AN ANALYSIS OF INTERACTIONS AND OUTCOMES ASSOCIATED WITH AN
ONLINE PROFESSIONAL DEVELOPMENT COURSE FOR SCIENCE TEACHERS

by

David Edward Randle

Submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy
under the Executive Committee
of the Graduate School of Arts and Science

COLUMBIA UNIVERSITY

2013
ABSTRACT

AN ANALYSIS OF INTERACTIONS AND OUTCOMES ASSOCIATED WITH AN ONLINE PROFESSIONAL DEVELOPMENT COURSE FOR SCIENCE TEACHERS

David Edward Randle

This mixed-methods study examined the interactions and learning outcomes of science teachers in an online graduate-level course on evolutionary biology intended to improve their content knowledge and science lesson planning.

Discussion posts made by the teachers in this seven-week course were analyzed for cognitive presence using the Community of Inquiry framework. Compared to other studies examining cognitive presence, high levels of Integration level cognitive activity were observed (47% of total posts). This was most likely due to the design of the discussion prompts and expectations used to frame student participation. The questions were open-ended, and students were expected to use reference materials to construct their responses. During the course, 395 student posts contained statements that could be coded for scientific accuracy. Of these, 85% were coded as scientifically accurate. This reinforces reports from previous literature that the online environment is conducive to reflective and careful contributions by participants.
As the course progressed, the number of faculty posts per discussion declined, while the number of student posts remained relatively constant. Student-to-student posts increased in frequency as faculty participation dropped. The number of student posts increased towards the end of each two-week discussion period, however the frequencies of posts with scientifically accurate statements and Integration level cognitive activity remained relatively constant over this same period. The increase in total posts was due to the increase in other types of communication in the discussions.

Case study analysis was used to examine patterns of online behavior in three participants who achieved different course grades. A low-performing student had a pattern of intermittent activity, made low numbers of posts in each discussion, and had low percentages of posts that contained scientific statements or indicators of Integration level cognitive activity compared to classmates. A medium-performing learner posted infrequently but was efficient in making scientifically accurate posts that demonstrated Integration. Both the medium and low performer made most of their posts near the end of each two-week discussion period and had limited interaction with other learners. The high-performing learner demonstrated high levels of engagement with the course material. She posted frequently, introduced new resources to the other learners, and had high numbers of scientifically accurate and Integration level posts.

An examination of teachers’ views of the Nature of Science (NOS) using a pre- and post course Views of Nature of Science – C survey indicated that this group of teachers began the course with relatively informed views of many of the nature of science aspects. An exception was views about the nature of scientific theories and laws. At the start of the course 10 of 18 participants had naïve views, five had partially informed
views, and three had informed views. While scientific definitions of theories and laws were addressed in the course, there was no task that asked teachers to apply their understanding of this topic. When the course finished, six participants still had naïve views, six held partially informed views, and six had informed views.

Participants used course content to create teaching unit plans that indicated how they might use the course outcomes in their practice. Most of the learning objectives stated in the unit plans were grade-level appropriate when referenced to the Benchmarks for Science Literacy. The exception was the inclusion by some middle school teachers of detailed analyses of evolutionary relationships using genetic data. Although there was alignment of stated objectives to content from the online course and lesson activities, some of the teachers did not fully align assessments with their objectives.

Based on these findings, it is suggested that designers of online instruction be mindful in the framing of learning tasks and use open-ended discussion prompts that require the use of reference materials if Integration level cognitive activity is the goal. The teachers in this course were generally able to utilize content from the course to create teaching applications, but more support for pedagogical applications could be an important addition for teachers who struggled with this task. This study reinforces previous research that indicates that online asynchronous discussions encourage reflection by learners. However, analysis of individuals who struggled in the course indicates that the online format may not suit all learners since consistent effort and the ability to communicate effectively in writing are important for success.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Statement of Purpose</td>
<td>1</td>
</tr>
<tr>
<td>Organization of the Thesis</td>
<td>2</td>
</tr>
<tr>
<td>II OVERVIEW</td>
<td>4</td>
</tr>
<tr>
<td>Literature Review</td>
<td>4</td>
</tr>
<tr>
<td>Theoretical Framework</td>
<td>17</td>
</tr>
<tr>
<td>Research Questions</td>
<td>19</td>
</tr>
<tr>
<td>III. METHODS</td>
<td>20</td>
</tr>
<tr>
<td>Overview</td>
<td>20</td>
</tr>
<tr>
<td>Research Setting</td>
<td>21</td>
</tr>
<tr>
<td>Disclosures and Researcher Background</td>
<td>23</td>
</tr>
<tr>
<td>Validity and Reliability</td>
<td>24</td>
</tr>
<tr>
<td>Methods for Investigating Individual Research Questions</td>
<td>25</td>
</tr>
<tr>
<td>Questions 1 and 2 (Patterns of Online Interaction)</td>
<td>25</td>
</tr>
<tr>
<td>Question 3 (Views of Nature of Science)</td>
<td>30</td>
</tr>
<tr>
<td>Question 4 (Unit Plan Objectives and Alignment)</td>
<td>32</td>
</tr>
<tr>
<td>Questions 5 and 6 (Unit Plans and Nature of Science)</td>
<td>33</td>
</tr>
<tr>
<td>Research Timeline</td>
<td>36</td>
</tr>
<tr>
<td>Summary of Research Methods Used</td>
<td>37</td>
</tr>
<tr>
<td>IV. RESULTS</td>
<td>39</td>
</tr>
<tr>
<td>Research Question #1</td>
<td>39</td>
</tr>
</tbody>
</table>
Cognitive Levels .................................................... 39
Scientific Accuracy ............................................... 41
Other Interactions ................................................. 45
Instructional Implications ..................................... 46
Faculty/Student Interaction .................................... 46
Temporal Patterns of Course Participation .............. 49

Research Question #2 (Case Studies of Participation) .......... 56
  Case Study of a Low Performer .............................. 57
  Case Study of a Medium Performer ....................... 64
  Case Study of a High Performer ......................... 72

Research Question #3 (Views of Nature of Science) .......... 85

Research Question #4 (Unit Plan Objectives and Alignment) .... 90
  Objectives ...................................................... 90
  Alignment of Unit Plans to Objectives ................. 95

Research Question #5 (Unit Plan Analysis) ..................... 97

Research Question #6 (Unit Plans and Nature of Science) .... 99

V. DISCUSSION .......................................................... 102

Research Question #1 (Patterns of Online Interaction) ......... 102
  Cognitive Level ................................................. 102
  Scientific Accuracy ........................................... 106
  Other Interactions ............................................. 108
  Instructional Implications ................................... 109
  Faculty/Student Interactions .............................. 110
# LIST OF TABLES

Table 3.1: Science Lesson Plan Analysis Instruments Elements and Weights .....34

Table 3.2: Summary of Three-Phased Research Approach ......................... 36

Table 3.3: Research Questions, Procedures and Instruments ....................... 37

Table 4.1: Examples and Descriptions of Integration, Exploration, and Triggering Events ................................................................. 40

Table 4.2: Total Numbers and Percentages of Posts at Different Cognitive Levels ......................................................................................... 42

Table 4.3: Total Number of Posts Categorized as Other Interactions ............. 46

Table 4.4: Number of posts by a low performing learner per discussion .......... 64

Table 4.5: Number of posts by a medium performing learner per discussion ...... 72

Table 4.6: Number of posts by a high performing learner per discussion ........ 85

Table 4.7: Teaching Experience (in years) and Grade Level of VNOS Participants .................................................................................. 86

Table 4.8: Overall Participant Pre- and Post-Course Views of Nature of Science Aspects ................................................................. 89

Table 4.9: Frequencies of Change in Views of Nature of Science Aspects ..... 90

Table 4.10: Categorized Lesson Objectives .................................................. 92

Table 4.11: Summary Scores for Unit Plan Alignments ............................... 96

Table 5.1: A Comparison of Studies That Used Community of Inquiry Coding For Cognitive Presence as Percentages of Total Posts .....104
LIST OF FIGURES

Figure 4.1: The number of posts coded as scientifically accurate, having partial scientific misconceptions, and as scientifically inaccurate during each discussion ................................................................. 44

Figure 4.2: The percentage of posts that are scientifically accurate, with partial scientific misconceptions, and inaccurate as a function of the total number of posts that contained scientific statements ........ 45

Figure 4.3: The number of student and faculty posts for each discussion .......... 47

Figure 4.4: The number of student posts to faculty and faculty posts to students during each discussion ................................................................. 48

Figure 4.5: The number of student posts made to the discussion prompt, to other students, and to faculty during each discussion ......................... 49

Figure 4.6: The total number of posts made by students on successive days of each discussion ................................................................. 50

Figure 4.7: The proportion of Other Interaction posts made by learners as a function of the total posts made on successive days of all discussions .......... 52

Figure 4.8: The proportion of posts from each successive discussion day that contained scientifically accurate statements as a function of the total number posts on each day .............................................. 53

Figure 4.9: The proportion of posts from each successive discussion day that contained statements coded at the Integration level as a function of the total number posts on each day .............................................. 54

Figure 4.10: The proportion of posts from each successive discussion day that contained scientifically accurate statements, partial scientific misconceptions, or scientifically inaccurate statements as a function of the total number of posts that contained scientific statements ........ 55
ACKNOWLEDGEMENTS

I would like to thank the following people who made this work possible …

To Laura, Lindsey, and Brooke: You have surrounded me with laughter and love. Your patience and support made it possible for me to take this over the finish line.

To my parents and family: You have always been, and continue to be there for me. You taught me how to chase my dreams and not give up.

To my friends and colleagues at the American Museum of Natural History: You keep me on my toes and make going to “work” so much fun.

And a special thanks to Dr. O. Roger Anderson: You helped me find this path many years ago and provided wisdom, guidance, confidence, and encouragement for every step along the way.
Chapter I

INTRODUCTION

Statement of Purpose

Education using online computer-mediated communications has gained considerable popularity over the last decade. Both formal and informal educational institutions are utilizing online courses to reach out globally to audiences who may not otherwise have access to their programs. As this format gains popularity in general education, it is also being adapted as a means for delivering professional development to science teachers. There has been considerable evaluation to justify the expense of such programs, however there is still a significant need for empirical research to examine teachers’ behaviors in online professional development and to determine how their practice changes as a result (Dede et al., 2009). An important, yet difficult question relating to any teacher professional development program is how to measure the effects that the program has on classroom practice and ultimately on student learning.

As a science teacher in New York City, I spent fifteen years teaching middle and high school, life, Earth, and physical science. During that period I began teaching online science courses for teachers through the American Museum of Natural History’s Seminars on Science program. Since 2004, I have worked full time doing science teacher professional development at the American Museum of Natural History, including continued involvement in Seminars on Science. These experiences have led me to questions about how online science teacher professional development influences teacher knowledge and practice. It is my hope that my experience teaching in both school classrooms and online settings, providing in-person professional development to teachers,
and designing online educational experiences will provide a perspective that leads to a meaningful contribution to the research base for online education and informs the development of future online science teacher professional development.

This study uses a mixed-methods model to examine the case study of an online course on evolution for science teachers. An analysis of online interaction along with pre- and post-course written surveys and interviews has been used to examine the social construction of scientific content knowledge and understandings of the nature of science. Unit plans created by course participants were used to examine classroom application of the course content.

Organization of the Thesis

The thesis is organized into six chapters. Chapter 1 contains the statement of purpose and a description of the thesis organization. Chapter 2 is an overview of the topic, containing the literature review, a discussion of the theoretical framework, and the research questions. The Methods, Results, and Discussion chapters utilize a parallel framework in which each research question is considered in separate sections, the sequence corresponding to the numbered order of the questions. Chapter 3 is a description of the methods used for this study. Separate sections describe the research methods for each research question, except for cases where the methods for two questions were similar enough to be combined. Chapter 4 is a presentation of the results, once again, presented by order of the research question. Chapter 5, the Discussion, considers the results in greater detail and presents the author’s interpretation of trends that emerged from the data as well as connections to literature in the field of online education. The
parallel organizational framework is applied in this chapter. Chapter 6 is a brief conclusion that summarizes some of the main findings and presents some of the potential implications of this research.
Chapter II
OVERVIEW

Literature Review

Online education is a rapidly growing field. Many universities are turning to online undergraduate education as a means of reaching a broader range of students, especially those that have difficulties commuting long distances to school, and to mitigate a lack of physical classroom space for growing enrollments (Allen & Seaman, 2006). It is much less expensive to serve a larger student body through online programs, as opposed to large-scale capital construction of school buildings. Business communities have also turned to online education as a means of increasing efficiency and to improve access by busy employees who may be geographically dispersed (Friedman, 2006; Wutoh, Boren, and Balas, 2004).

There has also been an increase in online forms of professional development in teacher education (Whitehouse, Breit, McCloskey, Jass Ketelhut, & Dede, 2006). Many of these programs are offered for graduate credit through degree-granting universities (Allen & Seaman, 2006), while others are associated with government agencies or informal educational institutions such as museums and public television stations (Asbell-Clarke & Rowe, 2007). These may or may not be available for graduate credit. Several of these programs are concerned with science teacher professional development (Asbell-Clarke & Rowe, 2007).

In considering online professional development over more traditional models of face-to-face learning, it is important to consider the advantages and disadvantages of the medium, including issues such as the following. What are the inherent advantages and
disadvantages of online learning? What are the trade-offs? What does one give up by using an online model? Other than convenience, what types of learning outcomes is online learning suited to achieving?

While there is a large research base concerned with online professional development for teachers, the field of online professional development for science teaching is still developing. There is only a small body of empirical research in this field and there are few papers that are consistently cited in the literature. Much of what does exist is in the form of program descriptions. There appears to be a need for more empirical research in this field (Dede et al., 2009).

There is a growing body of work and a consensus developing about what the elements of effective professional development are (Desimone, Porter, Garet, Yoon, & Birman, 2002; Garet, Porter, Desimone, Birman, & Yoon, 2001; Loucks-Horsley, Hewson, Love, & Stiles, 2010; Penuel, Fishman, Yamaguchi & Gallagher, 2007). Since online technology is merely one way of offering services to teachers, it is worthwhile to review what is known about traditional professional development.

Loucks-Horsley et al. (2010, p. 68) described some of the elements of effective science professional development. They state that effective professional development is research-based and driven by student learning data and a well-defined image of effective classroom learning and teaching. It provides opportunities for teachers to examine and build their pedagogical and content knowledge by engaging as adult learners in the learning approaches they will use with their students. In addition, effective professional development invites teachers to collaborate with colleagues and other experts to improve their practice and supports them to serve in leadership roles. It links with other parts of
the education system and is constantly evaluated and improved. While many professional development providers base their program designs on these principles to some degree, there is little empirical evidence that teases out the effects of these elements on teacher practice. Much of the work that has been done on professional development relies on participant satisfaction surveys. While there is evidence that reliable conclusions can be drawn from self-reported data (Banilower, Heck, & Weiss, 2007), it is important to note that teacher perceptions and understandings of what “best practice” is can influence their reporting (Crawford, 2007). In other words, if teachers know that inquiry-based teaching is the “hot thing” they are likely to report that they are doing it. However, they may be defining it in their own terms or, at the very least, differently than the research community.

Garet et al. (2001) performed a large scale study of over one thousand science and math teachers involved in the Eisenhower Math and Science program to determine the effects of different elements of professional development on teachers’ learning. They reported several effective structural and core features. The structural features included a reform orientation, extended duration, and collective participation of teachers from the same school. Penuel et al. (2007) also report that a reform-oriented teacher education program using study groups was more effective at promoting teacher learning than traditional workshops or college courses. Core features that were found to contribute to acquisition of knowledge and skills were: a focus on content knowledge, active or inquiry learning approaches in the professional development, and a high level of coherence with the curricula and standards being used by the participants.
Reform types of professional development such as study groups, mentoring, and coaching have received attention recently (Garet et al., 2001). Loucks-Horsley et al. (2010) report participant dissatisfaction with what the authors characterize as traditional workshop structures. Traditional workshops usually take place away from a school, are held outside of school hours, and typically involve some sort of “expert” leader. These experiences are common, but they are criticized as being ineffective in changing teachers’ practice due to short duration and lack of activities and sufficient content to increase teachers’ knowledge (Loucks-Horsely et al., 2010). Reform types of professional development may take place during a teacher’s regular workday or, in the case of coaching or mentoring, during classroom instruction. These activities may be more likely to connect directly to classroom teaching and also be easier to sustain over time (Garet et al., 2001).

The Garet et al. (2001) study was the first to do a large-scale empirical comparison of the effects of professional development characteristics on teacher learning. In Desimone et al. (2002), the same group reported on a three-year study of professional development effects. They were able to reinforce their earlier findings regarding the effectiveness of collective participation of teachers who work together, active learning components of professional development, and the value of reform-based activities.

Taken as a whole, the research suggests that beneficial changes in teaching would occur if teachers experienced consistent, high-quality professional development. But Garet et al. (2001) and Desimone et al. (2002) suggest that these types of experiences are rare. It appears that just as classroom instruction in science fails to reach goals in line with current learning theory, professional development experiences generally fall short as
well. Part of the issue seems to be the way districts and schools choose to allocate limited funds. The choice is often between providing less intense professional development for a larger number of teachers or more in depth and higher quality activities for fewer teachers (Desimone et al., 2002).

This discussion begs the question of the role that online programs for science teachers can play in improving the quality and reach of professional development. One major theme that emerges from the literature is that online environments seem to be particularly well suited for fostering critical thinking and developing reflective learning communities (Dede, Whitehouse, & Brown-L’Bahy, 2002; Bullen, 1998). This is in line with social constructivist learning models, including citations by several papers to Lave and Wegner (1991) for their work on community of practice. Asbell-Clarke and Rowe (2007) elaborate on the fact that all learners in an asynchronous online course have a voice no matter where they fall on the novice-expert continuum, thus supporting active learning by all participants in a constructivist learning environment. Asbell-Clarke and Rowe (2007, p. 6) note:

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.

Harlen and Doubler (2004) compared an online science course for elementary and middle school teachers, designed to promote inquiry thinking, to a face-to-face course created to cover the same content. While comparison of the two modalities is difficult, the online participants “reflected on their learning and on the process of enquiry to a greater extent than the on-campus participants” (p. 1247). Advantages of the online
environment were communication through writing that required precise language, asynchronous communication that provided time for reflection and participation in multiple discussions, flexibility of time, opportunities to compare experiences with many classmates, and access to the thinking of a team of experts. The disadvantages identified in this study were a dependence on writing that is a disadvantage to teachers who do not write particularly well, the fact that written instructions can sometimes be ambiguous and lead to confusion and frustration, lack of individual feedback from the instructor that can lead to uncertainty as to whether or not views are being noted, and the online course imposes a specific mode of learning on people who may have different learning styles.

The group of Dede, Breit, Jass Ketelhut, McCloskey, and Whitehouse (2005, 2009) examined the empirical research in the field of online teacher professional development (oTPD). They examined more than 400 papers and chose 40 they believed were representative of high quality empirical research on oTPD to date. Their research questions aligned roughly to four categories: program design, program effectiveness, technological design, and learner interactions.

It is interesting to note that many of the studies cited in the program design category did not deal with online technology, but were explorations of best practice in teacher professional development. Some of the citations have been discussed previously in this literature review. Design decisions included examinations of content, delivery methods, and pedagogical strategies. These studies focused on ideas for fostering teacher-centered professional development online (Renninger & Shumar, 2004) and the necessity of including participants in design decisions regarding content and organization of online resources (Farooq, Schank, Harris, Fusco, & Schlager, 2007).
Methods for measuring effectiveness of oTPD typically involve surveys of participants. This methodology is typical of face-to-face professional development and measures perceived value of the experience. Dede et al. (2009) stress that the variety of data available from oTPD allows a richer analysis. For example, Graham (2007) used archived online discussion data in a mixed-methods study to determine the effectiveness of an online professional learning community in improving teaching practice. The study determined that oTPD can have an effect, but that results were highly dependent on school administrative support and the ability of teachers to develop collaborative skills.

The studies in the technical design category dealt primarily with communication and multimedia innovations that support learning or the building of learning communities. Barab, Kling, and Gray (2004) looked at the use of gaming to provide context for learning. The goal of the study was to engage the teachers by co-designing elements of the project with teachers. However, the early stages of the project lacked the specificity to be useful as a model for the larger education community.

Learner interaction studies examined the quality of interaction among participants. Hawkes and Good (2000) took advantage of the audio and text communication that is archived in online professional development, much of which is not available in face-to-face programs. They found evidence of reflective discourse that allowed teachers to examine their practice using current instructional theory. These findings reinforce the social constructivist strengths of online interaction. Other studies (Yang & Lui, 2004; Whitaker, Kinzi, Kraft-Sayre, Mashburn, & Pianta, 2007) used archived online interaction to examine formation of professional learning communities and reached similar conclusions. This archived communication is a rich source of data that is ripe for
innovative analysis about the outcomes of online professional development.

In a summary to their studies Dede et al. (2009) assert a need for a balanced approach to research in oTPD. Recognizing that purely evaluative studies are necessary for funding concerns, they point to a need for more “empirical research that provides answers about why some models have a greater impact than others on teacher behavioral changes” (p. 15). In other words, there is a need for more work that looks not just at whether a program works, but also at why it works. Another need that surfaced as a result of their analysis was the need for new methods for measuring outcomes. Much of the research on both face-to-face and oTPD is based on teacher self-reports. While not without value, this data does not allow an assessment of teachers’ knowledge or comparisons of practice to standards or goals for improvement.

Asbell-Clarke and Rowe (2007) described online science courses for teachers. They addressed three questions. 1) Who are the students in online science courses for teachers? 2) Who are the instructors in online science courses for teachers? 3) What does science teaching and learning look like in these courses? Their study covered six programs: three by education non-profits (the setting for the study reported in this thesis was included in this group) and three by universities. Two of the university programs were tied to master degree programs. All of the courses from each program were available for at least one graduate credit. The courses from the non-profits tended to be shorter in duration than the university courses. Presently, two of the programs, one university and one non-profit, have stopped offering online courses. Among the programs only one, a university program, is self-sustainable. The rest are dependent on grants or
support from their parent organization. All of the courses focused on science content rather than pedagogy.

Forty courses were studied. Twenty-eight included life science content, 14 Earth and space science, 13 environmental science, and 13 science education. Seven of the courses included physics, chemistry, or astronomy. Two hundred fifty of the 400 students in the courses were surveyed. Demographically the students in the courses were 64% female, 91% white, and 93% science teachers, with 48% identifying themselves as biology teachers. Fifty-seven percent were under 45 years of age. Eighteen percent were over 56, and 33% claimed to be from small towns or rural settings. Most (82%) reported that they were taking the course for professional advancement.

Instructors in the courses tended to be white, middle-aged males although there was a difference between the non-profits and the universities. Seventy-two percent of the 25 university instructors were male, while 6 of the 10 non-profit instructors were female. Across all programs, 71% of the instructors were over 50 years of age. The university instructors tended to hold doctorates although few were tenure track professors. The instructors for the non-profits tended to have master’s degrees. It is interesting to note that in courses designed for science teachers, fewer than half of the instructors had K-12 teaching experience. Nine of the 10 instructors for the non-profits had this experience while 7 of the 25 university instructors had taught at this level.

Course characteristics were assigned to one of three categories: course environment, instructional methods and materials, and nature of communication. The course environment included elements of course design and usage. Most of the university instructors (89%) were involved in the design of the course, compared to only half of the
non-profit instructors. Course development was supported by grants at five of the six institutions and costs ranged from a few thousand dollars to over $150,000. All but one of the courses were offered through a commercial web platform such as WebCT, Blackboard, or eCollege. On average students reported spending more than eight hours a week on course work, with 61% of students visiting the course seven or more times per week. Instructors reported that reading and responding to student posts was the most time-consuming task in teaching online.

An analysis of instructional methods and materials compiled by Borko, Stecher, and McClam (2003) was based on a list of 23 instructional activities likely to occur in online learning. Space in this literature review precludes a detailed review of all 23 activities but some general trends emerge and are summarized here. Courses offered by non-profits reported higher frequencies of student discussion of scientific ideas, while university courses emphasized student work on solving problem sets. Three quarters of instructors and 90% of students found web-based course materials easy to access and 90% of students and instructors reported that course materials were at an appropriate level. No instructors reported the materials too easy for the students, however, 5% of the students reported that they were. Five percent of instructors and 5% of students reported that the materials were too difficult.

None of the courses met face-to-face, so all communication was electronic via email, discussion boards, or synchronous chat. In 60% of the courses, there was an expectation by instructors that students would post to a discussion board at least once a week. In half the courses, discussion topics were pre-selected for students. Two thirds of students and instructors reported that nearly all students in the class contributed to the
discussions, but some students participated more than others. Seventy percent of students reported receiving feedback from instructors and from other students at least once a week. Students found feedback from the instructors to be more helpful than feedback from other students. Only 49% of students agreed that the course was designed to address multiple learning styles.

As evidenced by much of this review, the research focus in the field of oTPD is still descriptive in nature. A move to a more empirical and analytical approach will likely provide information to enhance the work of designers of these programs and inform the research community about the elements of online education that are able to promote change in teacher practice. This type of research is, of course, not without major challenges. For example, Dede et al. (2005, p.5) note:

In particular, measuring the educational effectiveness of an online teacher professional development program is a major challenge. How should implementers define “success” for an online teacher professional development program, and what evidence should they collect to determine whether the program has reached its objectives? Effectiveness includes issues of scalability, sustainability, and cost-benefit. Moreover, assessing “impact” (the degree of transformation in practice) and “reach” (the number of teachers and organizations influenced) are important, but complicated. Often, within the complexity of educational settings, where multiple school change and professional development initiatives may be underway simultaneously and students move from teacher to teacher, it can be difficult to isolate and attribute the contribution of one professional development program on a teacher’s development, and even more difficult to gauge the effect of professional development on student achievement or understanding.

