instructors report spending 8-10 hours in a typical week on coursework. This is in line with the typical workload estimation of two hours of out-of-class work for each hour of class time. Thus, a typical three-credit course would yield 9 hours per week (for a semester).

There was great variation in development processes and costs across programs. Most instructors reported involvement with the development of their courses, but often there were technical developers or content experts involved as well. The variation of development costs for one course was vast, ranging from $3000 at a university to $150,000-$200,000 estimated by a nonprofit institution for its development (under an external grant). The great difference in spending speaks to the non-uniformity across online science courses for teachers, and raises questions about the relationship of spending to quality in these courses. A panel of science content experts is currently rating the 40 online science courses in this study in terms of the relevance, accuracy, and depth of their science content. Subsequent analyses will examine the types of instructional methods used for the different courses and how the methods relate to these dimensions of quality of science content.

Most students perceived materials to be at an appropriate level for them, with men more frequently than women reporting that materials were too easy for them. Students in university programs had a harder time than those in nonprofit programs seeing how concepts built upon previous learning and how concepts were linked together. This latter difference may be explained by a difference in the depth of the science content in courses between university and nonprofit programs—perhaps the content in university-based courses was more difficult than the content in nonprofit-based courses or perhaps they are intended to serve students with different levels of preparedness. These possibilities will be examined once the panel of science experts had its science content review.

Discussion boards, books, online readings, and images were primary instructional materials in nearly all of the online science courses for teachers. Students and instructors reported very little use of physical materials and real-world phenomena in these courses. The instructional activities that were most frequently reported by both students and instructors included:

a) Articulating and reflecting on their own ideas and the ideas of others

b) Reading and responding to discussion postings from the instructor and their peers

c) Raising questions with other students about their scientific ideas

d) Providing evidence to support their scientific ideas.

This combination of instructional tools and activities suggests these courses created active communities of practice that emphasized active participation by students, through sharing ideas and engaging in collaborative activities and dialogue. While some courses relied on instructional activities that emphasized one-way content delivery from the instructor (e.g., readings, worksheets), online discussions were often key components of these courses.

Instructors most often chose new topics for discussion, particularly in university courses. Both students and instructors reported that most students participated in discussion, with some students participating more than others. Most students agreed that the class environment encouraged them to participate in discussions. This suggests that the social interaction is structured by the instructor but not at the expense of student engagement. These perceptions of the course environment did not vary by gender, contradicting other findings that women are intimidated in science classes and that women may sometimes be silenced in online discussions (Herring 2000). These differences in findings are likely attributable to the nature of the environments in which they occurred—formal courses in LSO versus informal listservs and bulletin board in Herring's studies.

Most students in online science courses for teachers reported frequent feedback from their instructors and found this feedback helpful in improving their understanding of the science content in the course. Students reported that their instructor was accessible, countering a common myth that online students may feel isolated or abandoned. However, it is important to recall that students with higher final grades were more likely to participate in the study than students with lower final grades. It is possible that students with less favorable course perceptions did not participate in this study.

In summary, the online science courses for teachers in this study appear on the surface to use instructional methods advocated by research and standards in science teacher professional development and online learning, such as articulation and reflection of students' ideas in discussion boards. Students and instructors invest a large amount of time in their coursework, and students responding generally report feeling supported in these environments.

These courses show promise for future research on science learning online and science teachers' mastery of content. The textual and archival nature of the majority of communications in the courses provides rich resources to examine. Interesting questions to pursue include:

- What is the depth and nature of students' articulation and reflection of scientific ideas in these courses?
- Is discussion fostering learning in a meaningful way and if so, how?
- In what ways do (or don't) these online courses create communities of science learning?

Not only does the rampant growth in online education evoke a sense of responsibility to study its quality, but this new medium may provide a new lens to study the process and features of science learning in action.

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