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The effect of a biology learning community on ISU secondary science education students and the teaching of biological evolution

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The effect of a biology learning community on ISU secondary science education students and the teaching of biological evolution

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ABSTRACT

The concept of biological evolution is essential to a deep understanding of biology. Biological evolution is a well-established scientific theory that explains how the diversity of life on this planet arose from a single or several original life forms. Nevertheless, public controversy has often clouded the extent to which biological evolution is addressed by science teachers in K-12 public education classes.

This study investigated the evolution education teaching practices of Iowa State University (ISU) students who completed the evolution education component of the Biology Education Teaching and Learning (BETAL) community, and the evolution education teaching practices of ISU students who did not take part in the evolution education component of BETAL. These two groups were compared to the evolution education teaching practices of teachers across the United States reported in prior studies.

Although the sample was small, that all BETAL evolution education participants taught biological evolution is encouraging. While BETAL evolution education participants faced opposition to teaching biological evolution, the BETAL evolution education participants continue to teach biological evolution despite the opposition. BETAL evolution education participants also reportedly spent overall more time teaching biological evolution and included ties to important nature of science topics while doing so.

CHAPTER 1. INTRODUCTION

The concept of biological evolution is essential to a deep understanding of biology. Despite this, many biology students leave high school, having only covered biological evolution briefly, if at all (Moore, 2007). Why does this happen with a concept that is widely accepted and considered central in the biological sciences? Opponents to the teaching of biological evolution make claims that the concept is inaccurate or “just a theory” (Alters & Alters, 2001), and the public listens. Ask a biologist and he or she will undoubtedly say that biological evolution is a well-supported explanation for the diversity of life. Yet, the public wrongly thinks that scientists debate whether biological evolution is a valid scientific idea, and opponents point to this as a reason to exclude it from science curricula (McComas, 2008). This creates a controversy surrounding the teaching of biological evolution, but the controversy is a public education controversy not a scientific controversy. This conflict results in a biological evolution education that is severely lacking for many of our K-12 students.

The Biology Education Teaching and Learning (BETAL) learning community at Iowa State University (ISU) was developed, in part, to help ISU pre-service biology teachers effectively and confidently teach biological evolution. The current research study investigated seven former BETAL participants’ current teaching practices regarding biological evolution to determine the BETAL learning community’s impact, if any, on their teaching of biological evolution.

Biological Evolution: A Major Unifying Theme

Biological evolution is a well-established scientific theory explaining how the diversity of life on this planet arose from a single or several original life forms. The theory does not address how life might have first arisen, although that is a question science continues to investigate. Some of the public wrongly envisions biological evolution as an idea that is controversial among scientists. Conveying the confidence in biological evolution among scientists, Alters and Alters (2001) noted that, "...the factuality of evolution is as well confirmed as any major discovery of science..." (p. 1).

According to the National Science Teachers Association (NSTA) position statement (2003) regarding the teaching of biological evolution, if students are not taught about biological evolution they will not be able to "achieve the level of scientific literacy they need" to be successful in biology. The National Association of Biology Teachers (NABT) (2008) position statement on biological evolution states that evolution is a "major unifying concept" in biology/life science and should be included in the K-12 science curriculum. The list of organizations that have made statements over the years in support of the teaching of biological evolution is very long. In *Voices for Evolution* (NCSE, 2008), statements appear from scientific organizations and religious organizations of all different types, supporting the concept of biological evolution. Effectively and accurately teaching biological evolution to students is essential for understanding biology, paleontology, and other related scientific disciplines. Without this unifying concept, students entirely miss the big picture of biology.

Public Education Controversy

With such strong support for the inclusion of biological evolution in the secondary school science curriculum, one would expect to find most, if not all, biology/life science teachers covering evolution in some fashion. However, while there is evidence of biology teachers including biological evolution in their curriculum (Berkman et al., 2008; Bowman, 2008; Moore & Kraemer, 2005), the percentage is not as high one would expect. The reluctance of many biology teachers to accurately and effectively teach biological evolution mirrors the general public's attitude toward biological evolution. The public has strong and widely varying opinions regarding the validity of biological evolution (Newport, 2009). One factor that seems to contribute to the public's opinion is the amount of education completed. For example, of those polled with a high school education or less, 21% chose "yes" when asked if they believed in evolution. The percentage jumps to 74% for the group with postgraduate education (Newport, 2009). Unfortunately, the use of "believe" can be problematic in relation to science. Most of this conflict stems from a misunderstanding of the nature of science and the language of science. Scientists in the field of biology and life science have agreed that biological evolution is the only satisfactory naturalistic explanation for how life has changed over time. However, opponents make false claims that evolution is "just a theory" or that scientists themselves argue about the mechanisms of evolution (Scott, 2007).