From a research perspective, online education provides a rich opportunity for exploring text-based interactions, and there have been significant efforts in the past decade to create frameworks and methodologies for studying computer-mediated communication in online courses. The Community of Inquiry (CoI) Framework (Garrison, Anderson, & Archer, 2000) is a framework that has been adopted by a large
community researching online education. Survey tools (Rovai, Wighting, Baker, & Grooms, 2002; Arbaugh, et al., 2008) and coding schemes (Shea, et al, 2010) have been developed and validated. The CoI framework is based in part on Dewey’s beliefs that “inquiry was a social activity and went to the essence of an educational experience” (Garrison, Anderson, & Archer, 2010, p. 6). The framework addresses three components, each characterized as a “presence,” related to the online learning experience. They are: social presence, which can be described as an online student’s ability “... to project their personal characteristics into the community, thereby presenting themselves to the other participants as real people” (Garrison, Anderson, & Archer, 2000, p. 89); cognitive presence, which is the “extent to which learners are able to construct and confirm meaning through sustained discourse” (Garrison, Anderson, & Archer, 2000, p. 89); and teaching presence, which “consists of three areas of responsibility -- design, facilitation and direct instruction. Each of these is associated with the integration of social and cognitive processes in terms of the purposeful nature of the learning experience” (Arbaugh, et al., 2008, p. 134). Research using the Community of Inquiry framework has produced validated instruments for surveying participants (Arbaugh, et al., 2008) and coding text-artifacts of asynchronous course communication (Shea et al., 2010).

In most of the CoI literature, investigations have focused on one presence at a time. Recently there have been attempts to look at all three simultaneously (Shea et al., 2010) and to make correlations between presences. Shea also recognizes that there is communication in an online class that occurs apart from the asynchronous discussion boards, such as email and feedback on assignments that are important artifacts that may be useful in evaluating the dynamics of online course interactions.
Another aspect of the current study examined teachers’ views about the Nature of Science (NOS). Reforms in science education have promoted the construction of knowledge by learners (American Association for the Advancement of Science [AAAS], 1993; Hodson, 1988; National Research Council [NRC], 1996) and an emphasis on the process of inquiry in scientific investigation (AAAS, 1993; NRC, 1996). As a means of achieving these goals, teacher understanding of the nature of science (NOS) has been identified as a critical factor in bringing an improved understanding of science processes to students (AAAS, 1993; NRC, 1996; Lederman, 1992). While indicating that interpretations of the meaning of the term Nature of Science vary depending on the source and the purpose, Schwartz, Lederman, & Crawford (2004) define NOS as referring “... to the values and underlying assumptions that are intrinsic to scientific knowledge, including the influences and limitations that result from science as a human endeavor” (p. 611).

Lederman (1998) makes the case that an understanding of NOS is crucial if learners are to avoid the construction of an image of science as more than just a body of facts. For teachers to gain the necessary knowledge and skills associated with NOS, inquiry experiences should be provided throughout science teacher education (AAAS, 1993; Gallagher, 1991; NRC, 1996; Schwab, 1962; Welch et al., 1981). How inquiry experiences translate into NOS views has been examined. Schwartz et al. (2004) explored the difference between implicit and explicit NOS instruction and point to research on early inquiry-based curriculum models such as BSCS Biology and PSSC that used an implicit approach and were unsuccessful in achieving NOS learning objectives (Lederman, 1992). One of the factors in the
failure of these programs was a limitation of teacher knowledge and experience with actual scientific investigation (Hodson, 1988). Abd-El-Khalick and Lederman (2000) found that including explicit NOS instruction in teacher education programs improved the acquisition of NOS views more effectively than inquiry-based instruction that did not include this element. In a study of 15 pre-service science teachers, Schwartz et al. (2004) showed that the laboratory portion of an internship program had little effect in developing NOS views in the participants. However, direct reflection through journaling and group discussion were effective in achieving this goal.

Theoretical Framework

This research examines online learning about science content and the nature of science from a Social Constructivist perspective. Social Constructivist learning theory is based in large measure on the work of Lev Vygotsky (1962) who believed that social interaction is an important part of the learning process. The zone of proximal development (ZPD) is a critical piece of this theory. The ZPD is considered the difference between what a learner can do on their own and what they can do with the help of a teacher or more experienced other. The commonly used educational term “scaffolding” addresses this concept. Asynchronous online discussions are hypothesized to be a format that is suited to supporting socially constructed learning.

An online learning community engaged in social constructivist learning should show evidence of learners interacting with others to develop their knowledge. There should be a grappling with understandings of topics that is assisted by other learners and
faculty. Scaffolding will occur through questioning that illuminates previously unseen lines of reasoning. Instead of focusing on one right answer or an instructionally correct view, instructors should promote democratic dialogue (Buraphadeja and Dawson, 2008).

Community of Inquiry (CoI) is a framework for understanding how social constructivism works within an online community. Introduced by Garrison, Anderson and Archer (2000), the CoI framework is a means of understanding computer-mediated conversations such as discussion boards. The CoI framework consists of three categories of interaction: teaching presence, social presence, and cognitive presence. Social presence can be described as an online student’s ability “. . . to project their personal characteristics into the community, thereby presenting themselves to the other participants as real people” (Garrison, Anderson, & Archer, 2000, p. 89); cognitive presence, which is the “extent to which learners are able to construct and confirm meaning through sustained discourse” (Garrison, Anderson, & Archer, 2000, p. 89); and teaching presence, which “consists of three areas of responsibility—design, facilitation and direct instruction. Each of these is associated with the integration of social and cognitive processes in terms of the purposeful nature of the learning experience” (Arbaugh, et al., 2008, p. 134).

This study uses a CoI coding scheme to evaluate levels of cognitive and teaching presence in online discussions. This approach is grounded in a body of work that has been validated by other groups using the Community of Inquiry framework. These methods have been useful for illuminating discussion trends and examining interactions between members of online learning communities, including both students and faculty.
Research Questions

This study addresses the following six research questions:

1. What are teachers’ patterns of online interaction through seven weeks of an online course on evolution?
2. Based on case-study analysis, what characterizes the patterns of online interaction for a sample of teachers involved in a seven-week online course on evolution?
3. How do teacher views of the nature of science change over the seven-week period of an online course on evolution?
4. What are the objectives of teacher-created unit plans that are based on experiences from an online science course for teachers? How do finished unit plans align with these objectives?
5. Using the Science Lesson Plan Analysis Instrument (Jacobs et al, 2008), what are the weighted scores from analysis of teacher-created unit plans using content from an online course on evolution?
6. What relationship, if any, is there between teachers’ Nature of Science profiles and the quality of their science lesson plans as determined through elements of the Science Lesson Plan Analysis Instrument?
Chapter III

METHODS

An overview of the rationale for the methods is presented followed by information on the research setting, general methods of analyzing data, and issues of validity and reliability. This is followed with more detailed information on the methods used for each of the six research questions. An outline of the timeline for the research (Table 3.2) and a summary of the methods used for each research question (Table 3.3) are included at the end.

Overview

This research is a mixed-methods case study designed to characterize and document outcomes of an online course on evolution for science teachers. The study took place within the context of one offering of the Seminars on Science online course Evolution: Modern Evolutionary Biology that occurred during the summer of 2011. Seminars on Science is the online, graduate-level, science teacher professional development program at the American Museum of Natural History. Creswell (2007) and Merriam (1998) cite the existence such a bounded system as criteria for case study research.

The focus is on the analysis of teacher-produced work in the form of discussion posts and teaching unit plans based on course content. Twenty-four subjects participated in the online course discussions. Eighteen participants completed a pre- and post-course survey about their views of Nature of Science. Five teachers participated in pre- and post-course telephone interviews designed to validate their statements on the written Nature of
Science survey. Analysis of surveys, interviews, and unit plans were used to assess participants’ acquisition of scientific content knowledge, knowledge about the nature of science, and application of the material to a classroom setting. Artifacts of asynchronous communication within the course were used to examine the social construction of scientific content knowledge and knowledge about the nature of scientific investigation.

The Research Setting

One offering of Evolution: Modern Evolutionary Biology from Seminars on Science, the online science teacher professional development program at the American Museum of Natural History (AMNH), was used for this study. Seminars on Science offers 12 courses in the life, Earth, and physical sciences. The courses are seven weeks long and are considered to be semester equivalent graduate level courses. Learners can obtain graduate credit through a number of higher education partners.

The instruction for the course was based on AMNH-authored essays and media that supported a content outline based on the following essential questions: What is the evidence for evolution? How do we reconstruct evolutionary history? How does evolution work? How do new species form? How have humans evolved? How does evolution impact our lives?

Learners participated in asynchronous discussions prompted by open-ended questions related to the topic for each unit. Using a “guide on the side” instructional model (Collison, Elbaum, Haavind & Tinker, 2000), experienced educators, who had been trained to teach online, facilitated the discussions. A working scientist who is a specialist in the field also took part in the discussions. Together, the instructional team
probed for understanding and supported discussions that dealt directly with the specifics of each question, but also had the latitude to move into areas that were of interest to the learners. The scientist was encouraged to deal with factual information and student misconceptions as well as discussing the nature of scientific investigation. For the discussions, learners were graded on the content of their posts as well as their level of meaningful participation.

In addition to the discussions, there were three assignments that were delivered directly to the instructor for assessment and feedback. One involved the construction of an evolutionary tree using phylogenetic inference software and downloaded molecular sequences. Another was based on a natural and sexual selection simulation. The third assignment dealt with human evolution using a computer interactive that facilitated anatomical comparisons between modern humans, chimpanzees, and Neanderthals.

A third type of assessment was based on a final project. Learners were asked to create a five-day unit plan describing how course content can be transferred to their teaching practice. There were three milestones involved in creation of unit plans. In the third week of the course, participants were expected to post ideas for their units to a discussion board where they received feedback from faculty and fellow students. In the fifth week, an outline was submitted to the instructor who checked elements of the project using an evaluation rubric and gave detailed feedback to each learner. At the end of the seventh week, the final draft of the unit plan was due. Learners received an evaluation and feedback about their unit from the faculty in their final assessment documents.
Disclosures and Researcher Background

Creswell (2007) suggests that researchers share their background in order to increase case-study validity, therefore, I am presenting some appropriate background information. I have worked on Seminars on Science courses in various capacities since 1999, as a design consultant for course assignments and essays, as a course instructor, and, starting in 2004, as a manager overseeing the instructional staff and providing pedagogical guidance for course offerings. I participated by designing course outlines, editing content, selecting instructional materials, and creating assignments for eight of the twelve courses currently being offered.

Prior to coming to work at the American Museum of Natural History, I worked for 15 years as a teacher in the New York City public schools. The first 11 years were spent teaching seventh and eighth grade science in a middle school directly across the street from the Museum. During this time we developed a partnership with the Museum and worked with museum staff to develop teaching activities that utilized exhibitions and other resources. From 2000 to 2004, I taught Biology and Integrated Science at an alternative, portfolio-based high school on the Upper West Side of Manhattan.

While I know that it is common for researchers to study their own innovations, I understand that this could be a source of bias. However, I feel that the rich variety and types of data that were collected satisfy concerns about ethics, validity, and reliability. Moreover, this study is not an evaluation of the online experience, per se. Rather it is an analysis of the dynamics and outcomes from a scholarly perspective of this innovative, well-established program that has been formally evaluated by outside consultants.
Validity and Reliability

The data compiled for this study came from a variety of sources: pre- and post-course surveys, interviews, analysis of asynchronous computer-mediated communication, and analysis of course unit plans created by participants. Archives of text-based discussions provided the means to examine understandings about the science content and its application. Final projects provided a check on content understanding and application. Interviews with participants provided member checks (Merriam, 1998). This array of data for examining similar subjects fulfills the validity requirement of triangulation (Merriam, 1998). This researcher coded all of the qualitative data. A second coder analyzed a subset from each type of data (discussion transcripts, surveys, and lesson plans) and Cohen’s Kappa was used to obtain values for inter-rater reliability. Cohen’s Kappa gives a measure of the amount of agreement between raters that exceeds chance. Values can range from -1 to 1, with 0 indicating agreement that is due entirely to chance. A weighted kappa accounts for differences in ordered values; with rater disagreements calculated differently depending on proximity in the rank order (Fleiss & Cohen, 1973). The values for a weighted Cohen’s Kappa were at least .62 for all types of coding done in this study. This strength of agreement is considered good. The individual values of Cohen’s Kappa for each type of analysis will be given in the Methods section as each type of analysis is described.

Work on validating the instruments selected for use in this study has been ongoing and all have been used in prior published research. The Views of Nature of Science – C (VNOS-C) survey instrument was developed and tested by Lederman et al., (2002) and was the result of a long-term, iterative process of instrument development to
increase the understanding of nature of science views of school-age students and adults.
The Community of Inquiry coding instrument used in this study to code participant online posts was developed by Shea et al. (2010) through extensive research on computer-mediated communication and resulted in the consolidation of codes for teaching and social cognitive presence. Jacobs et al. (2008) developed The Science Lesson Plan Analysis Instrument. Validity was examined through triangulation with other measures of teaching practice that included direct observations, surveys, and comparisons with Reformed Teaching Observation Protocol scores (Sawada, Piburn, Judson et al., 2002; Sawada, Piburn, Turley et al., 2002).

*Methods for Investigating Individual Research Questions*

In the following sections, the methods used to address each of the research questions are presented.

*Research Questions 1 and 2 (combined): What are teachers’ patterns of online interaction through seven weeks of an online course on evolution for the entire sample and for selected participants in a case study?*

The goal of this research question is to determine the characteristics and patterns of interactions that are present in the online course discussions among participants and faculty on individual and class-wide levels. Discussion topics in the course change on a weekly basis. Students have two weeks to complete participation in each discussion.

Online interactions by students and faculty were coded for teaching presence and cognitive presence using the Community of Inquiry (CoI) instrument (Shea et al., 2010)
Teaching Presence falls into four categories: Design and Organization, Facilitating Course Discussion, Direct Instruction, and Assessment. Design and Organization is the basic pedagogical structure of the course. For this study, the curriculum design, which includes the learning management system, content, and due dates, are set at the program level so the course faculty was not involved in making these decisions. This presence was apparent in faculty posts when they assisted students with negotiating the online platform, made announcements about course logistics, or helped students understand proper online course etiquette (“netiquette”). Facilitating Course Discussion occurred when faculty posted responses to students that encouraged further contribution by the students. Activities that set a climate for learning might include identifying areas of agreement or disagreement, encouraging and acknowledging student contributions, and prompting discussion by presenting follow-up topics or asking probing questions. Direct Instruction was apparent when faculty provided analogies, illustrations, explicit reference to outside material, or clarifying information in the form of explanations of scientific principles. Assessment was the formative feedback given to students related to their discussion posts or assignments.

There are also four categories included within Cognitive Presence. A Triggering Event occurred when students expressed the recognition of a problem, indicated a sense of puzzlement, or asked a question that started a new topic of discussion. Exploration level posts presented ideas or opinions that were unsubstantiated, shared resources to help others build their knowledge, or generally exchanged information without elaborating, making meaning, or defending points or arguments. Integration occurred when learners provided substantive agreement or disagreement to previous messages, developed
defensible yet tentative hypotheses, or integrated information from authoritative sources to develop an argument or explanation. The CoI coding framework also includes a Resolution level, which was not applicable to this study. Resolution occurs when learners provide solutions to problems or defenses of these solutions. The discussion prompts in the course were open-ended questions that did not have specific solutions, so this coding level was not observed during this study.

The unit of analysis was one discussion post. For long posts that contained multiple statements and ideas, the highest cognitive level (Integration, Exploration, and Triggering Event in descending order) was recorded. A “post” refers to any single entry by an individual learner, ranging from one word to several paragraphs. A “thread” refers to any response to the general discussion prompt and all the subsequent posts made in response. In other words, a thread is the conversation spurred by one learner’s post to the discussion question. A discussion was all the posts and threads related to one of the weekly discussion prompts. In the first five units of the course, there was one discussion. During the sixth unit there were two discussions. The discussion questions were composed by the course designers and are listed in Appendix B.

The dynamics of each discussion were recorded by noting whether the posts were made to the discussion prompt, to another student, or to a faculty member. Statements in posts were evaluated for scientific accuracy and were coded in one of three categories as either: (1) accurate, (2) containing partial misconceptions, or (3) inaccurate. Posts with discourse on instructional strategies, elements of inquiry, or the nature of science were noted. Posts that did not contain statements that could be evaluated for scientific accuracy or cognitive level were coded as Other Interactions. The numbers of posts of each kind
were recorded for each participant, as well as the day on which each post was made. An analysis of totals and proportions of posts with differing levels of cognitive presence and scientific accuracy was performed to evaluate performance by individuals and to examine content and temporal patterns in the class as a whole.

Students participated in seven different discussions. Every post in each discussion was coded. Twenty-four participants took part in the majority of these discussions. Each discussion was open for a two-week period beginning on a Monday. A new discussion opened each week, so the first seven days of one discussion overlapped with the second seven of the previous discussion. Each participant received two grades for each discussion: one for content and one for participation. The grades were assigned and posted by the instructor at the end of each two-week discussion period.

The primary researcher coded every post from all seven discussions. A second rater coded one hundred posts and Cohen’s Kappa was used to establish inter-rater reliability. The kappa for cognitive and teaching presence coding using the Community of Inquiry scheme was .78, for which the strength of agreement is considered good. A weighted kappa that takes into account the proximity of groupings was .83, for which the strength of agreement is considered very good. The kappa for scientific accuracy coding was .77, for which the strength of agreement is considered good.

Totaled posts from corresponding days of each discussion were used to examine activity trends over each two-week discussion period. For example, all posts from the first day of each discussion were totaled, as were the totals from day
two of each discussion. This process was continued until concatenated results for each successive day were calculated.

Where appropriate, descriptive statistics were reported for the number of instances of a given category. Tables and line graphs were used to summarize the data. In some cases trends were analyzed using correlation analysis (Pearson product moment) or linear regression. Given the goals of the study and the small sample sizes, statistical regression analysis was used to obtain a fit of the data to a line in order to observe trends, and not for the purposes of inferential statistics.

To better understand interactions and knowledge construction by learners in the course, qualitative case study analysis (Merriam, 1998; Creswell, 2007) of three participants was performed. Participants were chosen from groups of learners who performed at high, medium, and low levels in the discussions. The high level performer consistently received grades of “Exceeds Expectations” from the instructor based on the course discussion rubric (Appendix C) and was in the top fifth of the class for frequencies of Integration level posts and scientifically accurate posts. This learner was selected because of her consistent involvement in the discussions and high grades on the scientific content of her posts. The medium level performer received discussion grades for content and participation that averaged to “Meets Expectations” based on the course discussion rubric and had frequencies of Integration level posts and scientifically accurate posts that were near the class average. This learner was selected because of his pattern of very efficient involvement in the course discussions. The low level performer received discussion grades for content and participation that averaged to “Approaches Expectations” based on the course discussion rubric and had frequencies of Integration
level posts and scientifically accurate posts that were in the lower fifth of the class. This learner was selected because she had a slightly higher frequency of posts than the other low performers. This addresses the need for a critical mass of posts in order to determine patterns of interactions, which is a limit to using text-based interactions to determine learner characteristics.

Activity of each learner was recorded through analysis of discussion text from all six units of the course. Discussion posts that illuminated the learners’ efforts to understand the scientific content were noted. Observations of types of interactions with the faculty and other learners were made to explore potential patterns of online behavior that would indicate individuals’ strategies for learning in an online, asynchronous environment. Indicators of Integration level cognitive activity and scientifically accurate statements were considered indicators of high quality posts.

*Research Question 3: How do teacher views of the nature of science change over the seven-week period of an online course on evolution?*

The goal of this research questions was to examine changes in teachers’ understanding of the nature of science (NOS) that occurred during the online course. The Views of Nature of Science - C instrument (Lederman et al., 2002) (Appendix D) was administered during the first week of the course using an online survey tool. The survey was repeated after the course. All 24 participants in the course were invited to participate in the VNOS survey and were offered a monetary incentive. Eighteen participants completed both surveys.
Views of Nature of Science were coded as informed, partially informed, and naïve based on a VNOS analysis framework by Abd-El-Khalick (2012) (Appendix E). The NOS aspects examined in this study were: empirical, inferential, creative, theory-laden, tentative, myth of the scientific method, understandings of theories and laws, and social aspects of scientific investigations. A profile of each participant was created using the pre- and post-course surveys. The profiles provided a picture of an individual learner’s NOS views and were used to characterize changes in these views as well as overall class trends. Each learner’s profile included statements from their surveys that indicated, with low-inference, either a naïve, partially informed, or informed view of the eight NOS aspects examined in this study. If no statements were made regarding a particular NOS aspect, that part of the NOS profile was left blank. Pre- and post-course profiles were compared to determine if and where changes in individual’s NOS views occurred. Text from the course discussions was examined for conversations related to the NOS that may have influenced changes in these views.

Pre- and post-course interviews were conducted with five participants. Interviewees were selected to represent a cross section of teaching experience. A 19-year high school teacher, a fourth-year high school teacher, a first-year middle school teacher, a pre-service education student, and an informal educator were selected. The fourth-year high school teacher did not complete the course and was replaced by a parochial school Advanced Placement Biology teacher to complete the sample for the post-course interview. An initial intention of this study was to observe teachers in their classrooms, so proximity of interview subjects to the New York City area was considered to facilitate travel. Classroom observations were excluded from the study plan at a later date due to
logistical concerns. The interview protocol was designed to elicit elaboration and clarification of statements on the written survey in order to validate written NOS views. In cases where the interview data was more informative than the written survey, interview results were used to complete the VNOS profiles.

The second rater for VNOS-C surveys coded 14% of the surveys. Cohen’s Kappa was used to calculate inter-rater reliability. The kappa for this coding was .70, for which the strength of agreement is considered good.

Research Question 4: What are the objectives of teacher-created unit plans that are based on experiences from an online science course for teachers? How do finished unit plans align with these objectives?

The goal of this research question was to examine how teachers translate science content from the online course into learning objectives for their students. Nineteen learners submitted teaching plans as final projects for the course. Learning objectives for the unit plans were recorded. Objectives were grouped by emergent themes aligned to course content and analyzed for patterns among teachers of elementary, middle, and high school.

Course objectives were examined for alignment to the course content, the activities in the unit plans, and the evaluation and assessment planned as part of the unit plan. A five-point rubric adapted from Contino and Anderson (2013) (Appendix F) was used to examine alignment of the unit objectives to the online course content, the unit objectives to the activities in the unit plan, the unit objectives to the evaluation and assessment presented in the unit plan, the evaluation and assessment to the activities
presented, and the planned activities to the course content. A rubric score of 5 represented full alignment. A score of 1 represented no alignment. Overall alignment scores and scores for the elements with the highest frequency of misalignments were compared to years of teaching experience using linear regression.

The second rater analyzed objectives for 6 of 19 projects. Cohen’s Kappa was used to calculate inter-rater reliability. The kappa for alignment coding was .59, for which the strength of agreement is considered moderate. The weighted kappa for alignment coding was .62, for which the strength of agreement is considered good.

Research Questions 5 and 6 (combined): Using the Science Lesson Plan Analysis Instrument (Jacobs et al., 2008), what are the weighted scores from analysis of teacher-created unit plans using content from an online course on evolution? What relationship, if any, is there between teachers’ Nature of Science profiles and the quality of their science lesson plans as determined through elements of the Science Lesson Plan Analysis Instrument?

Teaching unit plans, produced by 19 participants, were evaluated using an adapted Science Lesson Plan Analysis Instrument (SLPAI) (Jacobs et al., 2008). The original instrument uses 21 criteria that encompass alignment with endorsed practices, cognitive and metacognitive issues in lesson design and implementation, sociocultural and affective issues in lesson design and implementation, and the portrayal and use of the practices of science. A three-tiered rubric was used to evaluate each criterion as Exemplary, Making Progress, or Needs Improvement.
Seventeen items from the Science Lesson Plan Analysis Instrument (Jacobs, et. al., 2008) (Appendix G) were selected based on alignment to the course Final Project Guidelines (Appendix H), relevance to aspects of Nature of Science (NOS), and inclusion of basic pedagogical principles. Scores on each item were assigned using a rubric that awarded two points for Exemplary, one point for Making Progress, and no points for Needs Improvement. Raw scores from the SLPAI analysis were weighted by multipliers of three, two, or one to emphasize criteria that were required elements from the course, final project guidelines (Appendix H), or elements that might reflect teachers’ views on the nature of scientific investigation. The SLPAI elements selected for use in this analysis along with their weights are presented in Table 3.1.

Table 3.1: Science Lesson Plan Analysis Instrument Elements and Weights

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment with Standards</td>
<td>2</td>
</tr>
<tr>
<td>Awareness of Science Education Research</td>
<td>1</td>
</tr>
<tr>
<td>Goal Orientation</td>
<td>3</td>
</tr>
<tr>
<td>Content Accuracy</td>
<td>3</td>
</tr>
<tr>
<td>Content Presentation</td>
<td>3</td>
</tr>
<tr>
<td>Meaningful Application</td>
<td>2</td>
</tr>
<tr>
<td>Student Reflection</td>
<td>2</td>
</tr>
<tr>
<td>Assessment</td>
<td>3</td>
</tr>
<tr>
<td>Student Attitudes about Science</td>
<td>3</td>
</tr>
<tr>
<td>Student Engagement</td>
<td>2</td>
</tr>
<tr>
<td>Student Participation</td>
<td>1</td>
</tr>
<tr>
<td>Classroom Discourse –fostering a community of learners</td>
<td>2</td>
</tr>
<tr>
<td>Variety</td>
<td>1</td>
</tr>
<tr>
<td>Hands-on-exploration</td>
<td>2</td>
</tr>
<tr>
<td>Nature of Science</td>
<td>3</td>
</tr>
<tr>
<td>Student Practitioners of scientific inquiry</td>
<td>3</td>
</tr>
<tr>
<td>Analytical Skills</td>
<td>2</td>
</tr>
</tbody>
</table>
To examine possible relationships of views of nature of science (NOS) to elements of unit planning, participants’ profiles from the VNOS-C instrument were compared to scores from SLPAI elements that relate to NOS instruction. Five lesson plan elements were selected: student attitudes about science, student engagement, hands-on exploration, nature of science, and student practitioners of scientific inquiry. VNOS-C categories of informed, partially informed, and naïve were converted to numerical scores of 3, 2, and 1 respectively. NOS views about the social and cultural dimensions of science and views about scientific theories and laws were used for this analysis as these two VNOS elements showed the most variability in the sample and greatest frequencies of change from pre- to post-course VNOS surveys. These elements were compared to weighted scores from the five SLPAI elements listed above. Scores were analyzed using linear regression.

The second rater analyzed objectives for 6 of 19 projects. Cohen’s Kappa was used to calculate inter-rater reliability. The kappa for alignment coding was .64, for which the strength of agreement is considered good.
### Research Timeline

Table 3.2: Summary of Three-Phased Research Approach

<table>
<thead>
<tr>
<th>Phase</th>
<th>Data Collected</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>One: Pre-Course</td>
<td>VNOS-C Surveys (18 completed)</td>
<td>Quantitative analysis and descriptive statistics assessing knowledge and dispositions related to Nature of Science</td>
</tr>
<tr>
<td></td>
<td>Interviews (5 participants)</td>
<td>Coding for knowledge and dispositions related to Nature of Science</td>
</tr>
<tr>
<td>Two: During Course</td>
<td>Asynchronous dialogue in discussions (24 participants)</td>
<td>Coding scheme guided by Community of Inquiry model (Shea, et al., 2010). Coded for levels of teaching presence, cognitive presence, and scientific accuracy. Recorded temporal data and instances of discussion related to inquiry, pedagogy, and Nature of Science.</td>
</tr>
<tr>
<td>Three: Post-Course</td>
<td>Final unit plan projects (15 submitted)</td>
<td>Teacher lesson plan analysis using the Science Lesson Plan Analysis Instrument (Jacobs, Martin, &amp; Otieno, 2008)</td>
</tr>
<tr>
<td></td>
<td>VNOS-C Survey (18 completed)</td>
<td>Quantitative analysis and descriptive statistics assessing knowledge and dispositions related to Nature of Science</td>
</tr>
<tr>
<td></td>
<td>Interview of selected participants (5 participants)</td>
<td>Coding for knowledge and dispositions related to Nature of Science</td>
</tr>
</tbody>
</table>
Table 3.3: Research Questions, Procedures and Instruments

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Collection/Procedure</th>
<th>Data Collection and Analysis Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research Question 1:</strong> What are teachers’ patterns of online interaction through seven-weeks of an online course on evolution?</td>
<td>Online interactions from seven asynchronous discussions were coded for cognitive presence, teaching presence, and scientific accuracy.</td>
<td>Community of Inquiry coding for teaching and cognitive presence (Shea et al., 2010) Appendix A</td>
</tr>
<tr>
<td><strong>Research Question 2:</strong> Based on case-study analysis, what characterizes the patterns of online interaction for a sample of teachers involved in a seven-week online course on evolution?</td>
<td>Case study analysis of high, medium, and low performers based on course discussion grades and coding of cognitive elements and scientific accuracy.</td>
<td>Case study analysis (Merriam, 1998; Creswell, 2007)</td>
</tr>
<tr>
<td><strong>Research Question 3:</strong> How do teacher views of the nature of science change over the seven-week period of an online course on evolution?</td>
<td>Construction of pre- and post-course nature of science (NOS) profiles for 18 participants. Pre- and post-course interviews with five participants. Analysis of online interactions in asynchronous discussions.</td>
<td>Views of Nature of Science – C survey completed online (Lederman et al., 2002) Appendix D. Coding and correlation of interviews with a subset of participants (5).</td>
</tr>
</tbody>
</table>
Table 3.2 (cont): Research Questions, Procedures and Instruments

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Collection/Procedure</th>
<th>Data Collection and Analysis Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Question 4: What are the objectives of teacher created unit plans that are based on experiences from an online science course for teachers? How do finished unit plans align with these objectives?</td>
<td>Analysis of stated project objectives.</td>
<td>Emergent coding of unit plan objectives to analyze patterns and organization of teacher created unit plans.</td>
</tr>
<tr>
<td>Research Question 5: What are the weighted scores from analysis of teacher created unit plans using content from an online course on evolution</td>
<td>Scoring and analysis of unit plans.</td>
<td>Science Lesson Plan Analysis Instrument (Jacobs et al., 2008) Appendix G</td>
</tr>
<tr>
<td>Research Question 6: What relationship, if any, is there between teachers’ Nature of Science profiles and the quality of their science lesson plans as determined through elements of the Science Lesson Plan Analysis Instrument?</td>
<td>Cross comparison of selected lesson plan elements with changes in participant views of the nature of science.</td>
<td>Science Lesson Plan Analysis Instrument (Jacobs et al., 2008) Appendix G</td>
</tr>
</tbody>
</table>
Chapter IV

RESULTS

The results for each of the Research Questions are presented in sequential order.

*Research Question 1: What are teachers’ patterns of online interaction through seven weeks of an online course on evolution?*

*Cognitive levels.*

Posts were coded using the Community of Inquiry (CoI) framework (Shea, et al., 2010). Examples of posts coded at different CoI cognitive presence levels (Integration, Exploration, or Triggering Event) are presented in Table 4.1. The results of the coding for these levels are presented in Table 4.2. In all but two of the seven discussions, Integration level posts (the use of information from authoritative sources or previous posts to develop an argument or explanation) were more frequent than Exploration level posts (presenting unsubstantiated ideas or opinions, sharing, or exchanging information without elaborating). The exceptions were the Unit 1 discussion, where there were 56 Exploration level posts and 51 Integration level posts, and the second discussion of Unit 6, where there were 70 Exploration level posts and 49 Integration level posts. The discussion prompt for the first unit was to discuss the Theodosius Dobzhansky quote that “nothing in biology makes sense except in the light of evolution”, and the topic of the second Unit 6 discussion was to discuss the implications and importance of teaching evolution.

Triggering Events in the form of questions by learners occurred less frequently than Integration and Exploration level posts. Triggering Events reached a high of 18 in the Unit 3 discussion about the mechanisms of evolution. Overall there were 843 total
posts by learners in the course. 394 (47%) were on the Integration level, 319 (38%) were on Exploration, and 48 (6%) were characterized as Triggering Events. Seventy (8%) of learner posts were characterized as Other Interactions since they could not be coded for one of the CoI cognitive presence levels and did not contain statements that could be coded for scientific accuracy.

Table 4.1: Examples and Descriptions of Integration, Exploration, and Triggering Event Posts

<table>
<thead>
<tr>
<th>Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>The writer uses material from authoritative sources to make conclusions</td>
</tr>
<tr>
<td>I was surprised to learn how integral phylogenetic analysis has become in detecting and combating human pathogens. Dr. Walter Fitch, who came up with the first algorithms that are used for genetic sequencing in phylogenetic trees, explains that RNA viruses mutate so quickly that you are able to observe the equivalent of what would take millions of years in vertebrates in only a few years in these viruses. In Health Applications of the Tree of Life, David Hillis points out that because these pathogens mutate so quickly and don't have genomes that are fixed enough to use &quot;matching methods,&quot; &quot;phylogenetic placement is the only means available to identify them.&quot; These rapid mutations make not only identifying a given pathogen extremely difficult but also pinpointing when, where and how a pathogen will be introduced into the human population seemingly impossible. It has been through understanding the pathogen's evolutionary history by phylogenetic analysis that more meaningful and accurate predictions have been made.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td>The writer presents an idea that is not developed or defended</td>
</tr>
<tr>
<td>What is life and how do you define whether something is living or not? No one seems to know what to do with viruses but maybe in this case it is more philosophical than anything. In contrast to the Biological Species Concept, I think the Phylogenetic Species Concept would allow us to study viruses' relationships to living things without having to define whether or not they are actually living.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Triggering Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>The writer poses a question to the group</td>
</tr>
<tr>
<td>I have a question --would viruses be living under the phylogenetic species concept (vs. the biological species concept)? As much as we study evolving viruses and they do have genetic material--should we still be quibbling on whether they are life forms or not?</td>
</tr>
</tbody>
</table>
Integration level posts by learners ranged from 45 to 70 posts in the seven discussions and averaged 56 per discussion. The highest frequencies occurred in Units 3, 4, and 5, with 67, 60, and 70 Integration level posts, respectively. The lowest frequencies occurred in Unit 2 and the second Unit 6 discussion that focused the social implications of understanding evolution, with 45 and 49 posts, respectively. Integration level posts ranged from 36% of total posts in the aforementioned Unit 6 discussion to 64% in Unit 5.

Exploration level posts by learners ranged from 26 to 70 with an average of 46 posts per discussion. The highest frequencies occurred in Units 1 and the second Unit 6 discussion, with 56 and 70 Exploration level posts respectively. The lowest frequencies occurred in Unit 5 with 26 posts, Unit 3 with 34 posts, and Unit 2 with 37 posts. The percent of Exploration level posts relative to total posts ranged from 24% of total posts in Unit 5 to 52% in the second Unit 6 discussion.

*Scientific Accuracy.*

During the seven-week course, a total of 843 posts were coded. The number of posts that contained sufficiently identifiable science content to be analyzed for accuracy was 395. Figure 4.1 represents the data for this coding. There were 336 posts that contained scientifically accurate statements. These posts ranged from a Unit 1 high of 61 to a low of 20 in the Unit 6 discussion on the importance of teaching evolution. The low of 20 was an apparent anomaly as 45, 60, 49, and 46 scientifically accurate posts were made in Units 2 through 5, respectively, and there were 55 scientifically accurate posts in
Table 4.2: Total Numbers and Percentages of Posts at Different Cognitive Levels.

<table>
<thead>
<tr>
<th></th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
<th>Unit 5</th>
<th>Unit 6 #1</th>
<th>Unit 6 #2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learner Posts</td>
<td>140</td>
<td>100</td>
<td>125</td>
<td>123</td>
<td>109</td>
<td>110</td>
<td>136</td>
<td>843</td>
</tr>
<tr>
<td>Integration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>51</td>
<td>45</td>
<td>67</td>
<td>60</td>
<td>70</td>
<td>52</td>
<td>49</td>
<td>394</td>
</tr>
<tr>
<td>Percent of Total</td>
<td>36</td>
<td>45</td>
<td>54</td>
<td>49</td>
<td>64</td>
<td>47</td>
<td>36</td>
<td>47</td>
</tr>
<tr>
<td>Exploration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>56</td>
<td>37</td>
<td>34</td>
<td>49</td>
<td>26</td>
<td>47</td>
<td>70</td>
<td>319</td>
</tr>
<tr>
<td>Percent of Total</td>
<td>40</td>
<td>37</td>
<td>27</td>
<td>40</td>
<td>24</td>
<td>43</td>
<td>52</td>
<td>38</td>
</tr>
<tr>
<td>Triggering Event</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>9</td>
<td>2</td>
<td>18</td>
<td>9</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>48</td>
</tr>
<tr>
<td>Percent of Total</td>
<td>6</td>
<td>2</td>
<td>14</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

Note: The sum of Integration, Exploration, and Triggering Event posts do not equal the total number of learner posts. This is due to the fact that some posts did not contain statements that could be coded for Cognitive Level.

In the seven discussions, 40% of total posts contained scientifically accurate statements. When the apparently anomalous low of 20 from the first Unit 6 discussion was removed from analysis, the regression line for the number of scientifically accurate posts in Figure 4.1 flattens to a slope of -1.1 with r = -.29. The new y intercept of 56 is within the range of data points for the remaining discussions.

During the course, 55 posts contained statements with partial scientific misconceptions. These posts ranged from 14 in Unit 1 to 2 in the second discussion of Unit 6. There were 8, 9, 6, 12, and 4 posts with partial scientific misconceptions in Units 2, 3, 4, 5 and the first discussion of Unit 6, respectively. The percentage of posts that contained partial scientific misconceptions over the entire course was 7%. There were
four statements that were scientifically inaccurate. One learner made three of these statements.

Out of the 395 statements that contained statements that could be coded for scientific accuracy, 85% were coded as scientifically accurate, 14% had partial misconceptions, and 1% were scientifically inaccurate. Percentages of posts with scientific content are presented by accuracy in Figure 4.2.
Figure 4.1: The number of posts coded as scientifically accurate, having partial scientific misconceptions, and as scientifically inaccurate during each discussion. Note: There were two discussions for Unit 6 and one for all other units.
Figure 4.2: The percentage of posts that are scientifically accurate, with partial scientific misconceptions, and inaccurate as a function of the total number of posts that contained scientific statements.

Other Interactions.

Posts that could not be coded for cognitive level or scientific accuracy were coded as Other Interactions. There were 70 posts (8.4% of total posts) in this group. Emergent coding was used to categorize these posts. Table 4.3 lists the categories, frequencies, and some examples of these posts.
Table 4.3: Total Number of Posts Categorized as Other Interactions.

<table>
<thead>
<tr>
<th>Type of Interaction</th>
<th>Number of Posts</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thank you for an example, explanation or resource.</td>
<td>18</td>
<td>“Thank you for the websites.”</td>
</tr>
<tr>
<td>Personal Message</td>
<td>14</td>
<td>“I’m interested in …”</td>
</tr>
<tr>
<td>Exclamation</td>
<td>12</td>
<td>“Congrats” “Oh the occupational hazards of teaching.”</td>
</tr>
<tr>
<td>Agreement</td>
<td>8</td>
<td>“That’s for sure.”</td>
</tr>
<tr>
<td>Metacognition</td>
<td>7</td>
<td>“This week answered my questions from last week.” “I have a much better understanding now.”</td>
</tr>
<tr>
<td>Acknowledgement</td>
<td>5</td>
<td>“Yes, that’s what I meant.”</td>
</tr>
<tr>
<td>Jokes</td>
<td>3</td>
<td>“Are you a cannibal?” “Do finger sandwiches count?”</td>
</tr>
<tr>
<td>Logistics</td>
<td>3</td>
<td>“I’ll add it to the webliography.”</td>
</tr>
</tbody>
</table>

*Instructional Implications.*

During the course, 229 posts (27% of the total) discussed classroom instruction. Ninety-three of these posts occurred in Unit 6 Discussion 1, which asked learners to “discuss the implications and importance of teaching evolution”. Apart from this instance, instruction was discussed 44, 21, 22, 29, and 5 times in Units 1, 2, 3, 4, and 5, respectively, and 15 times in Unit 6 Discussion 2.

*Faculty/Student Interaction.*

The number of posts made by the faculty (Instructor, Teaching Assistant, and Scientist) declined as the course progressed. Posts by faculty ranged from 68 to 10 and averaged 36 posts per discussion. Except for Unit 3, the number of posts by faculty decreased in each successive unit. After a high in Unit 1 of 68 posts, faculty posted 44 times in Unit 2, 60 times in Unit 3, 21 and 31 times in Units 4 and 5 respectively, and 10 and 20 times in the two Unit 6 discussions. The frequency of posts by learners was less
variable. The number of student posts ranged between 140 and 100 and averaged 120 per discussion. Unit 1 was the high for learners with 140 posts, followed by 100, 125, 123 and 109 in Units 2 through 5. There were 110 and 136 posts in each of the Unit 6 discussions. Figure 4.3 summarizes this data.

Figure 4.3: The number of student and faculty posts for each discussion

Email and assessment activities related to grading and course logistics were not coded. The number of posts that students made to faculty declined as the numbers of faculty posts declined (Figure 4.4). The number of posts that students made to other students increased as the course progressed. The number of posts that students made to
directly address the discussion prompt remained relatively constant (Figure 4.5). Student posts to the discussion prompt (the weekly framing question) ranged from 24 to 31 and averaged 27 posts per discussion.

Figure 4.4: The number of student posts to faculty and faculty posts to students during each discussion.
4.5: The number of student posts made to the discussion prompt, to other students, and to faculty during each discussion.

*Temporal Patterns of Course Participation.*

Each discussion was open for a two-week period beginning on a Monday. A new discussion opened each week, so the first seven days of one discussion overlapped with the second seven days of the previous discussion. Totaled posts from corresponding days of each discussion were used to examine activity trends. For example, all posts from the first day of each discussion were totaled, as were the
totals from day two of each discussion. This process was continued until concatenated results for each successive day were calculated.

There were a total of 326 posts made by students during the first seven days of all discussions combined. During the second seven-day period there were 524 posts made. Figure 4.6 represents the total number of posts on each day (1 through 14) from the seven discussions. Note the peaks on Day 7 and 14, which correspond to Sundays. Each participant received two grades for each discussion: one for content and one for participation. The grades were posted at the end of the two-week period. Day 14 is the last day that posts were counted toward a participant’s

![Figure 4.6](image.png)

**Figure 4.6:** The total number of posts made by students on successive days of each discussion. Totals are the concatenated results from each corresponding day from all seven discussions.
grade. Students were still able to post after the two-week period, but these posts were not considered in the discussion grade. Over the seven discussions, there were a total of 29 total posts made after the discussions closed for grading.

The posts made on each day were analyzed to determine if the quality of the posts varied as the discussions progressed. Quality was examined using the proportion of posts coded at the Integration cognitive level and the proportion of scientifically accurate statements compared to the total number of posts made on a particular day. Posts that could not be coded for cognitive level or scientific accuracy were coded as Other Interactions.

Three trends were evident from this analysis. First, the proportion of Other Interaction posts (Figure 4.7) increased as the 14-day discussion period progressed ($r = 0.77$). There were 70 posts that were coded as Other Interactions. Seventy-three percent of these occurred in the second half of the discussion period, with 33% on the last two days. Second, the proportion of posts that contained statements that were coded as scientifically accurate (Figure 4.8) declined ($r = -.87$). It is important to note that this does not indicate a greater number of posts that contained statements coded as partial scientific misconceptions or as scientifically inaccurate. It also does not indicate a lower number of scientifically accurate posts. Third, the proportion of posts that were coded at the Integration cognitive level (Figure 4.9) declined ($r = -.73$).

Scientific accuracy as a proportion of posts that contained scientific statements was examined. The proportions of posts that were accurate, contained partial misconceptions, and were inaccurate remained relatively unchanged during the discussion period. The regression line for the proportion of accurate posts had a slight
negative slope due to the fact that there were few posts with scientific content made after Day 14. None of the statements made after Day 14 were accurate. Also, on Day 1 there were only four posts with scientific content and two were accurate. Otherwise the proportion of accurate posts ranged from .94 to .74. Posts with slight misconceptions ranged from .05 to .26 after similar Day 1 and 15 anomalies were accounted for (Figure 4.10).

Figure 4.7: The proportion of Other Interaction posts made by learners as a function of the total posts made on successive days of all discussions. Note: Other Interactions were posts that could not be coded for scientific accuracy or cognitive level.
Figure 4.8: The proportion of posts from each successive discussion day that contained scientifically accurate statements as a function of the total number posts on each day.

Note: This does not imply a rise in statements that are scientifically inaccurate or contain partial misconceptions.
Figure 4.9: The proportion of posts from each successive discussion day that contained statements coded at the Integration level as a function of the total number posts on each day.
Figure 4.10: The proportion of posts from each successive discussion day that contained scientifically accurate statements, partial scientific misconceptions, or scientifically inaccurate statements as a function of the total number of posts that contained scientific statements. Note: Outliers of .5 from Day 1 (2 of 4 posts) and 0 (0 of 3 posts) from Day 15 were removed from the analysis of accurate statements. Outliers of .5 (2 of 4 posts) and 1.0 (3 of 3 posts) were removed from the analysis of partial misconceptions.
Research Question 2: Based on case-study analysis, what characterizes the patterns of online interaction for a sample of teachers involved in a seven-week online course on evolution?

The following case studies report in detail on the interactions and performance of some of the individuals in the course. To get a broad overview, participants with different levels of performance were selected. Learners were categorized as high, medium, or low performing based on grades received from the course instructor and the frequencies of integration level and scientifically accurate posts. One student from each level was selected for a detailed case study.

The high level performer consistently received grades of “Exceeds Expectations” from the Instructor based on the course discussion rubric (Appendix C) and was in the top fifth of the class for frequencies of Integration level posts and scientifically accurate posts. The medium level performer received discussion grades for content and participation that averaged to “Meets Expectations” based on the course discussion rubric and had frequencies of Integration level posts and scientifically accurate posts that were near the class average. The low level performer received discussion grades for content and participation that averaged to “Approaches Expectations” based on the course discussion rubric and had frequencies of Integration level posts and scientifically accurate posts that were in the lower fifth of the class.

There were four low performing students in the course. All four posted below the class average of 35 total posts for the course, ranging from 13 to 22. They were also below the average for total numbers of integration level posts (16), ranging from 9 to 12; exploration level posts (13), ranging from 2 to 8; and scientifically accurate posts (14),
ranging from 1 to 13. They received a rubric-based grade of “Approaches Expectations” (roughly equivalent to a letter grade of C) from the course instructor on their discussion performance evaluation.

The medium performing students were the 10 learners who received a discussion assessment of “Meets Expectations” from the course instructor based on the course rubric. The frequency of posts was below the class average of 35 for all but two of these learners and ranged from 15 to 73. Frequencies of scientifically accurate posts were generally close to the average of 14 and ranged from 9 to 20. Frequencies of Integration level posts were close to the average of 16 and ranged from 11 to 19. Involvement in the course may have been inconsistent and frequencies of scientifically accurate posts and indicators of Integration level cognitive activity were generally lower than for the high performing students.

The 10 high performing students received a discussion assessment of “Exceeds Expectations” from the course instructor based on the course rubric. These individuals demonstrated an understanding of the course content through their posts and participated meaningfully and substantively in the course discussions. In the cases where they were not above the average for numbers of integration level and scientifically accurate posts, they were close.

Low Performer.

At the time the course took place, BG was a 26 year-old, first year sixth- and seventh-grade science teacher from New York City.
BG logged into the course on 21 out of the 49 days it was open. She posted on 11 different days. BG posted 22 times during the course: once in each of the first two units, twice in Unit 3, six times in Unit 4, three times in Unit 5, seven times in the Unit 6 Discussion 1, and twice in Unit 6 Discussion 2. Posts on the Integration level were second lowest in the class (eight), as were posts that contained scientifically accurate statements (three). The number of posts that contained slight misconceptions (four) was among the highest in the course. Seven posts out of 22 contained statements that could be coded for scientific accuracy. Of these, four contained slight misconceptions and three were scientifically accurate.

Through seven discussions BG never started a new thread that directly responded to the prompt, as is the standard procedure followed by most students. Even if her apparent intention was to address the question in the discussion prompt, her post was added as a response to the post that appeared lowest on the page.

While all course discussions are available to students for the entire course, posts are assessed and credited to a learner’s grade only if they are made during a 14-day period that starts with the first day of a unit topic. Posts made after this two-week window rarely generate interaction from other students. BG made 8 of 22 posts (36%) on Day 15 or later. Eight posts were made near the end of this posting period: on Days 12, 13, or 14 of the discussion. Only 3 posts were made during the initial seven days of the posting period.

BG’s participation in the course was intermittent. There was a stretch of nine days from the middle of Unit 1 into Unit 3 when she did not log into the course. There were
also non-login stretches of five days in Unit 4 and the middle of Unit 6, and a three-day stretch early in Unit 6.

BG made posts to the discussions on 11 of the 49 days that the course was open to students. Late posting limited her interaction with other students and she received grades of “Approaches Expectations” for the Participation portion of her discussion grade for most units. The one exception was a grade of “Meets Expectations” in Unit 4. For the Unit 2 discussion she did not make any posts during the 14-day window and received a failing grade for that unit.

During the first three units of the course, BG did not engage with other learners or faculty except in the introductory Icebreaker discussion where she posted her introduction as a response to another learner instead of opening a new thread. The pattern of posting responses to the prompt in threads that were already opened by other learners, rather than starting a new thread, continued through the duration of the course.

BG made one post each in the content discussions for Units 1 and 2 and two posts in Unit 3. Her Unit 1 post was made on the third day of the discussion. The Unit 2 and 3 posts were made on the fifteenth day of the discussion. Posts in Units 1 and 2 were coded as Exploration level using the CoI coding scheme. There were no statements in these posts that could be assessed for scientific accuracy. The Unit 3 posts were coded as Integration level using the CoI framework. Scientific statements in these posts showed slight misconceptions. This statement from one of BG’s Unit 3 posts demonstrates her misconceptions about how natural selection works:

I enjoyed being reminded that natural selection is not always good for the entire population at large, or a species over time. While it is good for the individual, it might be the result of extinction in due time.
BG makes qualitative statements about natural selection being “good for” individual organisms. While it is unclear exactly what she means by this statement, this may indicate that she has a misunderstanding about natural selection working on the population rather than individual level.

During Unit 4 BG posted six times. Four of these posts were Exploration level and two were Integration level. Her initial posts in this unit correctly described the differences between the biological (BSC) and phylogenetic (PSC) species concepts and were coded as scientifically accurate. Unit 4 was also the first time that BG engaged in a discussion about the scientific concepts with the faculty and other learners. It was focused on the tentative nature of science and the different uses of the BSC and PSC. During this discussion BG posted three times in the same thread. BG’s posts in this discussion were made on the ninth, tenth, eleventh, twelfth, and fourteenth day of the discussion. She did not make any posts during the first week of this discussion.

In Unit 5 BG made three posts. One was a substantive response to the discussion prompt, though it was posted as a response to another learner. The other two were shorter, one sentence posts. One was a social comment and the other was a scientific speculation about human ancestry. The first and third posts were Integration level posts. BG’s first post had some minor scientific misunderstandings. The first two posts were made on the fifth and seventh day of the discussion. Along with her very first post in Unit 1, these were the earliest posts made in any discussion during the course. The last post was made during the final week of the course when grading for Unit 5 had closed.

There were two discussions in Unit 6. One focused on how an understanding of evolution influences the quality of modern life and the other on the implications and
importance of teaching evolution. BG posted one substantive post to the quality of life discussion in which she discussed the uses of evolutionary theory to create influenza vaccines. This post was on the Integration level and contained statements that were scientifically accurate. Her only other post in this discussion was a post made at the very end of the discussion time period that could not be coded for scientific accuracy or cognitive level. BG made seven posts in the discussion about teaching, the most of any discussion in the course. One of these posts was a response to the prompt, which was posted as a response to another learner. This post was coded on the Exploration level and contained misconceptions about the nature of scientific theories.

Teaching evolution is extremely vital and although it is a theory overall, there are a lot of known FACTS and truths within the theory of evolution. We KNOW that species and organisms have all branched from common ancestors and that natural and sexual adaptations have occurred in order for species to attempt to survive longer.

This statement by BG implies that she holds the more colloquial view of a theory as hunch rather than the scientific view of a theory as well-supported explanation that allows scientists to predict outcomes. In this statement she also implies that species “attempt to survive”, indicating misconceptions about how natural selection works.

The other six posts in this discussion were part of a conversation with other learners and the Teaching Assistant. Four posts were part of a back-and-forth in which she shared and asked about where another learner taught and at what level evolution was introduced. Another conversation that took place in this thread was the result of a question by the course Teaching Assistant. BG responded to his question: “I agree and I think it would make both later DNA units and chemistry easier if students were introduced using these techniques at an earlier age. I have vivid memories of flies and
fast plants and Punnett Square activities.” All of the posts and conversations that BG participated in during Unit 6 took place near the end of the two-week discussion period (Days 12, 13, 14, and 15).

Overall, BG posted 22 times. This was seventh lowest frequency among all participants. While she composed a post that addressed the essential question in the discussion prompt during each Unit, she never started her own thread. This is the typical method of addressing the prompt and could indicate that BG did not achieve a working understanding of this aspect of the course learning management software.

Three of her 22 (14%) posts were in response to posts by the course faculty. One of these posts did not deal directly with the question posed by the Teaching Assistant. All of these posts were made late in the discussion period so there was little opportunity for a robust discussion to develop. Only one of these posts (a post to the course scientist) contained a statement with scientific content that could be evaluated for accuracy. This statement was scientifically accurate.

Seven of the 22 posts contained statements that could be evaluated for scientific accuracy. Three of these statements were scientifically accurate and four contained slight misconceptions. Three of these misconceptions were related to the role natural selection plays in evolution. The other was a misunderstanding of scientific theories.

BG’s frequency of participation in discussions ranged from one post to a maximum of seven. Five posts did not have statements that could be coded for either scientific accuracy or cognitive level. These were made to other students to thank them for resources, answers to questions, or to ask about the characteristics of another learner’s school. Seventeen posts were coded for Cognitive Presence. There were eight instances
of Integration, eight instances of Exploration, and two instances of a Triggering Event (posing a question). After Unit 2, BG posted at least one Integration-level post in each discussion. Only three of BG’s posts occurred in the first week of a given discussion. Six posts occurred after the date that learners could receive credit for posting. Seven posts were made on the last three days a discussion was open for grading.

BG’s low frequency of posts, and her pattern of posting late in the discussion period, limited her engagement with other members of the online learning community. She engaged in back-and-forth conversations with others on only two occasions during the course. Discussion grades are based on both content and participation. BG received an overall grade of “Approaches Expectations” (equivalent to a letter grade of C) for her discussions. Her content grade was “Approaches Expectations” (Did not adequately reflect on the discussion question or did not relate post to course materials) and her participation grade was “Approaches Expectations” (Occasionally responded substantively to other learners and course faculty, or failed to post in a timely manner).

BG’s posts were not deep enough or frequent enough to ascertain her scientific understanding or ability to integrate course content into detailed explanations of phenomena.
Table 4.4: Number of posts by BG per Discussion

<table>
<thead>
<tr>
<th></th>
<th>UNIT 1</th>
<th>UNIT 2</th>
<th>UNIT 3</th>
<th>UNIT 4</th>
<th>UNIT 5</th>
<th>UNIT 6.1</th>
<th>UNIT 6.2</th>
<th>Total</th>
<th>Percent of Total Posts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posts</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>2</td>
<td>22</td>
<td>100</td>
</tr>
<tr>
<td>Threads</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>13</td>
<td>100</td>
</tr>
<tr>
<td>Posts to Prompt</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Posts to Students</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>19</td>
<td>86</td>
</tr>
<tr>
<td>Posts to Faculty</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>CoI Integration</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>36</td>
</tr>
<tr>
<td>CoI Exploration</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>8</td>
<td>36</td>
</tr>
<tr>
<td>CoI Triggering Event</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Other Interactions</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td>Instructional Design</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>8</td>
<td>36</td>
</tr>
<tr>
<td>Scientifically Accurate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>Contains Scientific Misconceptions</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Scientifically Inaccurate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Posts can be coded for more than one of the characteristics; therefore, the percentage of each type of post does not total 100.

Medium Performer.

When he took the course, KE was 31 years old and working on completing his Masters Degree and teaching certificate. He had a Bachelors Degree in Communications and no teaching experience.

KE logged into the course on 29 of the 49 days it was open. He posted on 13 different days for a total of 16 posts, which was below the class average of 35 and fourth lowest among all participants. He posted twice in each discussion except for Unit 3 and Unit 5, when he posted three times. Posts to other students (5) and posts to faculty (4) tied for third lowest. He made 12 posts that were coded at the Integration level. He had two posts that were coded as Exploration level. This was the lowest frequency for all participants. He had nine posts that contained statements that could be coded for
scientific accuracy. Seven of these posts were accurate and two contained slight misconceptions.

KE’s work in the course could be characterized as efficient. He made no posts that were coded as Other Interactions and the percent of posts that were coded at the Integration level was 75%, the second highest in the course. He had at least one post from each discussion at the Integration level.

During the first four units, KE made his first post on the sixth or seventh day that the discussion was open. In the last two units he only made posts on the eleventh, twelfth, thirteenth, and fourteenth days. Overall, KE posted twice on the sixth day, four times on the seventh day, once on the eighth day, once on the eleventh, twice on the twelfth, three times on the thirteenth, and three times on the fourteenth.

In the Unit 1 discussion, KE never responded to the prompting question that asked learners to consider Theodosious Dobzhansky’s statement that “nothing in biology makes sense except in light of evolution.” He did demonstrate some independent reading and responded in detail to two questions posed by faculty to other students. One dealt with the Hardy-Weinberg Principle. KE stated that the “Hardy-Weinberg Principle essentially concludes that evolution (defined as a change in frequencies of alleles in the gene pool of a population) must occur.” This is a slight overreach of the principle, but his research and writing on the subject is quite thorough. The instructor and another learner replied to his post. He never responded. In another thread the Teaching Assistant, in response to another student’s comments about the Dobzhansky quote, asked learners to consider
whether evolution can help us understand why parents love their children? KE commented:

> With regard to the love that a parent feels for their child, I think it’s easy to see as support for Dobzhansky’s claim. Does not a parent’s love equate to the protection and nurturing of a vulnerable member of the same species? Maybe I’m simplifying the concept of love, but to me it seems inline with the basic tenets of evolution.

This is the only instance in his posts that he mentions the Dobzhansky statement. This post elicited a response by another student, to which KE did not respond.

KE’s posts in the Unit 1 discussion occurred on the seventh and eighth days of the 14 days the discussion was open. This provided opportunities for other students to respond to his posts. For Unit 1, the faculty graded KE as “Meets Expectations” for both content and participation.

In Unit 2 KE posted one direct response to the discussion prompt, which asked learners to discuss the importance of understanding phylogenies and the inferences that can be drawn from phylogenetic trees. KE’s response demonstrates a good understanding of phylogeny.

Phylogeny provides both a visual representation of evolutionary history, and it does so without assigning rank. Both distinctions are important because they differ from the traditional system of Linnaean classification. A phylogenetic tree shows evolutionary relationships such as sister groups, that is two groups who are each other’s closest relatives, and common ancestors, the ancestor from which both groups are derived. By analyzing evolutionary relationships, scientists can make predictions about the fossil record as well as understand the order of evolution, which in some cases, differs greatly from what traditional morphological data tells us.

His only other post in Unit 2 was a post responding to a question by the course scientist. This post was coded at the Integration level and contained scientifically
accurate statements. For Unit 2, the faculty graded KE as “Meets Expectations” for content and “Approaches Expectations” for participation.

KE posted three times in Unit 3. His post in response to the discussion prompt was a 537 word, five-paragraph explanation of natural selection, genetic drift, and aspects of evolutionary developmental biology (evo-devo) that included references. In response to his post, the instructor asked him to elaborate on genetic drift, which he did in a three-paragraph post that included references. His response to the instructor was made five days after her question. Both of these posts were coded as scientifically accurate and included Integration level elements. KE posted a response to another learner on the same day that he posted his initial post to the prompt. He posted a comment and question.

Good question! That's just what I was thinking as I read Raff’s essay on evo-devo. I have very little background knowledge in this field, but the mutation of regulatory genes seems a plausible explanation for birth defects.

I've always heard that alcohol and/or drug use can lead to birth defects. Are the two related? Could alcohol consumption during pregnancy lead to the mutation of regulatory genes, or would its effects be expressed in another form?

A four-post conversation between the instructor and two other learners stemmed from this post, however, KE did not post again to this thread.

During the third week KE logged into the course three times. He made no posts the first time, a post to the Unit 2 discussion the second time, and two posts to the Unit 3 discussion the third time. His third Unit 3 post was made during the second week of the discussion. KE’s Unit 3 discussion grades were an “Exceeds Expectations” for content and a “Meets Expectations” for participation.

During Unit 4, KE made two posts on the sixth day of the discussion. His post to the discussion prompt was 601 words, seven paragraphs, and included references. It
discussed the differences between the Biological (BSC) and Phylogenetic (PSC) Species Concepts. This post contained scientifically accurate statements and included Integration level elements. Another student responded to his post and the course scientist posed a question about how we define species in a K-12 setting. KE did not respond to either of these posts.

Also in Unit 4, KE responded to another learner’s post with a question about whether experimental lab results are used to determine BSC species. This post was coded as a Triggering Event. A nine-post chain of comments by five learners and the Teaching Assistant stemmed from KE’s question, but he did not make another post in this thread. KE’s Unit 4 discussion grades were an “Exceeds Expectations” for content and an “Approaches Expectations” for participation.

In Unit 5 KE made three posts late in the discussion period. His first post, on the eleventh day, was made to the prompt and was coded as a Triggering Event.

Near the end of Dr. Tattersall’s essay he points out that "Earth's 6 billion inhabitants are unprecedentedly mobile, and anyone can reproduce with anyone else on the planet." As I read this it dawned on me what a unique position Homo sapiens occupy in the natural world. More than anything I began to think about just how vast we are as a species. 6 billion (actually almost 7 at this point) is a huge number! It got me wondering about how we compare to other mammal species or even non-mammal animal species in terms of numbers. I would imagine that there are insects and sea-life that outnumber us (not to mention things like bacteria, etc.), but what about mammals, reptiles, or even birds? Does anyone have a sense of which particular species are similarly large, if any?

Another learner and the course instructor posted four times in response to this post. KE did not post again in this thread.

On the thirteenth day of the discussion, KE posted his main response to the prompt. This 806-word post discussed the course readings on human evolution and
included references. This post contained KE’s second, and final, instance of slight scientific misconception.

On the other hand, when we look at the different genus on the Hominid Timeline, we see that there are many instances of singular species existing for significant periods of time. In this respect, it may not be so unusual for Homo sapiens to be the only living Hominid.

This statement is an inaccurate reading of the hominid timeline presented in the course, which shows no other time where only one hominid species existed alone. Aside from this statement, KE’s post contained many other statements that were scientifically accurate and the post was a comprehensive treatment of many of the aspects of human evolution that were presented in the course. The post had elements that were coded on the Integration level.

KE’s only other post in Unit 5 was an Exploration level post made on the last day of the discussion. It contained thoughts about several aspects of human evolution.

Your statement that "many human cultural traditions and artifacts accumulate modifications over time, whereas this does not seem to be the case for nonhuman primate cultural traditions" got me thinking about the role of time in the context of evolution. It makes me wonder... Will the change in human culture over time ever play a role in defining our own evolution? How great are the differences among animals of the same species over vast periods of time? I’ve heard that horseshoe crabs have changed very little over the millennia, but what about other animals? How different is a modern chimpanzee from its 100,000-year-old ancestor? Is there any evolutionary classification for how a species has changed over time without speciation? I just can’t seem to get over how different we must be from our Homo sapien ancestors. Could those differences ever equate to a separate evolutionary classification? This seems like a risky proposition with many negative implications, but still I wonder…

Even coming at such a late date, the learner that KE posted to responded with her own thoughts about some of his questions and the course scientist made a brief comment on tool use by hominids. KE did not post again in this thread. KE’s Unit 5 discussion
grades were an “Exceeds Expectations” for content and an “Approaches Expectations” for participation.

KE posted late in the discussion period during the two Unit 6 discussions. He posted on the twelfth and fourteenth days to the discussion on instructional implications, and on the thirteenth and fourteenth days in the discussion on societal implications. KE’s initial post to the social implications prompt was 477 words, four paragraphs long, and included one reference. It was coded as scientifically accurate and contained Integration elements. Another learner responded with a probing question that KE replied to the next day. His response contained details about DNA testing and included a reference that he may have found as a result of research prompted by the question. This post contained Integration level cognitive activity but did not have any scientific statements that could be coded for accuracy.

The two posts that KE made in the instructional implications discussion were the only instances where he discussed the classroom instruction of evolution. His post to the prompt was 313 words and three paragraphs long, his shortest post to a prompt. Perhaps because he lacked classroom experience, KE used this post to share his thoughts about why it is important to teach evolution.

I believe that in any school setting where science is taught, evolution must be included as part of the curriculum. Why? Because despite lack of public consensus, the fact remains that evolution is science through and through. Clearly, this discord stems from a general misunderstanding of what actually constitutes good science and is made worse when specific scientific terminology (“theory” is a good example) is confused with colloquialism. I can admit that my own education did not leave me with a concrete sense of how science is defined, and it wasn’t until I took this course that I fully understood how evolution withstanded the test of scientific rigor.
His response demonstrated an understanding of the nature of scientific terminology and a grasp of the applications of evolutionary theory in daily life. He used these understandings to build his case for teaching evolution.

To make a final point, I believe that the study of evolution is a must given how it impacts our everyday lives (as per our other discussion). From medicine, to food, conservancy, criminal justice, and beyond, the principles and applications of evolution are present all around us. While most of us accept these things at face value there still remains a controversy over its teaching in school. How can we deny the scientific basis for something, yet benefit so greatly from its study?

KE’s Unit 6 discussion grades were a “Meets Expectations” for content and “Approaches Expectations” for participation in both discussions.

Overall, KE received assessments of “Exceeds” or “Meets Expectations” on content during each unit of the course. His overall content grade was “Meets Expectations”. His participation grades were five “Approaches Expectations” and two “Meets Expectations” for an overall participation grade of “Approaches Expectations”. His overall Discussion grade for the course was “Meets Expectations”, which is roughly equivalent to a B.

KE got by on his extensive posts to the discussion prompts. He was thorough in his answers to the unit questions and gave detailed and well-developed explanations that usually contained reference citations. Throughout the course, KE posted scientifically accurate posts that demonstrated Integration level cognitive activity. The content of his posts demonstrated that he was working his way through the curriculum and developing an understanding of the content and concepts presented in the course.

However, KE did not engage in a robust manner in any of the conversations in the course. When he did post to other students, he only returned to the discussion and
reposted one time. Most of his posts to other learners occurred late in the discussion period, when there was little chance for others to respond to him.

Overall, KE succeeded on a medium level (“Meets Expectations” or B) due to his reflection on the course content in his posts to the prompts. While his posting frequency was low compared to other students in the course, he was able to demonstrate significant understanding of the course content in a limited number of posts.

Table 4.5: Number of posts by KE per Discussion

<table>
<thead>
<tr>
<th>UNIT</th>
<th>UNIT 2</th>
<th>UNIT 3</th>
<th>UNIT 4</th>
<th>UNIT 5</th>
<th>UNIT 6.1</th>
<th>UNIT 6.2</th>
<th>Total Posts</th>
<th>Percent of Total Posts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posts</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Threads</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Posts to Prompt</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Posts to Students</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Posts to Faculty</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>CoI Integration</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>12</td>
<td>75</td>
</tr>
<tr>
<td>CoI Exploration</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>CoI Triggering Event</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Other Interactions</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Instructional Design</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Scientifically Accurate</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Contains Scientific Misconceptions</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Scientifically Inaccurate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*High Performer.*

CG was 42 years old with 19 years of experience teaching middle and high school science when she took the online course. She holds a B.S. in Biology and a M.A. in Education.

CG made 42 posts in the course. This was above the class average of 35. Her number of posts ranged from three in the Unit 2 discussion to nine during Unit 4. She
made 26 posts to other students, which was the fifth highest among course participants. She posted to faculty seven times, slightly below the class average of nine. Her 28 Integration level posts matched one other learner for the most in the course. The percentage of her posts that contained scientifically accurate statements (67%) tied for second among all participants. She made nine Exploration level posts. This was below the class mean of 13. Twenty-eight of her posts were coded as scientifically accurate. This was the second highest frequency in the course. She made two posts that contained slight scientific misconceptions.

Nineteen posts (45%) were made during the first seven days of the discussion and all of CG’s initial posts to the discussion prompt were all made during the first six days. The number of different discussion threads that CG participated in ranged from two to five per unit. CG participated in 26 threads during the entire course. This was the fifth highest among all students.

CG logged into the course on 44 of the 49 days that it was open. She did not log in on three of seven days during the first week. After that she logged in on all but two days during the last six weeks, including a stretch of 28 consecutive days from the second week into the fifth. She posted on 24 different days.

CG posted her initial response to the Unit 1 discussion question on the first day of the course. The post was 119 words long and addressed the prompt in broad terms with no references. The post was coded on the Exploration level.

Evolution is the fundamental concept of biology because it is able to unify all of the other major topics in biology. Evolution relates to: 1) ecology, with the influences of environment and competition, 2) genetics, by looking at difference in phenotypes in various offspring, 3) DNA, which may mutate and provide a new trait on which natural selection may act, and a host of other topics. By studying evolution, we can observe how the different species on earth are related to one
another based on their similarities and differences. For example, if 2 species are suspected to be closely related, then by analyzing DNA sequences, one should find that they share a large percentage of their DNA in common.

The instructor replied with a request for reference sources and asked CG to support her points with concrete examples. CG made a social reply in response.

Sorry about that, Pat. I have been teaching evolution for so long that I can't pinpoint where the information came from -- it is a conglomerate of all the texts and outside reading I have done over the years. I will be more diligent in future posts with referencing the sources of information.

Although CG did not supplement her initial post with references or examples, all subsequent posts met this expectation. The course scientist also responded to CG’s initial post with a question about how evolution and embryology relate. CG replied to this question with a post that attempted to explain evolutionary developmental biology. This post was on the Integration level. Her explanation of evo-devo contained slight misconceptions. However, a post made later in the course showed that she understood the main concepts in evo-devo.

A third response to CG’s original post was made by a student posing a question about the amount of DNA two species need to have in common in order to be considered closely related. CG did not answer this question directly, but stated

I did not know the answer to your question so I started poking around to try and find one. I did not find exactly what I was looking for (at least not yet), but I did come across some interesting information regarding epigenetics and evolution.

She then went on to explain epigenetics in an Integration level post that included two references and was coded as scientifically accurate. The thread started by CG’s initial post ended up with 11 posts by five different learners and two faculty members.

CG made two more posts in Unit 1. One was an Exploration level post in which she shared information from an article that she found to address some questions about
how multicellularity may have evolved. The other was an Exploration level post
explaining Hardy-Weinberg equilibrium to another learner who posted a question. Both
of these posts were coded as scientifically accurate. These two posts were made during
the second week of the discussion and demonstrated that CG was reading through the
discussion and researching questions posed by other learners. CG received grades of
“Exceeds Expectations” for both content and participation during Unit 1.

In Unit 2, CG posted three times. Her post to the prompt was made on the sixth
day of the discussion. It was 354 words and three paragraphs long with nine cited
references. The post was coded at the Integration level and contained scientifically
accurate statements. This post did not elicit a response from any other member of the
course learning community. CG’s other two posts were added to the same thread on the
seventh and ninth day of discussion. Another learner posted the question: “Does anyone
know if Archaea and Bacteria have a relatively small number of branches because they
are less diverse or because we know less about them?” CG responded by relating some
research of her own.

I just did a little bit of searching and came across and essay that estimates a
handful of soil contains about 10 million species of bacteria (eubacteria and
archaebacteria) while there are only about 1 million species of insects on the
entire planet. (http://www.gly.uga.edu/railsback/11111misc/Prokaryotes.html).
Granted, the article was not written by a microbiologist, but I think it illustrates
the point that prokaryotic cells make up a huge amount of the living species on
earth.

Later in the same thread CG responds to a resource cited by another student.

Thanks for the references. I found the 1st site you refer to
(http://vsites.unb.br/ib/cel/microbiologia/artigos/diversidade.pdf) very interesting,
especially in identifying the various way prokaryotic "species" are defined. When
I am teaching this, I usually stick with the conventional definition of species as a
group of organisms that are able to interbreed and produce fertile offspring. I
discuss with my students some of the problems with this definition, but I usually
don't explicitly discuss the problem of defining different species in asexually reproducing organisms due to lack of time.

Both of these responses are evidence that CG went beyond the content that was presented in the course and used Internet searches to find answers to questions posed by other students. She also used citations posted by other students to enhance her knowledge and reflected on these sources in subsequent posts. CG received grades of “Exceeds Expectations” for content and “Approaches Expectations” for participation during Unit 2.

In Unit 3 CG made six posts in four threads. She posted from the sixth to the fourteenth day of the discussion. Her post to the prompt was 596 words and five paragraphs long with six reference citations. She discussed natural selection, mutations in regulatory genes, evo-devo, and co-evolution by referring to the course resources. This post was coded on the Integration level and included scientifically accurate statements. The instructor responded to this post by asking CG about her thoughts on whether or not all evolution is the result of coevolution. CG responded the next day by doing some independent reading and posted the following:

I did a little research on the topic of coevolution looking for support to this idea and came across some interesting thoughts. First, in this analysis, coevolution is defined as reciprocal evolutionary change. According to this strict definition, there is a difference between evolving together and coevolution where a change in one organism is the cause of the change in the other. The argument is that in order to prove that coevolution occurred there must be evidence that “the traits in each species were a result of or evolved from the interaction between the two species” (http://biomed.brown.edu/Courses/BIO48/27.Coevolution.HTML).

As a case in point, one could look at the evolution of a plant-eating insect and its prey. If the plant developed a trait that made it more insect-resistant, such as production of a toxin, this would put selective pressure on the insect population, which, due to natural selection, could develop a mechanism for neutralizing the toxin. According to traditional coevolutionary thought, the resistant insect, in turn, would put selective pressure on the plant to develop a stronger toxin. In looking closely at the plants' response, the answer to may not
be as clear-cut as it initially seems. Many of the plant products that serve as a
deterrent to predators have multiple functions. For example, plant chemicals
such as flavonoids serve to protect the plant from UV radiation. The toxicity,
bad taste, etc. which ward off enemies may simply be a by-product of an
adaptation to another environmental factor, not necessarily to coevolution.
(http://www.as.wvu.edu/~kgarbutt/EvolutionPage/FinalPapers/Coev1.htm).

Overall, my thoughts on the idea that all biodiversity seen in nature is the result
of coevolution are that it is a stretch. Interactions between different organisms
with each other and their environment are complex, and therefore identifying
the source of selective pressure on species is probably equally complex. Before
we can state that two species coevolved, we must first have evidence to support
the claim that a change in one caused the change in another, which then result
in a change in the first and so on in a reciprocal arrangement.

This response is a well-developed analysis of the question posed by the instructor.
It includes a summary of the related reading and CG’s own conclusion based on what she
learned. It was coded on the Integration level and contained scientifically accurate
statements.

CG participated in three other conversations in Unit 3. She shared information
from an article about whether the loss of eyes in blind cave fish is the result of genetic
drift, she posted a “devil’s advocate” (her words) argument about preventing extinction
by conserving widespread species, and added two posts to a discussion about the
relationship of an animal’s size, climate change and the likelihood of extinction. The
“devil’s advocate” post was coded as Teaching Presence since it provided some
background information and ended with a thought-provoking question. However, it was
made on the thirteenth day of the discussion and did not elicit a reply. The other posts
mentioned in this paragraph were coded at the Integration level and contained statements
that were scientifically accurate. CG received grades of “Exceeds Expectations” for both
content and participation during Unit 3.
CG posted to the Unit 4 discussion nine times, her highest total for any discussion. She participated in four different threads. Seven of these posts were coded on the Integration level and eight contained scientifically accurate statements.

Her activity occurred primarily near the end of the first week of the discussion. She posted at least once on each day from the fourth through the seventh day. She revisited the discussion with two posts (one social) on the thirteenth day. She posted on five different days during the two-week period the discussion was open and logged into the course on all but the last day of this discussion.

Her 350-word post to the discussion prompt was made on the fourth day of the discussion and included five reference citations. She spent three paragraphs exploring the differences between the Biological (BSC) and Phylogenetic (PSC) species concepts. In her last paragraph she mentions that “these are not the only definitions of species” and elaborates on the “ecological species concept” and then discusses the goal of defining species, which is one of the core ideas of this unit.

I mention this third definition because as I was thinking about how to respond to the 2nd part of the discussion question, I was struck by the question of what is the goal of identifying species? Is it to trace evolutionary history? Is it to preserve biodiversity, and if so, what does that mean? Is the goal of preserving biodiversity to maximize on the genetic variety of organisms on the planet or to ensure that man is not eliminating organisms that occupy important ecological niches? Do organisms with different physical appearances (as in the example given for PSC) occupy different niches? I believe that because scientists have different goals for identifying species, coming to consensus on which definition of species is most appropriate/accurate will continue to be a difficult task.

The teaching assistant responded to this post with a question about how many different species concepts are in use. Two days later CG responded with a detailed answer that included a description of three other species concepts and a note that she had come across an article that mentioned 27 different species concepts. This post was
supported by five references. Two learners responded, thanking CG for her informative posts and the references.

Through her interactions with other learners in Unit 4, CG demonstrated a sophisticated understanding of why different scientists need different species concepts depending what and how they study. She also demonstrated an understanding of the utility of different species definitions in conservation practices.

With regards to conservation, I came across some interesting information. Preserving biodiversity and evolutionary history is one part of the picture, but the other half of the equation is preserving “evolutionary potential”. In this approach, the focus is on preserving environments/landscapes that have features likely to promote future diversification of species. The key feature of these environments is spatial heterogeneity. (http://evolution.berkeley.edu/evolibrary/news/070601_hotspotstrategy).

CG received grades of “Exceeds Expectations” for both content and participation during Unit 4.

During Unit 5, CG posted five times to four different discussion threads. She posted to the prompt on the fifth day of the discussion and then contributed to conversations by responding to other students and the course scientist on the sixth, eighth, ninth and tenth days. One of her posts was coded as Other Interactions. The other four posts were coded on the Integration level. Her response to the prompt and a post responding to the course scientist contained scientifically accurate statements.

CG’s post to the discussion prompt was a 263-word post that contained six references. This post was an efficient answer to the discussion question that asked learners to address the fact the Homo sapiens is the only hominid species alive today and make comparisons of modern humans to the closest living relatives. CG included reference citations that came from sources that were not mentioned in the course,
indicating that she continued her pattern of doing extensive reading and Internet research for each discussion. However, this post was unusual for CG in that she limited her response to reiterating statements made in one of the course essays, without developing detailed answers for each aspect of the discussion question:

In his essay, “Dr. Ian Tattersall Pieces Together the Human Past”, Dr. Tattersall states that “there's something very special about *Homo sapiens*. It is a very unusual situation for there to be only one hominid species.” While there are other lineages with only a single extant species, such as ginkos and numbats, (1) & (2), their distribution is limited. In contrast, *Homo sapiens* are ubiquitous.

The course scientist responded to CG’s prompt by inquiring about the significance of cooking to human evolution. To this question CG responded with a well-developed statement that was put together using three Internet references.

Interesting question. The first 2 things that came to my mind were: 1) that there might be some nutrient loss during the cooking process and 2) cooking helps to kill bacteria that might otherwise prove harmful. As cooking is not my strong point, I did some digging and found out some interesting information.

First, I was thinking in terms of cooking meat, but there is research suggesting that cooking vegetables/tubers may have been the catalyst for the development of our bigger brains and social structure. The proposal is that a very large amount of time would have to be spent not just gathering food, but also eating raw plant matter in order to get enough calories to support the larger brain size seen in *Homo erectus*. Cooking, however, makes the food easier to digest by softening it up, makes some toxic tubers edible and releases more nutrients. This could explain the differences in jaw and teeth size between *Australopithecus* and *Homo erectus*. One of the problems of this theory is determining whether the controlled use of fire dates back as far as *Homo erectus*.

I also found it interesting that the use of cooking could have led to some of the social changes seen in the human lineage. With more calories available from food, the difference in body size between males and females became reduced. Mating pairs would have evolved from the need to defend food – which would have been brought back to a common cooking area rather than eaten where it was found.

CG’s responses to other students during Unit 5 were not as detailed as her responses earlier in the course. One of the three responses she made to classmates was
two sentences long. The others were only one sentence in length. One of these responses contained a reference link. CG received a grade of “Exceeds Expectations” for content and “Meets Expectations” for participation during Unit 5.

CG posted six times in each of the Unit 6 discussions. Both of her responses to the discussion prompts were coded at Integration level and contained scientifically accurate statements. She posted in five different threads in the discussion on how an understanding of evolution influences quality of life and participated in three different threads in the discussion on teaching evolution.

CG’s post to the quality of life discussion was 230 words long and focused on antibiotic resistant bacteria. This post contained one reference to a course essay. The teaching assistant responded by asking about whether teachers spend time talking about antibiotic resistance in their classrooms. CG responded to this query with an anecdote about her teaching.

I do spend some time talking about resistance in my classes. I usually show students the video clip from the PBS Evolution series "Why Does Evolution Matter Now?" (http://www.pbs.org/wgbh/evolution/library/11/2/quicktime/e_s_6.html) and then we spend some time talking about why resistance has evolved and what everyone should know about taking antibiotics, when they are useful and when they're not. We don't usually touch on antibiotic use in livestock but, after doing the reading from Chapter 13, I think I am going to incorporate that into the discussion in the future.

As an aside... a few years ago I had a student whose mother was absolutely against a project I gave students on evolution based on religious grounds. Though she refused to let her daughter do the project, she did allow her to do a different project on antibiotic resistance. The mom worked in a hospital, and I think she realized the importance of the topic, but she still would not acknowledge that resistance demonstrates evolution.
CG’s response to the prompt in this discussion led to a thread with 26 responses. CG made one more contribution to this thread after her post to the Teaching Assistant. Each of CG’s other posts to this discussion question referred to the application of evolutionary understanding to disease resistance. CG received a grade of “Exceeds Expectations” for content and “Meets Expectations” for participation for this discussion.

In the Unit 6 discussion on teaching evolution, CG posted to the prompt on the second day of the discussion. This post was 398 words long with two cited references. CG summarized arguments from a course essay and a chapter in the course text to underscore the importance of teaching evolution. This post was coded on the Integration level and contained scientifically accurate statements. Though nobody in the course learning community responded to CG’s post to the prompt, a comment that she made to another learner elicited four direct responses.

You bring up an interesting point about where evolution falls in the sequence of most Biology curricula. From what I have seen, most high school textbooks place evolution around chapters 16/17. If a high school teacher were to follow the sequence in the book, most of us would not get to evolution until near the end of our course. Since evolution underlies all of biology, is this the proper placement for this topic?

In the past I have tried to rearrange my curriculum so that I introduce the basic idea of evolution right at the start of my course-- Darwin, natural selection, descent with modification. From there, as I cover each unit, I try to wrap around to how evolution fits in with the topic. At the end of the semester, after finishing genetics, I revisit evolution and conclude with a discussion of gene pools, Hardy Weinberg, etc. Though it doesn't allow me to discuss everything I would like to about evolution (and after taking this course, I am thinking of more ways to integrate evolution), I feel that it does convey to students the importance of evolution in every aspect of biology.

CG’s other posts in this discussion shared personal thoughts and experience about teaching and learning about evolution. Only one of her last four posts in this discussion contained a reference.
The more I learn the more I am amazed at how well evolution can fit in with other areas of science as well. This past year I made it a point to begin my unit on evolution by telling students that evolution is a process, just like photosynthesis or cell respiration. I am constantly looking for ways to improve my teaching, especially on the topic of evolution. In the coming year I plan on putting more emphasis than I currently do on the research aspect of evolution.

Another post demonstrated CG’s understanding of the nature of science and the way evolution is “debated” in the media.

Following up on your comment, Bridget, about there not being debate within the scientific community about whether or not evolution is occurring, I think teaching students about evolution is important because it teaches students to distinguish between what is and is not science. Very often the media treats all arguments and any dissent as if they were equal. Just because there is an opposing explanation about diversity (in the form of intelligent design) does not mean that this is a scientific view. When you watch a newscast like Nightline that talks about Intelligent Design, they generally give equal time to both sides, implying that there is equal support for both viewpoints. This is not the case.

CG received a grade of “Exceeds Expectations” for both content and participation for the discussion on evolution instruction.

Overall, CG received grades of “Exceeds Expectations” for content in her discussion posts in every unit of the course. Her participation grades ranged from one “Approaches Expectations” in Unit 2, when she only posted three times, to “Meets Expectations” in two discussions and “Exceeds Expectations” in four discussions. Her overall course discussion grade was “Exceeds Expectations”, which is roughly equivalent to an A.

CG was most active in the middle of each discussion. Her highest frequencies of posts occurred on the sixth, seventh, and eighth days of a discussion which fell on Saturday, Sunday and Monday. She also recorded a frequency of posts on the thirteenth day of each discussion, which fell on Saturday.
CG was a consistent contributor to the course discussion. She engaged with classmates and tended to respond to questions from the faculty with well-researched posts. Only 3 of her 42 posts were coded as Other Interactions. She made frequent posts that reflected on the material at the Integration level and contained scientifically accurate statements. She seemed motivated by other students’ posts. On several occasions she brought in resources that she found in response to these posts. This demonstrated a desire to go beyond the minimum requirements of the course and to engage in the material on a deep level.

In Unit 1, CG was asked to include references to course material or other resources to support the points she made in her post. From that point on most of her posts contained references and she used these references effectively to make and support her points.

Overall CG succeeded on a high level. Her number of posts, number of posts at the Integration level, and number of posts that contained scientifically accurate statements were all above the course averages.
Table 4.6: Number of posts by CG per Discussion

<table>
<thead>
<tr>
<th></th>
<th>UNIT 1</th>
<th>UNIT 2</th>
<th>UNIT 3</th>
<th>UNIT 4</th>
<th>UNIT 5</th>
<th>UNIT 6.1</th>
<th>UNIT 6.2</th>
<th>Total</th>
<th>Percent of Total Posts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posts</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Threads</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posts to Prompt</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>17</td>
</tr>
<tr>
<td>Posts to Students</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>26</td>
<td>62</td>
</tr>
<tr>
<td>Posts to Faculty</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>7</td>
<td>17</td>
</tr>
<tr>
<td>Integration</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>27</td>
<td>64</td>
</tr>
<tr>
<td>CoI Exploration</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>9</td>
<td>21</td>
</tr>
<tr>
<td>CoI Triggering Event</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Other Interactions</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>07</td>
</tr>
<tr>
<td>Instructional Design</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>13</td>
<td>31</td>
</tr>
<tr>
<td>Scientifically Accurate</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>28</td>
<td>67</td>
</tr>
<tr>
<td>Contains Scientific Misconceptions</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Scientifically Inaccurate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Research Question 3: How do teacher views of the nature of science change over the seven-week period of an online course on evolution?

Eighteen participants completed the pre- and post Views of Nature of Science version C (VNOS-C) (Lederman et al., 2002) (Appendix D). The VNOS-C consists of 10 open-ended writing cues and assesses participants’ views of the empirical, inferential, creative, theory-laden, tentative, myths about the scientific method, ideas about scientific theories and laws, and social aspects of science. Descriptions of each of these elements are included in Appendix E (Abd-El-Khalick, F., 2012). The VNOS-C was administered through an online survey tool during the first week of the course and was repeated after the course finished. Surveys were coded for informed, partially informed, and naïve views of each element. Five participants were interviewed before and after the course to assess accuracy of written surveys. One of the participants in the pre-course interview did
not complete the course. Another learner was substituted to complete the sample for the post-course interview. The participants ranged from pre-service teachers to a veteran of 39 years in the classroom. The grade levels taught by the participants and their teaching experience are presented in Table 4.7.

Table 4.7: Teaching Experience (in years) and Grade Level of VNOS Participants

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1 to 3</th>
<th>4 to 6</th>
<th>7 to 10</th>
<th>11 to 15</th>
<th>16 to 20</th>
<th>21 or More</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-service</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elementary</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle School</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High School</td>
<td></td>
<td></td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Middle and High School</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Informal (Museums)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

A detailed analysis of the VNOS results is presented here and an overview of the data is presented in Tables 4.8 and 4.9 at the end of this section. As a whole, the group of participants began the course with a fairly informed view of the nature of science (NOS). On the pre-test surveys 79 statements were rated as informed, 19 as partially informed, and 13 as naïve. The empirical, inferential, tentative, and creative aspects of NOS accounted for 57 of the informed and 6 partially informed responses. There was only 1 response that was coded as naïve in these four categories. For the social aspect of NOS, there were 12 informed, 4 partially informed, and 1 naïve response on the pre-test. The theory-laden and method myth aspects of NOS had a lower frequency of statements that
could be used to code for these aspects. The theory-laden aspect had five coded responses on the pre-test (all informed) and the method myth aspect had seven (two informed, four partially informed, and one naïve). The VNOS aspect of scientific theories and laws was the aspect for which the group had the least informed views. On the pre-test, 3 statements were coded as informed, 5 as partially informed, and 10 as naïve.

On the post-test 100 statements were rated as informed, 13 as partially informed, and 7 as naïve. The aspects of empirical, inferential, tentative, and creative, which showed high pre-test frequencies of informed responses, had a total of 63 informed, 2 partially informed, and 0 naïve responses on the post-test. For the social aspect, 16 responses were coded as informed, 1 as partially informed, and 1 as naïve. There were eight coded responses for the theory-laden aspect. All were coded as informed. For the “method myth”, seven responses were coded as informed, four as partially informed, and one response as naïve. For scientific theories and laws, six responses were coded as informed, six as partially informed, and six as naïve.

In a comparison of the pre- and post-test views, there was no instance where a respondent expressed a less informed view on the post-test than on the pre-test. There were 15 instances of a respondent expressing a more informed view on the post-test. There were 3 instances where views changed from naïve to informed. Two of these were regarding views on theories and laws and one regarding social aspects of NOS. In two cases, respondents views changed from naïve to partially informed regarding views on theories and laws. The 10 remaining changes were from partially informed to informed. There were no instances of change in views for the aspects of theory-laden, inferential, and tentative. The aspects of empirical and “method myth” each had one instance of
change from partially informed to informed. The creative aspect had three instances of
change from partially informed to informed. There were four changes from partially
informed to informed regarding the social aspect of NOS.

The NOS aspect of theories and laws had the highest frequency of naïve
responses in both the pre-test and the post-test. There were five instances of change in
individuals’ pre- and post-test within this aspect. Two changed from naïve to informed,
two from naïve to partially informed, and one from partially informed to informed. The
VNOS profile of three participants remained unchanged at the informed level, four
remained unchanged at the partially informed level, and five remained unchanged at the
naïve level.

There were five profile changes in the social aspect. One changed from naïve to
informed and the four from partially informed to informed. All 18 participants in the
VNOS survey were coded for informed views on the Social aspect on the post-test.
Eleven of these participants also held informed views on the pre-test. One participant did
not have statements that indicated her view about this VNOS aspect in the pre-test.

Participants’ written responses contained the second lowest number of coded
responses for the VNOS aspect of the myth of the scientific method. Six participants
made statements that allowed an assessment of their views of this aspect before and after
the course. Two people had informed views on both the pre- and post-survey, one
changed from partially informed to informed, and three had partially informed views on
both the pre- and post-survey.

The lowest frequency of coded responses concerned the theory-laden nature of
science. There were five coded responses in the pre-survey and eight in the post survey.
All of these responses indicated an informed view. Three participants had coded responses from both surveys. Their views remained unchanged at the informed level.

Table 4.8: Overall Participant Pre- and Post-Course Views of NOS Aspects

<table>
<thead>
<tr>
<th>VNOS Aspect</th>
<th>Pre-Course</th>
<th>Post-Course</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Informed</td>
<td>Informed</td>
</tr>
<tr>
<td>Empirical</td>
<td>14 (78%)</td>
<td>18 (100%)</td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td>1 (6%)</td>
</tr>
<tr>
<td></td>
<td>Naïve</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Inferential</td>
<td>13 (72%)</td>
<td>13 (72%)</td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td>2 (11%)</td>
</tr>
<tr>
<td></td>
<td>Naïve</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Creative</td>
<td>13 (72%)</td>
<td>17 (94%)</td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td>3 (17%)</td>
</tr>
<tr>
<td></td>
<td>Naïve</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Theory-Laden</td>
<td>5 (28%)</td>
<td>8 (44%)</td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td>0 (0%)</td>
</tr>
<tr>
<td></td>
<td>Naïve</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Tentative</td>
<td>17 (94%)</td>
<td>17 (94%)</td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td>0 (0%)</td>
</tr>
<tr>
<td></td>
<td>Naïve</td>
<td>1 (6%)</td>
</tr>
<tr>
<td>Method Myth</td>
<td>2 (11%)</td>
<td>8 (44%)</td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td>4 (22%)</td>
</tr>
<tr>
<td></td>
<td>Naïve</td>
<td>1 (6%)</td>
</tr>
<tr>
<td>Theories and Laws</td>
<td>3 (17%)</td>
<td>6 (33%)</td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td>5 (28%)</td>
</tr>
<tr>
<td></td>
<td>Naïve</td>
<td>10 (56%)</td>
</tr>
<tr>
<td>Social</td>
<td>12 (67%)</td>
<td>17 (94%)</td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td>4 (22%)</td>
</tr>
<tr>
<td></td>
<td>Naïve</td>
<td>1 (6%)</td>
</tr>
</tbody>
</table>

Note: Eighteen participants took the pre- and post-course VNOS-C. Percentages may not total 100 since some responses to the survey questions did not contain statements that could be used to assess beliefs about all NOS aspects.
Table 4.9: Frequencies of Change in Views of Nature of Science Aspects

<table>
<thead>
<tr>
<th>VNOS Aspect</th>
<th>No Change</th>
<th>Partially Informed to Naïve</th>
<th>Partially Informed to Informed</th>
<th>Naïve to Informed</th>
<th>Naïve to Informed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empirical</td>
<td>14</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Inferential</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Creative</td>
<td>13</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Theory-Laden</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tentative</td>
<td>17</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Method Myth</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Theories and Laws</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Social</td>
<td>11</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Research Question 4: What are the objectives of teacher-created unit plans that are based on experiences from an online science course for teachers? How do finished unit plans align with these objectives?

Objectives.

Unit plans created by teachers as a final project for the American Museum of Natural History’s Seminars on Science Evolution: Modern Evolutionary Biology were analyzed. The course is organized into six units that cover; the evidence for evolution including Charles Darwin’s work; constructing and interpreting evolutionary trees based
on morphological and genetic data; the mechanisms of evolution including natural selection, sexual selection, and genetic drift; the formation of species and the use of different frameworks for defining species; human evolution; and the impact of evolution on our daily lives, including the creation of influenza vaccines and the use of evolutionary theory in conservation and agriculture. As a final project, participants are expected to create a five-day unit plan for teaching course content. For Final Project guidelines see Appendix H.

Lesson objectives from the participants’ unit plans were categorized. The categories were created emergently as teaching objectives were grouped. The results of this categorization appear in Table 4.10. Some objectives were included in more than one category. Unit plans from 19 teachers were analyzed. One teacher submitted two unit plans for different grade levels. Twelve unit plans were geared to high school or first-year community college, six to middle school, and two to elementary school.

Two of the major topics of the course, the mechanisms of biological evolution and the construction and analysis of phylogenetic trees appeared most frequently as objectives in unit plans designed by middle and high school teachers. Evolutionary mechanisms were listed as objectives 39 times and elements of construction and analysis of phylogenetic trees were listed in objectives 38 times. Twelve out of the 19 teachers wrote objectives related to evolutionary mechanisms and 10 teachers included tree building. Ten teachers also utilized objectives related to adaptation and 10 included objectives dealing with classification based on morphology. Objectives on these topics appeared 31 and 23 times, respectively. Objectives related to the nature of science and scientific processes were included 20 times in nine different unit plans. Objectives
dealing with the evidence for evolution and the learning of definitions appeared 13 times in seven projects each. Objectives related to human evolution, the history of evolutionary theory, and the social implications of understanding evolution appeared less frequently.

Table 4.10: Categorized Lesson Objectives

<table>
<thead>
<tr>
<th>Number of Plans</th>
<th>Total</th>
<th>Elementary</th>
<th>Middle School</th>
<th>High School</th>
<th># of teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature of Science</td>
<td>20</td>
<td>2</td>
<td>6</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>Classification based on morphology</td>
<td>20</td>
<td>1</td>
<td>3</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>Phylogenetic Tree-building/Cladistics</td>
<td>38</td>
<td>0</td>
<td>16</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>Adaptation</td>
<td>31</td>
<td>13</td>
<td>10</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Mechanisms of Evolution</td>
<td>39</td>
<td>0</td>
<td>13</td>
<td>26</td>
<td>12</td>
</tr>
<tr>
<td>Evidence of evolution</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>Definitions</td>
<td>13</td>
<td>0</td>
<td>2</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>History</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Social Implications</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Human Evolution</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>

The two elementary level projects focused primarily on teaching about organisms’ adaptations for survival. Thirteen of 15 objectives aimed at this level dealt with adaptations. In addition, one objective addressed classification of organisms based on physical characteristics and one focused on the nature of science.
Examples of objectives that focus on animal adaptations at the elementary school level included:

- Students will be able to describe how animals must be adapted to their environment in order to survive.
- Students will be able to give examples of animal adaptations.
- Students will be able to explain the function of various adaptations.
- Students will be able to describe different ways in which animals respond to their changing environments.

The elementary level objective that focused on nature of science was:

- Students will be able to make observations and inferences.

The elementary level objective on classification based on morphology was:

- Students will be able to design categories based on their own knowledge and also group according to defined categories.

Examples of middle and high school unit plan objectives that addressed mechanisms of evolution included:

- Explain how evolutionary forces such as natural selection, sexual selection, and genetic drift can account for human variation.
- Analyze the relationship between organisms and propose hypotheses as to why 2 species may have diverged.
- Analyze the relationship between organisms and propose hypotheses as to why 2 species may have diverged.

Examples of middle and high school unit plan objectives that addressed construction and analysis of phylogenetic trees included:
• Students will build a phylogenetic tree to solve a biological problem (and defend the solution) using bioinformatics tools (BLAST, pBLAST, GALAXY, NCBI Gene Entrez etc.)

• Students will interpret the relationship(s) between organisms in their phylogenetic tree from an evolutionary perspective.

• Explain how a phylogenetic tree shows the evolutionary relationship between organisms.

• Explain how differences in DNA arise and how these differences can then be used to determine relationships between organisms.

Examples of middle and high school unit plan objectives that addressed classification based on morphology included:

• Students will be able to explain the origins of taxonomy and how modern scientists use it to determine relationships between organisms.

• Make inferences about organisms' relationships based on observations of physical traits.

• Use clues from the “Meet the Relatives” simulation and images of relatives to create a family tree, showing which species they believe are the most related.

Examples of middle and high school unit plan objectives that addressed the nature of science included:

• Students will gain respect for scientific processes through classify/grouping organisms based on similarities/differences and defending each classification/grouping.

• Students will be able to explain why evolution is a scientific theory and not a law.
• Develop methods of testing hypotheses.

Examples of middle and high school unit plan objectives that addressed the evidence for evolution included:

• Describe the types of evidence gathered to support and study evolution including fossil evidence, anatomical evidence, molecular and biochemical evidence, and biogeographical evidence.

• Diagram the major milestones in the evolution of modern humans from hominin ancestors. Explain the evidence available to support our current thinking about the human evolutionary timeline.

• Be able to describe how the fossil record helps paleontologists understand the evolution of life on earth and speciation.

Examples of middle and high school unit plan objectives that addressed definitions related to evolution included:

• Students will be able to define the types of selective pressures and give an example of each type.

• Students will be able to explain what natural selection is.

• Students will form an opinion as to which concept they believe defines a species, Biological Species Concept or Phylogenetic Species Concept.

Alignment of Unit Plans to Objectives.

Course objectives were examined for alignment to the course content, the activities in the unit plans, and the evaluation and assessment planned as part of the unit plan. An adapted five-point rubric from Contino and Anderson (2013) (Appendix F) was
used to examine alignment of the unit objectives to the online course content; the unit objectives to the activities in the unit plan; the unit objectives to the evaluation and assessment presented in the unit plan; the evaluation and assessment to the activities presented; and the planned activities to the course content. A rubric score of 5 represented full alignment. A score of 1 represented no alignment. 20 projects were examined. Nineteen teachers submitted projects with one teacher submitting two projects. Overall results are presented in Table 4.11.

Table 4.11: Summary Scores for Unit Plan Alignments

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Median</th>
<th>Quartile 1</th>
<th>Quartile 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives to Course</td>
<td>4.8</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Activities to Objectives</td>
<td>4.5</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Evaluation to Objectives</td>
<td>4.3</td>
<td>4.5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Evaluation to Activities</td>
<td>4.7</td>
<td>5</td>
<td>4.75</td>
<td>5</td>
</tr>
<tr>
<td>Activities to Course</td>
<td>4.8</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Overall, there was a high degree of alignment for the components examined in this study. The average total alignment score was 23, with 25 the highest possible. Eight participants received scores of 25. Scores ranged from 25 to 18. For alignment of lesson objectives to the course content, only two participants received scores below 5, with both receiving a 4 indicating that the “objectives align significantly but not fully with the big ideas or concepts in the course.” Regarding alignment of lesson objectives to the lesson activities, six participants scored lower than a 5, with four receiving a score of 4 and one receiving a 2, indicating that the learning activities aligned poorly with the objectives. For alignment of objectives to evaluation, 10 teachers scored below a 5. Seven of the 10 received a score of 4. Two received a score of 3, indicating that the “evaluation in the
lesson aligns partially with the objectives.” One learner received a score of 2 on this alignment. There were five participants who received scores below 5 on alignment of evaluation to the unit activities. Four of these scored a 4, while one received a 3. And finally, there were three scores below 5 for alignment of activities to the course. Two of these scores were 4, and one was a 3.

Regression analysis to examine a potential relationship between overall scores and years of teaching experience did not indicate a relationship. However, the three lowest scores on alignment analysis were by teachers with less than three years of experience.

**Research Question 5:** Using the Science Lesson Plan Analysis Instrument (Jacobs et al., 2008), what are the weighted scores from analysis of teacher-created unit plans using content from an online course on evolution?

Seventeen items from the Science Lesson Plan Analysis Instrument (Jacobs, et. al., 2008) (Appendix G) were selected based on alignment to the course Final Project Guidelines (Appendix H), relevance to aspects of Nature of Science (NOS), and inclusion of basic pedagogical principles. Each item was weighted with a multiplier of 3, 2, or 1 based on relative importance to the unit plan guidelines and NOS aspects examined in this study. Scores on each item were assigned using a rubric that awarded 2 points for Exemplary, 1 point for Making Progress, and 0 points for Needs Improvement. The maximum score possible was 76. Scores ranged from 76 to 55, with an average of 66, a median of 71 and a mode of 71.
All participants received maximum scores on six elements: goal orientation, content accuracy, assessment, student reflection, classroom discourse, and student participation. On alignment with standards, student engagement, meaningful application of content, and use of analytical skills by students, all but one of the participants received the maximum score.

In the area of awareness of science education research, 13 unit plans received the maximum score, with five at the Making Progress level. The highest score for any of these five projects was 66. For variety, four projects scored below the Making Progress level. These included the two lowest scoring projects, a project that received a 67, and a project that received a 75 (this was the only area scored below the maximum for this project). Four projects scored below the maximum for hands-on investigation. Two of these projects received no points for this element, as they were at the Needs Improvement level.

The four areas with the lowest overall scores were all weighted in the highest category. For content presentation, six projects scored below the maximum with a Making Progress. For student practitioners of inquiry, nine projects were scored below the maximum at the Making Progress level. All six projects scoring 64 or below were deficient in this element. For the nature of science element there were 4 projects at the Exemplary level, 11 at the Making Progress level, and 3 at the Needs Improvement level. The element with the lowest scores was students’ attitudes about science. There were four projects at the Exemplary level, nine at Making Progress level, and six at Needs Improvement. No project with a score of 64 or lower received a score of Exemplary for student practitioners of inquiry, nature of science, and student attitudes about science.
Research Question 6: What relationship, if any, is there between teachers’ Nature of Science profiles and the quality of their science lesson plans as determined through elements of the Science Lesson Plan Analysis Instrument?

Fifteen participants completed both a unit plan and the pre- and post-course VNOS-C survey. Using 17 elements from the Science Lesson Plan Analysis Instrument (SLPAI), weighted scores on unit plans ranged from 76 to 55 with an average, median, and mode of 67. The students with the top three scores (76, 75, and 73) all had informed views of NOS aspects related to the social and cultural dimensions of science and views about scientific theories and laws, used in this analysis. Of the three students who scored 70 on this analysis, two had informed views of both NOS aspects and one had an informed view of the social aspects and a partially informed view of theories and laws. Four students scored 67 on the unit plan analysis. All ended the course with informed views of the social NOS aspects. With respect to theories and laws, one had an informed view, two had partially informed views, and one had a naïve view. There was one score each of 65 and 64. Both of these students ended the course with informed views of both NOS aspects. The students with the lowest scores in the group (61, 58, and 55) all ended with an informed view of the social NOS aspects. The students scoring 61 and 55 both had partially informed views of theories and laws. The student who scored 58 had a naïve view of theories and laws.

To summarize, all students ended with informed views of the social NOS aspect. Views of theories and laws varied from informed to naïve. In the top six scores (76 to 70) only one student held a partially informed view about this NOS aspect.
aspect. There were three students with informed views of theories and laws with scores below 70 (67, 65, and 64). Two students with naïve views scored 67 and 58.

The analysis was refined to include only SLPAI elements that are related to nature of science and inquiry-based instruction. Five lesson plan elements were selected: student attitudes about science, student engagement, hands-on exploration, nature of science, and student practitioners of scientific inquiry. Two elements, Classroom discourse – fostering a community of learners, and Student Participation, which are applicable to inquiry-based instruction were not included because all participants included these elements in their unit plans and received the highest SLPAI score. VNOS-C profiles were converted to numerical values (3 for informed, 2 for partially-informed, and 1 for naïve). Linear regression using the weighted SLPAI totals and the VNOS-C scores produced an r of .61.

The two students who had naïve NOS views of theories and laws received no points for the student attitudes about science SLPAI element. One of these students had maximum ratings for student engagement, hands-on experience, and student practitioners of scientific inquiry, and a middle rating for nature of science. The other student in this group had middle ratings for all the SLPAI elements considered in this analysis (except for the aforementioned student attitudes about science element).

The five participants who had partially-informed views about theories and laws included the individual with the lowest score for the weighted total (7). All five received maximum ratings for the student engagement rating. For the hands-on investigation element, three students received the maximum rating, while the other
two did not include this element in their unit plans. One person received the maximum rating for Nature of Science, with the rest of the group garnering a middle rating. The unit plans received the maximum rating for hands-on exploration, while the other two did not include this element. For student practitioners of scientific inquiry two students received the maximum rating and two were rated as medium.

Eight participants had informed views about theories and laws. These included the three top scorers for the SLPAI elements. They received the maximum rating for student attitudes about science. The remaining five received the middle rating for this lesson element. All eight received the maximum rating for student engagement and hands-on exploration. Four (including the three top scorers) received the highest rating for nature of science and five received the highest rating for student practitioners of science. There were no scores of “0” on any of these SLPAI elements recorded by anybody who had an informed view of theories and laws.
Chapter V
DISCUSSION

Research Question 1: What are the patterns of online interaction through seven-weeks of an online course on evolution for teachers?

Cognitive Level.

The cognitive presence, from the Community of Inquiry (CoI) framework (Garrison et al., 2001), allows an examination of how students in an online course engage with the content and interact with other learners to construct knowledge. The four levels of cognitive presence are Triggering Events, Exploration, Integration, and Resolution. While questioning (Triggering Events) and exploration of a topic are necessary parts of the CoI learning cycle (Garrison et al. 2000), the higher cognitive activity involved in achieving integration and resolution is the desired outcome. Previous research (Garrison, Anderson, & Archer, 2001; Garrison et al., 2000; Kanuka, Rourke, & Laflamme, 2007; Rourke & Kanuka, 2009; Stein et al., 2007; Vaughan & Garrison, 2005) suggests that it is difficult to achieve Integration and Resolution in online learning environments.

No Resolution level posts were recorded during this study. The CoI coding scheme (Appendix A) defines Resolution as the “vicarious application to real world testing solutions” and the defense of such solutions. The prompts that were used as discussion starters for this course were open-ended questions that were designed to get students involved in extensive discussion about each unit’s topic (Appendix B). As written, the prompts did not provide an opportunity for students to solve a specific problem through application of the course content.
In comparison to other studies using CoI coding for cognitive presence, this study found a relatively high level of Integration. Forty-seven percent of total posts by learners were coded at the Integration level and 38% at the Exploration level. Seven percent were Triggering Events. Since the discussion prompts supplied the initial question for each discussion, it is not surprising that students posted few Triggering Events. However, the percentage of Integration level posts contrasts with other studies that have presented cognitive presence levels as percentages of total posts. Results from McKlin et al. (2002), Meyer (2003), Vaughn and Garrison (2005), Garrison et al. (2001), Celentin (2007), and Meyer (2004) are summarized in Table 5.1.

The present study found higher levels of Integration than all of the other studies presented in this table. However, Meyer (2004) found levels of Resolution that were higher than all the other studies. The Meyer study looked at discussions that were started by prompts supplied by learners and will be discussed in context below.

The comparison to other studies raises an interesting question. What might account for the comparatively high level of Integration found in this study? It is doubtful that inconsistencies in analysis could account for the observed differences since all of these studies used the same basic rubric and care was taken in the coding for this study to follow the coding scheme as literally as possible.

The high frequency of Integration level posts may be related to how the discussion prompts framed the tasks and may also be influenced by student performance expectations laid out in the course discussion rubric (Appendix C) and communicated to students by faculty in the discussions and assessments of discussion performances. The CoI coding scheme uses the following as evidence of Integration: “Reference to previous
Table 5.1: A Comparison of Studies That Used Community of Inquiry Coding for Cognitive Presence as Percentages of Total Posts.

<table>
<thead>
<tr>
<th>Study</th>
<th>Course Type</th>
<th>Trigger</th>
<th>Exploration</th>
<th>Integration</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garrison et al. (2001)</td>
<td>Online Graduate Social Science</td>
<td>8</td>
<td>42</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>McKlin et al. (2002)</td>
<td>Blended Graduate</td>
<td>3</td>
<td>39</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Meyer (2003)</td>
<td>Blended Graduate</td>
<td>18</td>
<td>51</td>
<td>22</td>
<td>7</td>
</tr>
<tr>
<td>Vaughan &amp; Garrison (2005)</td>
<td>Blended College Faculty</td>
<td>8</td>
<td>61</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>Celentin (2007)</td>
<td>Online Foreign Language</td>
<td>4</td>
<td>40</td>
<td>22</td>
<td>4</td>
</tr>
<tr>
<td>Randle (Present Study)</td>
<td>Online Graduate Science</td>
<td>7</td>
<td>38</td>
<td>47</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Blended courses have both an online and a face-to-face component.

message followed by substantiated agreement or disagreement,” “Justified, developed, defensible, yet tentative hypotheses,” “Integrating information from one or more sources – textbook, articles, personal experience, other posts or peer contributions,” and “explicit characterization of message as a solution by a participant.” The course design provides students with essays by scientists, links to outside resources, and textbook readings that are intended for use in the construction of discussion posts. The discussion rubric prescribes explicit guidelines for reflection on the course content. To receive a grade of Exceeds Expectations (roughly equivalent to an A), a student must have “Reflected on the discussion questions using course materials while drawing in other resources and
asking additional questions.” To receive a grade of Meets Expectations (roughly equivalent to a B), a student must have “Reflected on the discussion question using course materials.” At either of these grade levels, the expectations laid out by the course framers are clear that students need to integrate resources from the course into their discussion responses, which is the third indicator of Integration level cognitive presence as noted above. The fact that 40% of a student’s overall grade is a result of discussion contributions may also increase the motivation for achieving higher cognitive levels.

Another factor that may have influenced the frequency of Integration level posts by students is interactions with faculty. As will be seen in the case study analysis that follows, there were occasions when the instructor specifically asked learners to cite the references that were used to compose posts. This practice may have played a role in increasing the frequency that one or more resources were used at an Integration level in learners’ discussion posts.

The explicit framing of learning tasks in an online environment appears to have a great deal of influence on learning outcomes. In this study, the discussion prompts did not pose problems that students needed to solve, but asked for open-ended reflection of course content. Hence, there were no instances of Resolution level posts but high levels of Integration. In the Meyer (2004) study included in Table 5.1, 20% of the posts were at the Resolution level. Forty percent of these posts came from 5 of the 17 discussions analyzed in the study. These discussions were framed by prompts that explicitly asked students to resolve a problem. The triggering question, therefore, influenced the “level of response from the students.” (Meyer 2004, p. 110).
The progression of posts by individuals in the discussions does not show a step-wise progression through the CoI learning cycle (Garrison et al. 2001). In other words, learners did not necessarily post a question (Triggering Event), follow it with an Exploration level post, and then respond with Integration. In many cases the Integration level post happened in the first post to the discussion prompt. Many learners tended to make this post a well developed, multiple paragraph treatment of the discussion prompt that included references.

Scientific Accuracy.

There were 395 posts made by learners that contained sufficiently identifiable science content to be analyzed for accuracy. There were 336 scientifically accurate statements made in the course. These statements outnumbered statements with partial scientific misconceptions (55) and statements that were scientifically inaccurate (4). The fact that 85% of posts containing scientific statements were accurate can be attributed to two possible factors. First, learners may have entered the course with a high level of previous knowledge. However, case study analysis of individual learners uncovered a pattern of knowledge development that is not consistent with extensive previous knowledge about evolution. This was evident even among learners who received high grades in the course. Therefore, it is not likely that the high percentage of accurate posts was a result of a high level of previous knowledge about evolutionary theory. The fact that many of the participants were experienced science teachers, who, presumably, were used to dealing with scientific content in an academic environment, may have helped them in their ability to use the course resources to develop and communicate their
understanding of the topics presented in the course. The low frequency of scientific statements that contained complete or partial inaccuracy may be due, in part, to the nature of online asynchronous interactions. Research indicates that online learning environments seem to be particularly well suited for fostering critical thinking and developing reflective learning communities (Dede, Whitehouse, & Brown-L’Bahy, 2002; Bullen 1998). The fact that most of the posts that included scientific statements were coded as accurate may indicate that participants were able to carefully compose their responses and check reference sources before submitting responses to the discussions.

The discussion with the lowest number of posts containing statements with scientific content (22) occurred in the sixth unit. This discussion prompt asked teachers to consider “the implications and importance of teaching evolution”. The conversations in this discussion centered on pedagogical concerns and learners’ thoughts about the need for students to understand evolutionary theory. The topic of the discussion was different from the other discussions in the course, which were framed to address scientific content knowledge. This helps explain why the data from this discussion appears to be anomalous. When the data point for this Unit 6 discussion is removed from analysis, the regression line for the number of scientifically accurate posts in Figure 4.1 flattens to a slope of -1.1 with $r = -0.29$. The new y intercept of 56 is within the range of data point for these discussions. This reinforces the idea, presented earlier in this discussion, that explicit framing of learning tasks in an online environment appears to influence learning outcomes.
Other Interactions.

Posts that did not contain statements that could be coded for scientific accuracy or cognitive level were coded as Other Interactions (Table 4.3). These post were often brief and often occurred at or near the end of a discussion thread. These statements can be considered social interactions and, while they did not deepen the conversation about the scientific content, they are hypothesized to strengthen the online community and lead to higher levels of cognitive presence (Shea, Li, & Pickett, 2006).

Twenty-six percent of the Other Interaction messages expressed thanks for explanations, examples, or links to resources communicated by other learners or faculty. Personal messages about likes, dislikes, interests, or household events were also common (20%) as were quick exclamations (17%) such as expressions of congratulations when the course instructor announced to the class that she had just retired from classroom teaching.

An interesting group of Other Interaction was comments left by learners about their own metacognition (10%). This information could be potentially useful for the faculty and sheds light on how students processed information in the course. An example is:

My knowledge of evolution is somewhat limited, but I am trying to glean all I can from the readings and other posts. I think once things “click”, I’ll be O.K., but I’m still waiting for the defining moment to come. I understand parts of evolution and phylogenetics, but I have a long way to go.

This statement helps the instructor know to check back with this learner at a later point to see if the “click” happened. Bransford, Brown, & Cocking (2000) identified metacognition as one of the key elements in learning, suggesting that teachers use strategies to help students develop metacognitive processes. Given its utility in promoting reflective discussion, online asynchronous discussion may be an appropriate vehicle for developing metacognitive processes.
Instructional Implications.

One of the two discussion prompts in Unit 6 asks the participants to reflect on “the implications and importance of teaching evolution”. There were 110 posts to this discussion. Of these, 93 posts dealt, in some manner, with instructional application of the course content. Since this prompt required the discussion of pedagogy, this discussion was not a good gauge of the inclination of this learning group to bring conversations about teaching into the otherwise science content-based discussions. When posts from this discussion were removed from the totals, 19% of the remaining posts contained content related to teaching.

All of the participants in the course were practicing teachers, pre-service graduate education students, or informal educators. Posts related to how the course content of a given unit might influence instruction occurred in every unit. The instructor was a retired high school biology teacher who sometimes asked questions related to pedagogy and offered her own suggestions for teaching evolution. Since evolution is a core topic in most biology curricula, it is natural that teachers would discuss instruction as they worked their way through the science content. While the course was designed as a science content course, there was an undercurrent of discussion about teaching that ran throughout the duration of the course. This discourse included, but was not limited to, the identification of resources that would be helpful for classroom instruction, the sharing of activities that teachers had implemented successfully, and commenting on how a teacher’s students would react to, or perhaps struggle with, content presented in the course.
While it is not assumed that the number of posts is an indicator of the quality of interaction in an online course, these numbers can give indications of the patterns of interaction and course dynamics. In this study the number of student posts per discussion stayed relatively constant over the six units. The regression line for the number of student posts had a correlation value of -.14, a regression slope of -1.00, and y intercept of 124, which was within the range of 140 to 100 posts per discussion (Figure 4.2). In contrast to student posts, posts by the faculty (instructor, teaching assistant, and scientist) declined as the course progressed. The slope of the regression line for faculty was -9.8, with r = - .90. The number of faculty posts was highly correlated to Teaching Presence (r = .99), while Teaching presence by faculty was not correlated to any of the three levels of student cognitive presence.

As faculty posts declined, the opportunity for students to reply to the faculty was reduced and student posts to the faculty declined as well (Figure 4.3). Student posts to the discussion prompt were relatively constant in number across all discussions. Therefore, it follows, that as student posts to faculty declined, student posts to other students increased. This is evident in Figure 4.4. One explanation for this trend is that the students developed a learning community that did not depend on faculty to stimulate conversation. In the first three units faculty posts were 32% of the total posts made in the discussion. In the last three units faculty posts made up 15% of the total posts. It is possible that more involvement by faculty early in the course modeled expected posting behavior for the student and helped set expectations for levels of course participation.
Shea et al. (2010) found a similar trend of increased student-to-student interaction in two courses they compared and hypothesized that “… students' teaching presence may have a “floor” threshold level and when the instructor's teaching presence drops to zero students attempt to recreate “instructional equilibrium” (p. 14). In comparing two courses Shea et al. found slightly higher teaching presence on the part of students in a course that had lower teaching presence from the faculty. In the current study there was no increase in teaching presence from students as the faculty reduced teaching presence during the later units.

Another explanation is that since students’ grades are dependent on discussion participation (40% of their total grade for the course), they post responses to whoever is available. By the later stages of the course they have received grades for previous discussions and should be well informed of discussion grading criteria. The instructors were explicit about setting participation expectations through announcements, feedback in the grade book, and references to the grading rubric for discussions (Appendix C). This aspect of course communication is discussed in the analysis of the case studies.

Temporal Patterns in Course Participation.

Analysis of temporal patterns was done by compiling the combined number of posts from corresponding days (first, second, third, etc.) from all seven discussions. The discussion prompts for each unit were open-ended questions that required learners to reflect on resources such as essays, internet links, and assigned text readings provided by the course designers and to bring in other resources in order to take part in meaningful discussions. The course faculty made a practice of reminding learners of the need to cite
the resources used to construct posts. The time taken to read through essays and textbook readings, as well as to compose reflective, multiple paragraph responses to the discussion prompt, explains a lag in involvement at the beginning of each discussion. There were only four posts made on the combined Day 1 of all seven discussions. Only 20 posts were made on Day 2. New discussions opened on Mondays. Days 1 and 2 correspond to the first Monday and Tuesday a discussion period. During the first week, the number of posts increased steadily over the first four days, dipped on Day 5 (Friday) and then peaked on Day 7, which corresponded to the first Sunday.

Participating in discussions that have already started required less effort than starting new conversations. Activity on the Days 8, 9, 10, and 11 (Monday through Thursday of the second week) ranged from 58 to 81 posts. After a dip on the second Friday (to 44 posts), discussion activity reached the highest level (104 posts) on Day 14, which corresponds to the second Sunday of the discussion. This is the cut off point for grading eligibility. Forty percent of a participant’s course grade is based on discussion posts so this peak is partially explained by students adding posts to meet the crediting deadline. As discussed in the analysis of discussion case studies, some of the lower performing students made the majority of their posts in the latter days of the discussions.

Student posts that could be coded for either scientific accuracy or cognitive level were characterized as “Other Interactions”. These types of posts are discussed above. As the discussion progressed through the 14-day period, the proportion of the total number of post made on each day coded as Other Interactions increased (Figure 4.6). It is important to note that the numbers of statements that contained scientific statements or cognitive level indicators did not decrease. Since the numbers of posts made by the
students increased as the discussions progressed, the increase in Other Interaction posts did not correspond with a significant decrease in the numbers of posts with scientific content or cognitive level indicators. It appears that the Other Interaction posts are statements that could be expected at the conclusion of interpersonal communications. Expressions of gratitude or congratulations occurred late in discussion threads in response to previous posts. Reflections on metacognition came after discussions of content in which learning outcomes were achieved. The nature of these types of posts is such that they occur late in the discussion period and can be attributed to the natural cycle of a conversation.

As mentioned previously, the desired student discussion outcomes are posts that contain scientifically accurate statements and statements that indicate Integration level cognitive activity. As the discussions progressed, the proportion of these two types of posts declined (Figures 4.7 and 4.8). It is important to note, however, that the numbers of these types of posts did not decline.

The decline in the proportion of Integration level posts can be partially attributed to a moderate increase in the number of Exploration level posts ($r = .55$) and a rise in the numbers of Other Interactions ($r = .69$) as the discussions progressed. This occurred while the number of Integration level posts remained relatively unchanged. The number of scientifically accurate posts likewise did not decline. However, students made more posts near the end of the discussion period that did not contain content that could be coded for scientific accuracy. So, although students were contributing a greater number of posts late in the discussion period, the increase was the result of posts that were not
presenting or integrating science content. Rather, students were engaging in activities such as sharing resources and finishing conversations.

Research Question 2: Based on case-study analysis, what characterizes the patterns of online interaction for a sample of teachers involved in a seven-week online course on evolution?

Case study analysis was used to examine the characteristics of learners who performed at high, medium, and low levels in the course discussions. Selection of learners for the case study is described in the Methods section. Three learners were selected, one at each level.

Some patterns emerged from this analysis. The two students who failed the class stopped participating in the discussions after Unit 1 and stopped logging into the course around the same time. Learners who performed at a low level ("Approaches Expectations") generally showed low levels of engagement compared to other learners. Learners who performed at a medium ("Meets Expectations") level generally had moderate levels of engagement compared to classmates and had moderate levels of high quality posts containing Integration level cognitive indicators and scientifically accurate statements. The posting profiles of these learners fell on a continuum from a high frequency of posts with a low percentage of quality indicators (Integration level and scientifically accurate statements) to a lower frequency of posts with a higher percentage of quality indicators. The high performers ("Exceeds Expectations") were generally more engaged in the course and had high frequencies of quality indicators. High performers also fell on a
continuum, with higher quantity of posts containing a lower percentage of quality indicators on one end, compared to learners who made a slightly lower quantity of posts with a higher percentage of quality indicators. In general, the high performers were more active during all stages of each two-week discussion period.

Low levels of engagement in the course as well as low levels of apparent understanding about course logistics characterized the low performer (BG) in the case study. Not only did she contribute a low number of posts (22 total), she only included statements that could be evaluated for scientific accuracy in 32% (seven) of these posts. This contrasts with the course average of 47%. The fact that four of these posts contained minor scientific inaccuracies indicates that BG struggled with the content. Whether lack of understanding and confidence with the material resulted in a reluctance to engage in the course or whether her non-engagement resulted in a low understanding of the content was not clear. There were three stretches of five days or more when she did not log into the course and most of her posts (18 of 22) were made after the ninth day of the discussion. Eight of her 22 posts were made after the 14-day window for credit had closed. This tardiness indicated either a misunderstanding of course deadlines or perhaps hopefulness that she could get some credit if the faculty was lenient. The lateness of her posts limited her engagement with other students and there were only five instances of other students replying to one of her posts. The fact that she never posted to the discussion prompt by starting a new discussion thread, even when it was obvious that her post was addressing the prompt, indicated that she did not understand the operation of the course learning management software.
This learner appeared to struggle with both the content of the course, the logistics of using the online learning management software, and the expectations and deadlines laid out by the course administrators. It is difficult to speculate on why this learner struggled. She was a first year teacher, taking a fast-paced graduate-level science course that overlapped with the culmination of her school year and a family emergency that she did not elaborate on. Perhaps the time demands of this type of course were just not achievable for her. It is also possible that this learning environment, which requires self-motivation and a certain degree of confidence and comfort to present ideas in text to the learning community (Harlan & Doubler, 2004) did not fit her learning style.

The faculty made an effort to give BG specific feedback in order to improve her performance. The following is the feedback posted in the grade book at the end of Unit 1.

There are a few things you can do in upcoming discussions to bring your grade up considerably. First, try to make concrete references to the readings in your initial response and be sure that you list your resources. Additionally, be sure to return to the discussion board and make additional comments based on your new knowledge. I look forward to our conversations in the coming weeks.

Similar feedback accompanied subsequent grades. The reasons why BG was not able to follow these recommendations to improve her performance are not clear.

Despite her limited engagement, there were indications that she was learning about evolution as the course progressed. She posted in Unit 5 that, “This week answered my questions from week 4...thanks.” and there were instances in her Integration level posts were she followed statements from the course essays with accurate thoughts about how the resources connected to the subject of the prompt.
The medium performer (KE) featured in the case study modeled efficiency in his posting. He only made 16 posts during the course. 75% of his posts had indicators of Integration level cognitive activity and nine contained statements that could be coded for scientific accuracy. Seven of these were coded as scientifically accurate. This learner could be characterized as a “weekend warrior.” Early in the course he responded to the prompt during the first weekend each discussion was open. During the last two weeks he was active primarily during the final weekend of the discussion.

KE rarely engaged with other learners. There were instances when other students responded to his posts, but he only replied to them five times, usually too late in the discussion period for a back-and-forth conversation to develop. The lack of engagement with other members of the learning community limited his ability to get more than a grade of “Meets Expectations” for the discussions, since 40% of that grade is based on participation. However, his posts to the prompt were well-developed responses to the discussion questions and demonstrated that he was reading and understanding the course material. It is not clear how much more he would have learned about evolution if he had engaged more robustly in the discussions. Many of the discussion threads were deep explorations into the topic presented in the prompt or took tangents to related material that learners and faculty referenced. There was little evidence found in the case study analysis that indicated that KE was looking at these deeper discussions on a regular basis or doing more than just responding to the discussion prompt. The fact that much of his work happened close to the grading deadline opens the speculation that he was
motivated primarily by the grading requirements of the course and not by a more innate curiosity about the subject of evolution. This raises questions about his motives for posting to other students. The late nature of his posts might indicate that he was more concerned with getting credit for participation rather than engaging in a meaningful discussion about the course content with classmates.

Another type of medium performing learner that would be interesting to examine in more detail, is a student who used a strategy that was opposite from KE’s. Rather than a few high quality posts, this learner contributed a high number of posts that contained percentages of Integration and scientifically accurate statements that were well below the class average. This learner also posted late in the discussion periods raising the same questions about motivation that were discussed for KE. However, while his percentage of high quality indicators was low, he addressed the content and displayed Integration level cognitive activity enough to earn a grade of “Meets Expectations” (equivalent to a B) for the discussion component of his grade.

The high performing student that was the focus of the case study (CG) demonstrated consistent engagement in the course. She logged in on almost every day the course was open to learners (44 of 49 days). She made 42 posts during the course, which was higher than the average of 35. Twenty-eight of her posts contained indicators of Integration level cognitive activity and 31 posts contained statements that could be coded for scientific accuracy. Twenty-nine of the 31 were coded as accurate.
CG engaged with other members of the learning community, particularly with other students, on a regular basis. A consistent characteristic of her discussion involvement was to respond to other students with in-depth posts that usually included a reference to a resource. She followed up on other student’s questions with her own thoughts about the topic, often referencing resources that she found in response to the questions. Her posting behavior was shaped by an early interaction with the course instructor who asked her to include references to resources that she used to compose her initial response to the first discussion question. For the duration of the course CG consistently referred to the course essays and text as well as to material that she identified on her own.

Evidence of learning was present in CG’s posts. There were two instances when she posted scientific content that indicated that she held slight misconceptions about the subject. She later revised this initial misconception in an accurate, multiple-paragraph post in a subsequent unit. Another response that was evidence of her learning progression came in response to another student. This post indicates not only her interest in improving her knowledge, but her willingness to engage with other learners to explore the content.

I did not know the answer to your question so I started poking around to try and find one. I did not find exactly what I was looking for (at least not yet), but I did come across some interesting information regarding epigenetics and evolution.

Another example of CG’s learning occurred in a three-paragraph post that started with “I did a little research on the topic of coevolution looking for support to this idea and come across some interesting thoughts.”
CG’s involvement in the course is a model for learners who want the richest possible learning experience. Her posts to the discussion prompt occurred during the first few days of each discussion period. This provided an opportunity for other learners to post responses and develop conversations. She engaged with other learners and faculty to explore the discussion topics in much more depth than the course resources provided. She posted new resources and commented on resources that other learners posted. She went well beyond the minimum requirements of the highest grade, seemingly motivated by interest in the subject matter and a comfort and willingness to engage with others in a text-based discussion format.

Overall, the case study analysis indicates a variety of learning participation profiles. CG’s profile illustrated a high degree of very reflective engagement. Two other learners who were categorized as high performers, tended towards the “efficiency” model that KE exemplified. However, they engaged with the community more frequently and therefore received higher discussion grades. Another high performing learner was the most prolific poster in the course, but she had a lower percentage of posts that contained scientifically accurate content and indicators of Integration level cognitive activity. The medium performers spanned a continuum from low posting and high efficiency with regard to quality indicators (scientific accuracy and Integration level posts) to having more frequent posts with lower percentages of quality indicators. The main characteristics that separated the medium performers from the high performers were either lower levels of quality indicators or inconsistent involvement through low participation in the discussions.
or discussions that were missed altogether. The common characteristic of the low performers was a very low level of engagement in the course.

Research Question 3: How do teacher views of the nature of science change over the seven-week period of an online course on evolution?

In general, the participants in this study had relatively informed views of several of the nature of science (NOS) aspects that were examined. VNOS profiles of participants indicated informed views of the empirical, inferential, and tentative aspects on the pre-course survey and there was little change in these views on the post-course survey. Akerson, Buzzelli, and Donnelly (2007) and Borda et al. (2009) also observed relatively high incidence (above 80%) of informed views regarding the tentative nature of science on VNOS surveys administered before courses with pre-service elementary school teachers, indicating that this NOS aspect may be generally well understood among teachers. However, these two studies observed less informed views about the empirical and inferential NOS aspects than the current study. Other studies have consistently shown that teachers hold views of nature of science that are not consistent with generally accepted conceptions of science held by scientists and researchers in this field (Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick, & Lederman, 2000). The more informed views observed in the current study might be due to the makeup of the sample. While 5 of the 18 participants were pre-service education students with no professional teaching experience, 10 taught at the high school or adult level and had more than six years of experience (Table 4.7). Since many elementary and elementary-certified middle school teachers lack extensive science content background (Akerson & Flanigan, 2000;
Akerson, 2005; Parker, McConnell, & Eberhardt, 2013), this could account for some of the more informed NOS views in comparison with the Akerson et al. and Borda et al. studies. There has been little recent research in the United States using the VNOS-C with experienced secondary teachers. Further research is needed to determine if this pattern is generalizable throughout the population of high school science teachers. More informed VNOS views among this study’s participants might also partially account for the previously discussed high frequency of scientifically accurate statements that were made in the discussions.

The greatest numbers of changes were observed in NOS views regarding the social aspects of science and understandings of scientific theories and laws. These two NOS aspects were dealt with the most directly in the Evolution course. The course used case studies of scientific investigations to highlight some of the social dynamics of research in this field and the scientific use of theories and laws was discussed as an important element in understanding creationist reasoning that attempts to discredit evolutionary science by claiming that it is “just a theory.” While it seems likely that these resources had an effect on the participants’ views, there was no direct evidence from interview transcripts or discussion analysis that supports this assumption and more research is needed to verify and investigate these changes. Swartz et al. (2004) found that the biggest gains in NOS views are seen in students who began with the least informed views. Findings from this study confirm this observation. The greater frequency of changes in views about theories and laws and the social aspect of scientific investigation can be partially attributed to the fact that participants had the least informed views in these areas.
Despite the fact there was a high frequency of change in views about theories and laws, the post-course survey indicated that only one third (6 of 18) of the participants held informed views about this NOS aspect at the end of the course. As previously mentioned, scientific theories and laws were presented in readings in the course, however there were no explicit tasks that learners were asked to perform that would help them internalize this information. One of the discussions in Unit 6 asked learners to explore the importance of teaching evolution. Some, but not all, participants in this discussion addressed the definition of a scientific theory. The lack of an explicit assignment related to the understanding of theories and laws may partially explain why 12 of the 18 learners finished the course with naïve or partially informed views about this NOS aspect. This supports previous findings that implicit NOS instruction is not effective at changing participants’ NOS views (Abd-El-Khalick and Lederman, 2000; Akerson et al., 2003) and could be one area where course designers could improve instruction if NOS understandings are a desired learning objective.

The aspects of the theory-laden nature of science and the myth of the scientific method were difficult to examine in this study due to a lack of data. There were few low-inference statements made by the participants on the online VNOS-C form related to these aspects. This presents a potential limit to the use of this instrument in this format. This is the first known study that uses the VNOS-C to examine NOS views by participants in an online course. The online administration of the survey, rather than in a supervised and timed group setting, may have limited the motivation of participants to respond in depth to the survey questions. For future research using the VNOS-C as an
online survey, it is recommended that the researchers explore ways to communicate (and possibly incentivize) the need for expansive written responses by the participants.

**Research Question 4:** What are the objectives of teacher-created unit plans that are based on experiences from an online science course for teachers? How do finished unit plans align with these objectives?

The final research questions in this manuscript focus on how teachers plan instruction that incorporates elements from the online Evolution course. For the most part, the choices of objectives by the participants aligned with best practices for content level according to the Benchmarks for Science Literacy (AAAS, 1993). The exception was the inclusion of the construction of phylogenetic trees based on DNA sequences that were included in some middle school unit plans.

Both of the elementary school plans focused primarily on adaptation. This aligns with Benchmarks for grades three through five. “Different plants and animals have external features that help them thrive in different kinds of places” (p. 122) and “For any particular environment, some kinds of plants and animals thrive, some do not live as well, and some do not survive at all” (p. 116). One elementary plan also included an objective on classification based on morphology, which fits the following grade appropriate Benchmark: “A great variety of kinds of living things can be sorted into groups in many ways using various features to decide which things” (p. 103).

The middle school plans focused on grade appropriate topics such as classification based on morphology, adaptation, and mechanisms of evolution (natural
selection) and aligned with the following grade six to eight Benchmarks: “Similarities among organisms are found in internal anatomical features and patterns of development, which can be used to infer the degree of relatedness among organisms” (p. 104) and “Individual organisms with certain traits are more likely than others to survive and have offspring” (p. 124). However, the use of computer software to build evolutionary trees using genetic similarities was included in some unit plans. This topic is listed as a grade nine to twelve Benchmark: “The degree of relatedness between organisms or species can be estimated from the similarity of their DNA sequences, which often closely match their classification based on anatomical similarities” (p. 105). According to the Benchmarks for Science Literacy (AAAS, 1993) this topic is best taught after students understand the structure of DNA and how mutations occur and accumulate in a genome over time. These topics are also listed at the high school level in the Benchmarks. It is interesting that DNA structure is listed as a high school topic by the Benchmarks, since it is often featured in middle school biology texts, including some current reform-based middle school texts (Kolodner et al., 2009).

This raises the question of why teachers included tree-building with genetic sequences in their middle school unit plans. It is possible that they enjoyed the activity during the course and were anxious to try it with students, whose abilities they may be overestimating. The answer to this question will require qualitative case-study analysis that includes interviews with the teachers and possibly classroom observation to ascertain effectiveness of this activity with middle school students.
The high school unit plans were all on grade level and included the widest variety of subject matter related to evolution. This is most likely due to the fact that many of the topics presented in the course are accessible to high school students and teachers were able to choose different activities and topics to supplement what they already teach. Many teachers chose to include the construction of phylogenetic trees in their unit plans. An assignment in the course required participants to use phylogenetic inference software along with a multi-page protocol to download genetic sequences from organisms they selected, to format the sequences, and to construct an evolutionary tree. Many of the participants struggled with this assignment and the course did not offer any suggestions for adapting it for use with students apart from feedback from the course instructor on the unit plan draft. Since many teachers intend to use this activity with their students, it may be useful for the course designers to include some instruction on related pedagogy.

Overall, the participants in this course demonstrated a high proficiency in aligning unit plan objectives with the course content, teaching activities, and evaluation, as well as alignment of evaluations to objectives, and activities to the course (Table 4.11). Many of the unit plans, especially those for upper grade levels, incorporated activities presented in the course, leading to naturally high alignment of activities to the course. More teachers struggled with the alignment of objectives to evaluation then any of the other alignments looked at in this study. For future study, it would be interesting to look at how teachers sequence the creation of objectives, activities, and evaluation in this setting. It would be helpful to determine if they are designing evaluations based on the activities, if the evaluation drives the
creation of both the activities and objectives, or if they are using the objectives to design the activities and evaluations, as recommended by Wiggins and McTighe (2005). The writing of meaningful objectives may be an area that the course designers can support through supplemental materials, especially for beginning teachers, if the classroom implementation of the unit plans is a priority for the program.

**Research Question 5:** Using the Science Lesson Plan Analysis Instrument (Jacobs et al, 2008), what are the weighted scores from analysis of teacher-created unit plans using content from an online course on evolution?

All participants in the course received an Exemplary rating for the following six SLPAI elements: goal orientation, content accuracy, assessment, student reflection, classroom discourse, and student participation. As discussed previously in this study, this group of participants had high percentages of scientific accuracy in their online discussions posts, so it is not surprising that accuracy in content presentation would carry over into the final project. High scores for some of the other areas may be partially attributable to the guidelines and expectations provided in the course, and to feedback given to participants by the faculty on unit plan drafts. Goals, in the form of objectives, are an explicit item in the unit plan guidelines (Appendix H). The guidelines state “objectives should be stated in terms of what students will be able to do after completing the lesson. Do not tell what students will do during instruction (that’s scope and sequence).” (The bold faced emphasis is from the guideline document.) Assessment of student participant and evaluation of lesson success are two separate items in the
guidelines, so it is also not surprising that learners who followed the guidelines successfully included this SLPAI element.

The course is structured so that participants are required to turn in a draft of their unit plan for faculty feedback during the fifth week. Typical statements made by the faculty were reminders of the unit plan elements laid out in the project guidelines such as, “You have done some nice thinking for the overall "plan of attack" of your lesson. However, you still need to go through each of the required elements as you do your final project development.” Feedback to several students focused on assessment: “... the assessment and evaluation sections include a good list of indicators of student and lesson success. But for each, be sure to show how these can be measured in a reliable way. How do we gauge student participation, for example?” There was also an emphasis on inquiry: “The inquiry piece is, as you can see from the rubric, a big component of what we are looking for in the project.” Alignment with standards is also an explicit unit plan requirement for which all but one of the participants received the highest SLPAI score. It appears that explicit guidelines and faculty support may have had an influence on inclusion of specific lesson elements assessed by SLPAI.

The SLPAI areas that received the lowest overall scores were content presentation, student practitioners of inquiry, nature of science, and students’ attitudes about science. Although “To support scientific inquiry” is included in the unit plan grading rubric, which is available to participants, it is not an explicit item in the guideline document. Clarification of this expectation may help improve this element of lesson planning. These four items require more nuanced pedagogy and an understanding of nature of science by the designers. While there was not a significant correlation of SLPAI
scores to teaching experience measured in years, the five lowest scoring unit plans were produced by teachers with fewer than five years experience. This may indicate a need for support in lesson plan design that the course currently does not supply.

*Research Question 6:* What relationship, if any, is there between teachers’ Nature of Science profiles and the quality of their science lesson plans as determined through elements of the Science Lesson Plan Analysis Instrument?

There was a significant correlation of variations in nature of science views on social aspect and understanding of scientific theories and laws, as measured by the VNOS-C, to scores on SLPAI items related to nature of science ($r = .61, p = 0.15$). This correlation must be taken with caution, since the majority of participants finished the course with an informed rating on most of the VNOS-C items and the variability for the correlation was derived from views related to theories and laws. However, the fact that three of the four lowest scoring items on the SLPAI were related to NOS issues indicates a need for instruction in this area if the course designers expect students to include elements of inquiry-based instruction in their unit plans.

The SLPAI was originally used and validated for use in assessing lesson plans produced by teachers in a professional development program designed to teach lesson plan design (Jacobs et al., 2008). This is the first known use of this tool to assess unit plans produced in an online course that was focused primarily on scientific content knowledge. Items that were specific to the original professional development were removed and weights were adjusted to highlight items from the unit plan guidelines as well as NOS aspects that were examined in other portions of
this study. Overall, the instrument proved effective in assessing the unit plans produced in this study, however, for future use, an expansion from a 3 to a 5 point scale may be useful to create more variability in scores (although a drop in inter-rater reliability may accompany this change).
Chapter VI

CONCLUSIONS AND IMPLICATIONS

The percentage of total learner posts in this study that were coded at the Integration level using the Community of Inquiry coding scheme for cognitive presence was 47%. This is higher than other studies that reported cognitive presence as a percentage of total posts and was most likely due to the design of the discussion prompts and the expectations for learner interaction that were communicated to the participants. This and other studies indicate that the prompts used to start online discussions elicit specific responses. If course designers desire high-level cognitive activity by learners, then one means of achieving this goal is to construct discussion prompts that are open-ended and require the use of reference materials.

The faculty decreased their discussion activity as the course progressed. However, there was no corresponding decrease in student activity. Students increased their communications with each other and there was no noticeable drop in the level of scientific accuracy or cognitive activity in their posts. An interesting follow up to this study could be to look at the intentionality of this faculty “fade out”. The staff of Seminars on Science is trained to use a “guide-on-the-side” instructional strategy, however, since the faculty of this course were not interviewed, it is unclear if the decrease was a carefully monitored strategy, or if other responsibilities, such as providing feedback on final projects, diverted them from the discussions. It is also unclear if this pattern will be found in other courses. Further study that not only repeats the analysis of student and faculty interaction reported here, but examines faculty motives could illuminate this finding further.
This study reinforces previous research that indicates that online learning environments seem to be particularly well suited to fostering critical thinking. Two factors point to this conclusion. First is the high percentage of Integration level cognitive activity mentioned above. Second is the fact that 85% of the posts that contained scientific statements were coded as accurate. These findings indicate that participants were able to carefully compose their responses and very possibly check reference sources before submitting them to the discussions. Previous research also concludes that online learning environments are conducive to the development of reflective learning communities. This study also reinforces these findings. As faculty presence decreased, students posted more frequently to each other and assumed roles that were previously held by faculty as they responded to classmates, elaborating on ideas and presenting resources they found independently.

Case study results indicate that a learner who was successful in this environment demonstrated a high level of engagement in the course by logging in and posting often, introducing new resources to the learning community, and making frequent Integration level and scientifically accurate posts. A low performing student exhibited a pattern of intermittent activity, made low numbers of posts in each discussion and had low percentages of posts that contained scientific statements or indicators of high cognitive activity compared to classmates. Performance, or success, was defined by the grade assigned by the instructor as well as the demonstration of high levels of scientific accuracy and high frequencies of posts with Integration level cognitive activity. However, it is important to note that this does not mean that students who did not participate at this level were not
learning in this environment. One of the limitations of this type of research is that assessments of activity can only be made based on the text-based communications that are submitted as discussion posts or assignments. Activities that may have occurred as learners pursue their own interests, digest course resources, or read discussion posts without making their own contributions are not recorded. The development of methods for studying how, and what, participants who can be characterized as “lurkers” learn in online environments will illuminate ways to meet the needs of all participants. Particularly as the field of online education moves into MOOC (Massively Open Online Courses) style offerings, which are designed to accommodate thousands of learners simultaneously, it will be important to develop methods for assessing learning outcomes among participants who may be highly engaged in the material, but not in a way that leaves a written trail that can be coded and analyzed.

An examination of teachers’ views of the Nature of Science (NOS) using a pre- and post course Views of Nature of Science survey indicated that the group of teachers in this study began the course with relatively informed views of many of the nature of science aspects. An exception was views about the nature of scientific theories and laws, for which the majority held naïve views. While there were some changes in these views, at the end of the course a third of the participants still held unscientific notions of scientific theories and laws. While this NOS aspect was defined and discussed in the course in the context of education about evolution, there was no specific task that asked teachers to apply their understanding of this topic. This study supports previous research that suggests that implicit NOS instruction is not effective in changing participants’ NOS
views and could be one area where course designers could improve instruction if NOS understandings are a desired learning objective.

One of the main goals of this study was to add to the research base related to how online teacher professional development influences teacher practice. While ideal future studies will observe the classroom implementation of lessons created during a course, the teachers in this study were generally able to utilize content from the course to create well-designed teaching applications. There was a high degree of alignment of lesson objectives to course content and planned teaching activities, although some teachers struggled to align objectives to assessments. The content presented in the lessons was generally grade-level appropriate according to the Benchmarks for Science Literacy, however some middle-school teachers included an assignment from the course that required an advanced understanding of mutations and the structure of DNA that may be difficult for middle-school age students. More support for pedagogical applications in the form of model lesson plans, access to lesson plan formatting instructions, exposure to research on student learning, and strategies for conducting inquiry-based instruction could be helpful for teachers who struggled with this assignment.

Broader implications of the findings from this study extend to other uses of online technology. Current trends in online learning include blended courses that incorporate both online and face-to-face instruction and the previously mentioned MOOCs. In blended courses there is an opportunity to take advantage of the best features of online and face-to-face instruction. As mentioned earlier in this conclusion, this study supports previous work that indicates that online learning environments are well suited to reflective participation by learners. Using an online discussion with prompts and rubrics
designed to elicit high level (Integration or Resolution) cognitive activity could be used effectively to either prepare for or reflect on activities in a face-to-face meeting. The face-to-face time could then be used for activities that require more spontaneous participation, such as group discussions or laboratory investigations. MOOCs are structured so that large numbers of learners have choice in ways to access the materials. Building a reflective community through the use of well-designed prompts may be one way to get learners to engage with the content material. This study indicates that students will form active communities that require minimal input from faculty if they are provided with appropriate structures. In a MOOC environment, this will be critical since it is impossible for course faculty to monitor and participate in the activities among the large numbers of people involved in these courses. While blended courses and MOOCs are certainly at opposite ends of a spectrum, this study indicate that the use of intentionally designed online learning tasks with clearly communicated performance outcomes may result in a demonstration of higher levels of cognitive activity among participants.

This study was a case study of one online course. Generalizations based on these findings have been made throughout this thesis with consideration of the limitations that a focused case study entails. In addition, this work offers some insight into important avenues for future research into online learning. These include, but are not limited to, the design of discussion prompts, the degree that faculty engage in text-based discussion with students, the development of a community of learners capable of supporting their own explorations independent of faculty support, ways of supporting the development of Nature of Science understandings and pedagogical applications of science content in an online environment (especially the more sophisticated aspects such as theory and theory
testing), and the direct effect of online educational initiatives on the learning of science by students in participants’ classrooms. As online learning becomes a more prominent vehicle for delivering professional development to science teachers, it is the hope of this researcher that the community of online educators delivering these services is attentive to the strengths and limitations of this medium, and develops the means of meeting the needs of students with multiple learning styles as we move into the next generation of science education.
REFERENCES


APPENDIX A: Community of Inquiry Coding Scheme

<table>
<thead>
<tr>
<th>Categories</th>
<th>Indicators</th>
<th>Code</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design and organization (DE)</strong></td>
<td>Setting curriculum and communicating assessment methods to be used in the course Designing methods</td>
<td>DE1</td>
<td>Communicates important course outcomes, e.g., documentation of course goals, topics, rubrics and instructor expectations</td>
<td>This week we will be discussing...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE2</td>
<td>Provides clear instructions (delete: and expectations) how to participate in course learning activities, e.g., clear explanation of how to complete course assignments successfully</td>
<td>Please refer to your discussion rubric.</td>
</tr>
<tr>
<td></td>
<td>Establishing time parameters</td>
<td>DE3</td>
<td>Communicates important due date/time frames for learning activities to help students keep pace with the course, e.g., accurate course schedule</td>
<td>I am going to divide you into groups and you will debate.</td>
</tr>
<tr>
<td></td>
<td>Establishing etiquette</td>
<td>DE4</td>
<td>Assists students to take advantage of the online environment to enhance learning, e.g., (delete: provides clear instructions on how to participate in discussions, submit assignments and) using LMS features for learning activities and resolving technical problems.</td>
<td>Please post a message by Friday.</td>
</tr>
<tr>
<td><strong>Facilitating Discourse (FD)</strong></td>
<td>Facilitating discourse indicators (FDI)</td>
<td>DE5</td>
<td>Helps students understand and practice the kinds of behaviors that are acceptable in online learning, e.g., providing documentation on polite forms of online interaction</td>
<td>Try to address issues that others have raised when you post (remove this example because not technology or CMS related?)</td>
</tr>
<tr>
<td></td>
<td>Making macro-level comments about course content</td>
<td>DE6</td>
<td>Provides rationale for assignment/topic</td>
<td>When you submit your written assignment first save your file as a word document then attach it to the drop box for this module.</td>
</tr>
<tr>
<td><strong>Seeking to reach consensus (S)</strong></td>
<td>Identifying areas of agreement/disagreement on course content in order to enhance student learning</td>
<td>FD1</td>
<td>Helps to identify areas of agreement and disagreement on course topics in order to enhance student learning</td>
<td>Keep your posts short. Remember, all uppercase letters is the equivalent of &quot;value&quot;, providing documentation on polite forms of online interaction.</td>
</tr>
<tr>
<td></td>
<td>Seeking to reach consensus</td>
<td>FD2</td>
<td>Assists in guiding class toward agreement about course topics in a way to enhance student learning</td>
<td>I am going to divide you into groups and you will debate.</td>
</tr>
<tr>
<td></td>
<td>Encouraging acknowledgment or reinforcing student contributions</td>
<td>FD3</td>
<td>Acknowledges student participation in the course, e.g., replied in a positive encouraging manner to student submissions</td>
<td>This discussion is intended to give you a broad set of tools which you will be able to use in deciding when and how to use different research techniques.</td>
</tr>
<tr>
<td></td>
<td>Setting climate for learning</td>
<td>FD4</td>
<td>Encourages students to explore concepts in the course, e.g., promotes the exploration of new ideas to enhance learning (i.e., tangential) or related (delete: but are outside of the initial design questions?)</td>
<td>Joe and Mary are saying essentially the same thing.</td>
</tr>
<tr>
<td></td>
<td>Drawing in participants, prompting discussion</td>
<td>FD5</td>
<td>Helps keep students engaged and participating in productive dialog</td>
<td>Don’t feel self-conscious about “thinking out loud” on the forum. This is the place to try out ideas after all.</td>
</tr>
<tr>
<td><strong>Presenting follow-up topics for discussions (FDI)</strong></td>
<td>Presenting follow-up topics for discussions (FDI)</td>
<td>FD6</td>
<td>Presents content or questions (delete: that enhance learning) (i.e., tangential or related (delete: but are outside of the initial design questions?)</td>
<td>Any thoughts on this issue?</td>
</tr>
</tbody>
</table>

**Assessment (AS)**

<table>
<thead>
<tr>
<th>Categories</th>
<th>Indicators</th>
<th>Code</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE-Focusing discussion on specific issues</td>
<td>FD7</td>
<td>Helps focus discussion on relevant issues (delete: that enhance understanding and) keeps participants on topic</td>
<td>Think that’s a dead end. I would ask you to consider. Be sure to address the differences between theory and practice. The original question was... we said... Mary said... We concluded that... We still haven’t addressed...</td>
<td></td>
</tr>
<tr>
<td>Summarizing discussion</td>
<td>FD8</td>
<td>Reviews and summarizes discussion contributions to highlight key concepts and relationships to further facilitate discourse</td>
<td>“Pump in the heart chamber”</td>
<td></td>
</tr>
<tr>
<td>Direct instruction (DI)</td>
<td>Providing valuable analogies</td>
<td>DI1</td>
<td>Attempts to replace/reformulate course material in ways that highlight similarities between content assumed to be understood and new content with the goal of making the material more comprehensible</td>
<td>My employer uses the following two methods to address the skills gap...</td>
</tr>
<tr>
<td>Offering useful illustrations</td>
<td>DI2</td>
<td>Attempts to make course content more comprehensible by providing examples that are substantive and advance understanding</td>
<td>For example – multimedia, links to online demonstrations</td>
<td></td>
</tr>
<tr>
<td>Conducting supportive (instructive?) demonstrations</td>
<td>DI3</td>
<td>Attempts to make course content more comprehensible through the exhibition of processes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplying clarifying information</td>
<td>DI4</td>
<td>Attempts to reduce confusion or misconceptions about course content by providing additional explanations</td>
<td>Let me provide you with some additional detail explaining how this staffing process works with employees, who have disabilities.</td>
<td></td>
</tr>
<tr>
<td>Making explicit reference to outside material</td>
<td>DI5</td>
<td>Provides useful information from a variety of sources, e.g., articles, textbooks, personal experiences, or links to external web sites.</td>
<td>I was at a conference with others once, and he said... You can find the proceedings from the conference at <a href="http://www">http://www</a>... You can also look at... Your posting would be even better if you talk about what changes are necessary and how you would implement them.</td>
<td></td>
</tr>
<tr>
<td>Giving formative feedback for discussions</td>
<td>AS1</td>
<td>Explicitly evaluates discussion/offer feedback OR diagnoses misconceptions to help students learn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Providing formative feedback for other assignments</td>
<td>AS2</td>
<td>Explicitly evaluates other assignment types/offers feedback OR diagnoses misconceptions to help students learn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delivering summative feedback for discussions</td>
<td>AS3</td>
<td>Provides post mortem feedback on discussions, including grades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplying summative feedback for other assignments</td>
<td>AS4</td>
<td>Provides post mortem feedback on other assignments, including grades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soliciting formative assessment on course design and learning activities from students and other participants</td>
<td>AS5</td>
<td>Seeks feedback upon completion of modules or during mid-course.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soliciting summative assessment on course design and learning activities from students and other participants</td>
<td>AS6</td>
<td>Seeks meta-level feedback at close of course.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase</td>
<td>Descriptor</td>
<td>Code</td>
<td>Indicators</td>
<td>Socio-cognitive processes</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Triggering event</td>
<td>Evocative (inductive)</td>
<td>CP-TE-1</td>
<td>Recognize problem</td>
<td>Presenting background information that may culminate in a question or presents a problem/issues</td>
</tr>
<tr>
<td></td>
<td>• Stimulate one's curiosity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Core organizing concept or problem</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Dilemma or problem that learners can relate to from their experience or previous studies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Framing the issue and eliciting questions or problems that learners see or have experienced</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Assessing state of learners knowledge and generating unintended but constructive ideas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inquisitive</td>
<td>CP-EX-1</td>
<td>Exploitation within the online community</td>
<td>Unsubstantiated agreement or disagreement/contradiction of previous ideas. Includes “good point” or “I agree” with or without unsubstantiated elaboration. Personal experience is substantiated and may be considered integration</td>
</tr>
<tr>
<td></td>
<td>• Understand the nature of the problem and then search for relevant information and possible explanation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Group activities – brainstorming</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Private activities – literature searches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Manage and maintain this phase of divergent thinking in such away that it begins to be more focused</td>
<td>CP-EX-2</td>
<td>Exploitation within a single message</td>
<td>Many different ideas/themes presented in one message (use even if prompt requires project instructions)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exploration</td>
<td>• Information exchange</td>
<td>CP-EX-3</td>
<td>Information exchange</td>
<td>Personal narratives or description (not necessarily regarding personal experiences) or facts (e.g., from sources such as websites, articles, programs, etc.) Adds points but does not systematically defend/justify/develop situation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Suggestions for consideration</td>
<td>CP-EX-4</td>
<td>Suggestions for consideration</td>
<td>Author explicitly characterizes message as exploration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Leaps to conclusions</td>
<td>CP-EX-5</td>
<td>Leaps to conclusions</td>
<td>Offers unsupported opinions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Integration among groups members</td>
<td>CP-IN-1</td>
<td>Integration among groups members</td>
<td>Reference to previous message followed by substantiated agreement or disagreement (I agree/disagree because…) Building on, adding to others' ideas</td>
</tr>
<tr>
<td>Integration</td>
<td>Tentative</td>
<td>CP-IN-2</td>
<td>Integration within a single message (response to prompt)</td>
<td>Justified, developed, defensible, yet tentative hypotheses</td>
</tr>
<tr>
<td></td>
<td>• Focused and structured phase of making meaning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Decisions are made about integration of ideas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Teacher must probe for understanding and misconceptions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>If IN is coded, do not include EI. 2, or 3 when coded (would be included under W). EI 4 or 5 could be considered if applicable depending on content.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Connecting ideas, synthesis</td>
<td>CP-IN-3</td>
<td>Connecting ideas, synthesis</td>
<td>Integrating information from one or more sources – textbook, articles, personal experience, other posts or peer contributions.</td>
</tr>
<tr>
<td></td>
<td>Creating solutions</td>
<td>CP-IN-4</td>
<td>Creating solutions</td>
<td>Explicit characterization of message as a solution by participant</td>
</tr>
<tr>
<td></td>
<td>Vicarious application to real world testing solutions</td>
<td>CP-BE-1</td>
<td>Vicarious application to real world testing solutions</td>
<td>Providing examples of how problems were solved</td>
</tr>
<tr>
<td></td>
<td>Resolution of the dilemma or problem</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reducing complexity by constructing meaningful framework or discovering a contextually specific solution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Confirmation or testing phase may be accomplished by direct or vicarious action</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Defending solutions</td>
<td>CP-BE-2</td>
<td>Defending why a problem was solved in a specific manner</td>
<td>How we solved this problem was…</td>
</tr>
</tbody>
</table>

APPENDIX B: Seminars on Science *Evolution: Modern Evolutionary Biology*

**Discussion Questions**

**Unit 1**

**The Fundamental Concept**
Theodosius Dobzhansky, the famous evolutionary geneticist, wrote in 1973 that "nothing in biology makes sense except in the light of evolution." Why is evolution the fundamental concept that underlies all life science? If evolution is "true"—if life really has evolved—what would we expect to observe as a consequence? How could this lead to testable hypotheses?

**Unit 2**

**Tree Thinking**
What inferences can you draw from a phylogenetic tree? Why is knowing phylogeny important?

**Unit 3**

**Mechanisms of Evolution**
There are many "forces" (drift and selection for example) that bring about evolutionary change. How do scientists connect the mechanisms discussed in the Futuyma essay to the topics discussed by Thompson and Raff? Use examples to illustrate your points.

**Unit 4**

**What Is A Species?**
The definition of what constitutes a species is a topic of hot debate in evolutionary biology. This week you've read about two different definitions of a species: The Biological Species Concept (BSC) and the Phylogenetic Species Concept (PSC). What are the differences between the two concepts? Discuss some of the implications for research and conservation. Based on what you understand about how species form, why do you think scientists studying different aspects of evolution would prefer different definitions of what a species is? Please give examples.

**Unit 5**

**What Makes Us Human?**
The fossil record shows that *Homo sapiens* is only one of many hominid species to have lived on Earth. Is the fact that we are the only species left from our lineage unusual in evolutionary terms? What can we learn from comparisons with our closest living relations, the bonobo and the chimpanzee? What do you think made us different from these other species?

**Unit 6**

**Discussion 1: Evolution in Schools**
Discuss the implications and importance of teaching evolution.

**Discussion 2: Evolution Today**
Please choose and discuss in detail one example of a way that the understanding of evolutionary theory influences the quality of modern life.
ASSESSMENT COMPONENT: DISCUSSIONS
A large part of learning in our online courses occurs through discussion (text-based, asynchronous message exchanges). You are expected to be in frequent contact with your instructional team and other learners in the course’s Discussion areas. While this can be different from face-to-face communication, the same characteristics make classroom and online discussions meaningful. Both consist of two-way exchanges between teachers and learners: a back-and-forth that engages and deepens the understanding of all participants.

Each Discussion is graded two weeks after it begins. Weekly grades are based on how well learners reflect on content, engage in discussion with faculty and other students, and extend the online conversation (see the first two rows in the rubric). These grades will appear in the gradebook and will be combined with grades for the completion of Discussion assignments (see the third row in the rubric) to determine an Overall Assessment for Discussions.

Overall Objective: To construct content knowledge and community.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Exceeds course expectations</th>
<th>Meets course expectations</th>
<th>Approaches course expectations</th>
<th>Does not meet course expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>To support reflections on content (Discussion Grade Weight: 45%)</td>
<td>Reflected on the Discussion question using course materials while drawing on other resources and asking additional questions.</td>
<td>Reflected on the Discussion question using course materials.</td>
<td>Did not adequately reflect on the discussion question or did not relate post to course materials.</td>
<td>Did not post, or posted without addressing the Discussion question.</td>
</tr>
<tr>
<td>To engage in the online learning community and extend the online conversation (Discussion Grade Weight: 35%)</td>
<td>Posted many substantive and timely responses to other learners and course faculty.</td>
<td>Often responded in a substantive and timely manner to other learners and course faculty.</td>
<td>Occasionally responded substantively to other learners and course faculty, or failed to post in a timely manner.</td>
<td>Posted few or no substantive responses.</td>
</tr>
<tr>
<td>To complete the Discussions (Discussion Grade Weight: 20%)</td>
<td>Completed all of the Discussions.</td>
<td>Completed almost all of the Discussions.</td>
<td>Completed more than half of the Discussions.</td>
<td>Completed few or no Discussions.</td>
</tr>
</tbody>
</table>

OVERALL ASSESSMENT: DISCUSSIONS (COURSE WEIGHT: 40%)
APPENDIX D: Views of Nature of Science – C Survey

VNOS-Form C

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge require experiments?
   - If yes, explain why. Give an example to defend your position.
   - If no, explain why. Give an example to defend your position.

4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
   - If you believe that scientific theories do not change, explain why. Defend your answer with examples.
   - If you believe that scientific theories do change: (a) Explain why theories change? (b) Explain why we bother to learn scientific theories? Defend your answer with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
   - If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
   - If you believe that science is universal, explain why. Defend your answer with examples.

10. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
    - If yes, then at which stages of the investigations do you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
    - If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

APPENDIX E: Views of Nature of Science Analysis Framework

A List of Consensus Aspects of NOS and Associated Dimensions

<table>
<thead>
<tr>
<th>NOS aspect</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Empirical</strong></td>
<td>Scientific claims are derived from, and/or consistent with, observations of natural phenomena, and eventually adjudicated by reference to these observations. Scientists, however, do not have “direct” access to most natural phenomena: Their observations are almost always filtered through the human perceptual apparatus, mediated by the assumptions underlying the functioning of “scientific” instruments, and/or interpreted from within elaborate theoretical frameworks.</td>
</tr>
<tr>
<td><strong>Inferential</strong></td>
<td>There is a crucial distinction between observation and inference. Observations are descriptive statements about natural phenomena that are accessible to the senses (or extensions of the senses) and about which observers can reach consensus with relative ease. Inferences are statements about phenomena that are not directly accessible to the senses. Most scientific constructs are inferential in the sense that they can only be accessed and/or measured through their manifestations or effects.</td>
</tr>
<tr>
<td><strong>Creative</strong></td>
<td>While necessarily rational and systematic in several respects, scientific investigation cannot be reduced to a merely rational and systematic activity. Generating scientific knowledge involves human creativity in the sense of scientists inventing explanations, and theoretical models and entities. Creativity is involved in all stages of scientific investigation, including prior to, during, and following the collection of data, and is particularly relevant to interpreting data and generating conclusions from these data.</td>
</tr>
<tr>
<td><strong>Theory-laden</strong></td>
<td>Scientists’ theoretical and disciplinary commitments, beliefs, prior knowledge, training, and expectations influence their work. These background factors affect scientists’ choice of problems to investigate and methods of investigation, observations (both in terms of what is and is not observed), and interpretation of these observations. This (sometimes collective) individuality or mind-set accounts for the role of theory in generating scientific knowledge. Contrary to common belief, science rarely starts with neutral observations. Like investigations, observations are always motivated and guided by, and acquire meaning in light of questions and problems derived from, certain theoretical perspectives.</td>
</tr>
<tr>
<td><strong>Tentative</strong></td>
<td>Scientific knowledge is reliable and durable, but never absolute or certain. All categories of knowledge (“facts,” theories, laws, etc.) are subject to change. Scientific claims change as new evidence, made possible through conceptual and technological advances, is brought to bear; as extant evidence is reinterpreted in light of new or revised theoretical ideas; or due to changes in the cultural and social spheres or shifts in the directions of established research programs.</td>
</tr>
<tr>
<td><strong>Myth of “The Scientific Method”</strong></td>
<td>This myth is often manifested in the belief that there is a recipe-like stepwise procedure that typifies all scientific practice. This notion is erroneous: There is no single “Scientific Method” that would guarantee the development of infallible knowledge. Scientists observe, compare, measure, test, speculate, hypothesize, debate, create ideas and conceptual tools, and construct theories and explanations. However, there is no single sequence of practical, conceptual, or logical (e.g., inductive, deductive, hypothetico-deductive) activities that will unerringly lead them to valid claims, let alone “certain” knowledge.</td>
</tr>
<tr>
<td>NOS aspect</td>
<td>Dimensions</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Scientific theories</td>
<td>Scientific theories are well-established, highly substantiated, internally consistent systems of explanation, which (a) account for large sets of seemingly unrelated observations in several fields of investigation, (b) generate research questions and problems, and (c) guide future investigations. Theories often are based on assumptions or axioms and posit the existence of non-observable entities. Thus, direct testing is untenable. Only indirect evidence supports and validates theories: Scientists derive specific testable predictions from theories and check them against observations. An agreement between predictions and observations increases confidence in the tested theory.</td>
</tr>
<tr>
<td>Scientific laws</td>
<td>In general, laws are descriptive statements of relationships among observable phenomena. Theories, by contrast, are inferred explanations for observable phenomena or regularities in those phenomena. Contrary to common belief, theories and laws are not hierarchically related (the naïve view that theories become laws when “enough” supporting evidence is garnered, or that laws have a higher status than theories). Theories and laws are different kinds of knowledge and one does not become the other. Theories are as legitimate a product of science as laws.</td>
</tr>
<tr>
<td>Social dimensions of</td>
<td>Scientific knowledge is socially negotiated. This should not be confused with relativistic notions of science. This dimension specifically refers to the constitutive values associated with established venues for communication and criticism within the scientific enterprise, which serve to enhance the objectivity of collectively scrutinized scientific knowledge through decreasing the impact of individual scientists’ idiosyncrasies and subjectivities. The double-blind peer-review process used by scientific journals is one aspect of the enactment of the NOS dimensions under this aspect.</td>
</tr>
<tr>
<td>science</td>
<td></td>
</tr>
<tr>
<td>Social and cultural</td>
<td>Science is a human enterprise embedded and practiced in the context of a larger cultural milieu. Thus, science affects and is affected by various cultural elements and spheres, including social fabric, worldview, power structures, philosophy, religion, and political and economic factors. Such effects are manifested, among other things, through public funding for scientific research and, in some cases, in the very nature of “acceptable” explanations of natural phenomena.</td>
</tr>
<tr>
<td>embeddedness of science</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX F: Lesson Plan Objective Alignment Rubric

Scoring Rubric used by researcher to judge alignments of unit plan objectives.

<table>
<thead>
<tr>
<th>Category</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Objectives and the Course</td>
<td>Teaching objectives align fully and clearly with the big ideas or concepts in the course.</td>
<td>Teaching objectives align significantly but not fully with the big ideas or concepts in the course.</td>
<td>Teaching objectives align partially with the big ideas or concepts in the course.</td>
<td>Teaching objectives align poorly with the big ideas or concepts in the course.</td>
<td>Teaching objectives do not align with the big ideas or concepts in the course.</td>
</tr>
<tr>
<td>2. Activities and Objectives</td>
<td>Learning activities align fully and clearly with the objectives.</td>
<td>Learning activities align significantly but not fully with the objectives.</td>
<td>Learning activities align partially with the objectives.</td>
<td>Learning activities align poorly with the objectives.</td>
<td>Learning activities do not align with the objectives.</td>
</tr>
<tr>
<td>3. Evaluation and Objectives</td>
<td>Evaluation used in the lesson aligns fully and clearly with the objectives.</td>
<td>Evaluation used in the lesson aligns significantly but not fully with the objectives.</td>
<td>Evaluation used in the lesson aligns partially with the objectives.</td>
<td>Evaluation used in the lesson aligns poorly with the objectives.</td>
<td>Evaluation used in the lesson does not align with the objectives.</td>
</tr>
<tr>
<td>4. Evaluation and Activities</td>
<td>Evaluation used in the lesson aligns fully and clearly with the activities.</td>
<td>Evaluation used in the lesson aligns significantly but not fully with the activities.</td>
<td>Evaluation used in the lesson aligns partially with the activities.</td>
<td>Evaluation used in the lesson aligns poorly with the activities.</td>
<td>Evaluation used in the lesson does not align with the activities.</td>
</tr>
<tr>
<td>5. Activities and Course</td>
<td>Activities align fully and clearly with the big ideas or concepts in the course.</td>
<td>Activities align significantly but not fully with the big ideas or concepts in the course.</td>
<td>Activities align partially with the big ideas or concepts in the course.</td>
<td>Activities align poorly with the big ideas or concepts in the course.</td>
<td>Activities do not align with the big ideas or concepts in the course.</td>
</tr>
</tbody>
</table>

## APPENDIX G: Science Lesson Plan Analysis Instrument

**Lesson Design and Implementation—Cognitive and Metacognitive Issues**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Exemplary</th>
<th>Making Progress</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal orientation</strong></td>
<td>Explicit learning goals and objectives for the unit are comprehensive and clearly comprise a big idea of science. Lesson activities clearly support goals and objectives</td>
<td>Learning goals and objectives are accurate but</td>
<td>Learning goals and objectives</td>
</tr>
<tr>
<td>(Weight 2)</td>
<td></td>
<td>o implied rather than explicitly stated</td>
<td>o are not implied by the planned learning activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o do not fully encompass the big idea of the topic area</td>
<td>o reflect an inaccurate understanding of the topic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o are too vague to assess or include inappropriate level of detail</td>
<td>o do not help students attain understanding of the big idea</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o are not completely supported by the lesson activities</td>
<td>o are not reflected in the planned learning activities</td>
</tr>
<tr>
<td><strong>Content accuracy</strong></td>
<td>Factual information is accurate and complete with respect to standards and objectives</td>
<td>Factual information is mostly accurate and may not completely reflect the learning goals or standards cited</td>
<td>Inaccurate factual information or other errors are present</td>
</tr>
<tr>
<td>(Weight 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Content presentation</strong></td>
<td>o Levels of detail and abstraction are challenging but accessible to most students; represents high expectations</td>
<td>o Level of detail and/or abstraction is not challenging to a significant proportion of the class</td>
<td>o Level of detail or abstraction is inappropriate for the course; reflects average to low expectations for all students</td>
</tr>
<tr>
<td>(Weight 3)</td>
<td>o The sequence of topics is appropriate</td>
<td>o Level of detail and/or abstraction is not accessible to a significant proportion of the class</td>
<td>o The sequence of topics seems random or illogical</td>
</tr>
<tr>
<td></td>
<td>o Appropriate examples are included</td>
<td>o The sequence of topics is somewhat disjointed</td>
<td>o Inappropriate examples are included</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Appropriate examples are lacking</td>
<td></td>
</tr>
<tr>
<td>Criteria</td>
<td>Exemplary</td>
<td>Making Progress</td>
<td>Needs Improvement</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Alignment with standards</strong></td>
<td>Direct and explicit links to appropriate NSES, state, and/or district process AND content standards</td>
<td>Clearly contributes to students' learning of one or more standards or benchmarks, which are not explicitly listed OR Either process or content standards are ignored</td>
<td>Not well aligned with standards</td>
</tr>
<tr>
<td>(Weight 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Awareness of science education research</strong></td>
<td>The lesson plan gives evidence that the teacher is knowledgeable about contemporary science education research on learning, teaching, and/or curriculum, and implements these ideas regularly and effectively</td>
<td>The lesson plan gives evidence that the teacher is aware of contemporary science education research on learning, teaching, and/or curriculum, but may implement these ideas sporadically, ineffectively, or inappropriately</td>
<td>The lesson plan is antithetical to commonly accepted research findings in science education</td>
</tr>
<tr>
<td>(Weight 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Preassessment</strong></td>
<td>The lesson plan is structured to actively solicit students' preconceptions at the start of a topic, and refers to possible ways in which instruction could be modified in response to preassessment information</td>
<td>The lesson plan does include preassessment activities, but information is not used to inform instruction OR teacher simply attempts to refute or replace misconceptions with correct information</td>
<td>The lesson does not reflect an understanding that students' preconceptions can affect how they understand new information.</td>
</tr>
<tr>
<td>(Weight 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Meaningful application</strong></td>
<td>Content is given a meaningful personal context for students</td>
<td>Some attempt is made to give content a meaningful personal context or real-world significance</td>
<td>Content is largely devoid of</td>
</tr>
<tr>
<td>(Weight 2)</td>
<td>Content is portrayed as significant to real-world issues</td>
<td></td>
<td>real-world relevance OR student-engaging context</td>
</tr>
<tr>
<td><strong>Student reflection</strong></td>
<td>Either individually or as a class, students are required to reflect on and summarize their understanding verbally or in writing at an appropriate point(s) during the unit in order to build conceptual understanding</td>
<td>Lesson is structured to allow for (but not fully promote or support) meaningful student reflection or summation that furthers conceptual understanding</td>
<td>Time is not reserved for student summation or other reflective practices</td>
</tr>
<tr>
<td>(Weight 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Assessment</strong></td>
<td>Includes effective tools(s) that assess for conceptual understanding</td>
<td>Includes tools or suggestions for assessment that may address conceptual understanding but emphasize factual recall</td>
<td>Assessment tools do not measure student conceptual understanding OR there is no assessment tool or method described</td>
</tr>
<tr>
<td>(Weight 3)</td>
<td>Includes criteria and/or rubrics for performance-based assessments (reports, participation, etc.) if necessary</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assessment results used to modify the lesson as it is being taught, and as formative feedback to students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Criteria</td>
<td>Exemplary</td>
<td>Making Progress</td>
<td>Needs Improvement</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Equity</strong> (Weight 1)</td>
<td>Explicit attempts were made to address equity and access for underrepresented populations</td>
<td>No mention of issues of equity or access</td>
<td>The lesson suggests bias against identifiable populations</td>
</tr>
<tr>
<td><strong>Student attitudes about science</strong> (Weight 1)</td>
<td>The teacher’s lesson objectives or activities are designed to affect a change in student values, attitudes, or beliefs about the importance and appeal of science, their ability or desire to learn science, etc. Student’s attitudes and beliefs are evaluated in order to measure progress toward these goals</td>
<td>The lesson objectives and/or activities imply a desire for changing student values, attitudes, or beliefs about science, but no means for measuring such change is utilized</td>
<td>Lesson objectives and activities are exclusively cognitive and include no implied desire for changing student values, attitudes, or beliefs about science</td>
</tr>
<tr>
<td><strong>Student engagement</strong> (Weight 1)</td>
<td>Activities regularly engage students by promoting curiosity and/or motivating future learning</td>
<td>Students are sometimes but not consistently engaged by activities or material OR activities engage students in a manner unproductive to learning</td>
<td>Largely devoid of engaging or motivational content</td>
</tr>
<tr>
<td><strong>Student participation</strong> (Weight 1)</td>
<td>Lesson regularly requires active participation of students in their own learning</td>
<td>Lesson involves some level of student participation OR students are allowed but not required to participate in class discussions</td>
<td>Little or no opportunity for student participation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Exemplary</th>
<th>Making Progress</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Classroom discourse—Fostering a community of learners</strong> (Weight 3)</td>
<td>Students are part of a learning community: ○ Lesson is structured to require significant discussion among students focused on sense making ○ Lesson promotes evidence-based debate among students ○ Suggested open-ended questions for discussion are provided</td>
<td>Lesson is structured to allow for (but not require) meaningful student discussion that furthers conceptual understanding</td>
<td>○ Lesson structure inhibits meaningful discussion ○ Teacher or text acts as authority figure who provides the “right answer” and curtails discussion</td>
</tr>
<tr>
<td><strong>Appropriate use of technology</strong> (Weight 1 if applicable)</td>
<td>Appropriate use of available technology (e.g., digital projector, laboratory probes, Internet resources)</td>
<td>Could better utilize available technology resources</td>
<td>Inappropriate use of technology that distracts from learning goals</td>
</tr>
<tr>
<td><strong>Adaptability</strong> (Weight 1)</td>
<td>Discusses ways to adapt the lesson to a variety of types of students (i.e., varying levels of achievement and interest, grade level, etc.)</td>
<td>Has potential to be adaptable to various needs, but is not explicitly addressed</td>
<td>Narrow range of use (type of student, class size, etc.)</td>
</tr>
<tr>
<td><strong>Variety</strong> (Weight 2)</td>
<td>Innovative or creative approach, includes varying classroom activity to keep teacher and students engaged, including but not limited to: ○ teacher-designed or modified activities ○ interdisciplinary collaboration</td>
<td>May not be innovative or creative on the part of the teacher, but with enough variety to keep students engaged most of the time</td>
<td>Mundane or boring to most students, and showing a low level of engagement of the teacher with the material to be taught</td>
</tr>
<tr>
<td>Criteria</td>
<td>Exemplary</td>
<td>Making Progress</td>
<td>Needs Improvement</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
<td>----------------</td>
<td>------------------</td>
</tr>
<tr>
<td><strong>Hands-on exploration</strong> (Weight 2)</td>
<td>Well utilized and integrated to promote student exploration and learning, and includes a meaningful assessment of that learning</td>
<td>Used to verify topics, illustrate or apply processes after instruction has taken place OR Promotes student exploration and learning of content, but is not meaningfully assessed</td>
<td>Used solely as diversions OR Not integrated into the curriculum OR There are no appropriate hands-on experiences included in the lesson</td>
</tr>
<tr>
<td><strong>Nature of science</strong> (Weight 3)</td>
<td>Reflects a sophisticated view of the nature and processes of science: OR Explicit mention of how theories are tentative and develop and change over time based on new evidence or new treatment of previous evidence OR Science is treated as a social endeavor involving argumentation and explanation</td>
<td>Reflects attempts to represent the nature of science: OR Some mention of the tentative nature of scientific knowledge OR Mixed messages about the nature of “truth” and the “right answer” OR Illustrates the tentative and social nature of science, though exposure to the history of science in lieu of students’ own experiences</td>
<td>Treats science exclusively as a body of factual knowledge to be committed to memory AND/OR Treats experimentation exclusively as a way to find the “truth”</td>
</tr>
<tr>
<td><strong>Student practitioners of scientific inquiry</strong> (Weight 3)</td>
<td>Students are consistently engaged firsthand in learning content through inquiry or doing science (questioning, experimental design, testing hypotheses or predictions, measurement and data analysis, drawing conclusions, etc.), rather than being told “answer”; inquiry process skills are taught in context</td>
<td>Students do not engage in inquiry themselves, but do learn about inquiry as a scientific practice OR Some effort at engaging students in doing science is evident, with an emphasis on telling students science</td>
<td>Students learn science exclusively by being told the accepted canon of scientific knowledge without discussion of how the knowledge was developed by scientists</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Exemplary</th>
<th>Making Progress</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Analytical skills</strong> (Weight 1) (Weight 1 if applicable)</td>
<td>Students are supported in drawing (or refuting) conclusions based on evidence in order to develop their analytical skills; evidence may include quantitative data or qualitative observations OR Sources of experimental error and their size and effect on the experimental results and conclusions are discussed</td>
<td>Students are asked to draw conclusions based on evidence without sufficient and accurate teacher support or guidance; choice of variables, type of observation, etc. are not scaffolded appropriately for the students’ level OR Students are supported in developing higher order quantitative problem solving skills</td>
<td>Age-appropriate analytical skills are not developed because OR there is no opportunity provided for students to analyze qualitative or quantitative data OR students are allowed to draw conclusions based on opinion or outside information, rather than evidence OR students use quantitative data to “plug and chug” using formulas to arrive at the “right answer” Sources of experimental error are ignored or glossed over</td>
</tr>
</tbody>
</table>

APPENDIX H: Seminars on Science Unit Plan Guidelines

Final Project Guidelines

Application in the Classroom

This final project is for learners who would appreciate the opportunity to develop an application that could be taught to students or to other educators based on one aspect of the content covered in this course. The final form of your instructional material would be a lesson or workshop plan for a full curriculum unit. Select a topic that you might use in your own classroom or educational setting. Exemplary material would focus on fostering inquiry and/or technology integration. Regardless of the intended audience, this final project should have the following elements:

Plan Title

Introduction
The introduction will frame your sequence of lessons by briefly describing the topics in the unit, their connection to the course content, and your reason for choosing them. The Introduction is an opportunity to demonstrate your understanding of course content that may be referred to but not explained fully in the lessons that follow.

Define Learners
• Grade Level: Elementary, junior high, high school, college, adult learners, high school science teachers or museum educators.
• Population Characteristics: describe the characteristics of the learners.
• Lesson Groupings: choose individual, pairs, small groups, or whole class.

Standards
Which National Science Education content or teaching standards apply?

Topic
Define the main Science concept from the course that will be your focus and give details about the specific subject covered in the lesson.

Curriculum Links
Describe how this lesson might fit with the rest of the units and/or curriculum, what goes before it, how you will connect this lesson to this prior knowledge, what comes after this lesson, and how will you link it to what follows.

Objectives
What are the main concepts, skill, behaviors, values, attitudes, etc. you want students to get from the lesson; objectives should be stated in terms of what students will be able to do after completing the lesson, do not tell what students will do during instruction (that's scope & sequence).

Materials
What will you need to teach this lesson, which supplies, technologies, tools and resources will you need to access or create?

**Time**
The duration of this lesson plan should be one week — the amount of time needed to cover one curricular unit.

**Scope and Sequence**
Outline of the lessons itself, what will you teach and in what order; include the major points you want to make, any interactives or multi-media materials you may need and their function; all the activities students will undertake, and the products they will deliver at the lesson's end.

**Supplementary Materials**
Describe any off-line worksheets and/or activities you will design.

**Assessment of Students**
How will you grade or otherwise evaluate students' participation in this lesson?

**Evaluation of the Lesson**
How will you judge whether or not the lesson was successful? (This should relate back to the objectives.)

**Conclusion**
What are your final thoughts about the project? What potential challenges will you face in teaching these lessons? How well will this unit fit into what you currently teach (or anticipate teaching in the future)?