An important piece in solving the problem of the treatment of biological evolution in classrooms is teacher preparation. Berkman et al. (2008) found that the "best prepared teachers devoted 60% more time to evolution than the least prepared," But what constitutes a "best prepared teacher"? Moore and Kraemer (2005) surveyed teachers and found around 50% disagreed that their undergraduate methods class prepared them to teach evolution. Berkman et al. (2008) suggest that courses in evolutionary biology for teachers would have "substantial impact" on teaching practices. However, background knowledge alone is not enough. Bowman (2008) found that social pressures about biological evolution have a greater effect on a teacher's teaching practices than the state standards do. Teachers need training on how to deal with pressures not to teach biological evolution, along with increased background knowledge in the subject.

Research Questions

The BETAL learning community at Iowa State University (ISU) was, in part, directed at helping prospective biology teachers better understand the centrality of biological evolution in biology, the nature of science and its relevance to teaching and learning about biological evolution, and how to effectively teach biological evolution. This study investigated what impacts the BETAL learning community experience had on assisting teachers in teaching biological evolution.

Specifically, this study investigated the evolution education teaching practices of ISU students who completed the evolution education component of BETAL and the evolution education teaching practices of ISU students who did not take part in the evolution education component of BETAL. These two groups were compared to the the evolution education teaching practices of teachers across the United States reported in prior studies. The following research questions guided this study:

How do these groups compare in…

1. the amount of time spent teaching the concepts of biological evolution?
2. how they cover the concept of biological evolution?
3. how they assess the concept of biological evolution?
4. the type and number of resources used in teaching the concept of biological evolution? and
5. the connections made to the nature of science and biological evolution?

Overview of Research Methods

The names and contact information of past graduates of the Iowa State University secondary science education program, both undergraduates and graduate students, was first obtained. Letters were sent explaining the purpose of the study and inviting those who were teaching biology or life science to take part. Of the 24 individuals contacted, six replied that they were not currently teaching biology or life science courses, three respectfully declined to participate, and eight did not respond. The seven remaining graduates (four BETAL evolution education students and three non-BETAL evolution education students) replied that they were teaching biology/life science and agreed to take part in the study.

To determine the biological evolution teaching practices of study participants, two data sources were collected. Copies of the participants' teaching materials used in their teaching of biological evolution were collected. A semi-structured interview (Appendix A.) followed, and this was digitally recorded and transcribed. The teaching materials and interviews were analyzed and coded for each of the guiding research questions. When teaching materials were received, they were analyzed before the interviews took place, to allow for more specific interview questions about the materials. Coded data was compiled to look for any patterns among the non-BETAL evolution education and the BETAL evolution education participants. Comparisons were made between the two groups as well as with national data regarding biological evolution teaching practices.

Assumptions and Limitations

Several assumptions and limitations may have affected this research study. Many secondary school teachers find teaching biological evolution to be controversial. Thus, invited study participants who share this view and do not teach biological evolution may simply have declined the invitation. This would skew the results of the study.. In addition, those who did agree to participate may have purposefully conveyed ideas consistent with what they were taught in the BETAL experience, rather than in a way that accurately reflected their actual teaching practices. Reviewing participants' evolution education teaching materials reduces, but does not eliminate, this potential bias among those agreeing to participate in this study. Thus, the results of this study may not be representative of the entire BETAL student population (approximately 120 students).

Another limitation was access to participants. Securing participants depended on the researcher's ability to locate contact information for past ISU students and then having them meet the narrow criteria for the study. For example, while a potential participant may have taken part in BETAL, he or she may not be teaching biology. In an attempt to secure more participants, those who had graduated within the past five years were contacted. This was also a limitation, as the longer it had been since graduation, the more the participants may have failed to remember their BETAL experience accurately enough to respond adequately to the interview questions.

Finally, a major limitation was access to participants' teaching materials. One participant did not provide teaching materials, which would have enabled the researcher to make a comparison to the self-reported data. In addition, the participants who did provide teaching materials did not provide every teaching artifact they used while teaching biological evolution. In addition, participants may have purposefully selected teaching artifacts that fit with the image they were trying to convey. Self-reported data have limitations and, without complete teaching artifacts and classroom observations to back up the self-reported interview data, the validity of the findings in this study cannot be assured.

An assumption made about the data was that the findings may be attributed to whether the participants did or did not participate in the BETAL learning community. Participants who did not take part in BETAL had other classes in common with the participants who did take BETAL. Those other classes may have influenced the study participants' teaching of biological evolution, whether they had the BETAL coursework or not. Thus, factors other than participation in the BETAL evolution education component may be at play and account for the study's findings.

Another assumption made was that the participants' answers to the interview questions accurately reflected their teaching practices. Participants were not observed teaching biological evolution, so how they actually addressed biological evolution may deviate from what they said. Thus, participants' teaching biological evolution teaching materials were collected to provide a clearer picture of how biological evolution was addressed.

Significance of the Study

Despite the assumptions and limitations, this research is important because it addresses the perception that teachers are often unprepared to handle the teaching of subjects they and/or the public find controversial (Hermann, 2008). Based on this consideration and the paucity of teachers who teach biological evolution, determining the kinds of experiences that positively impact science teachers' teaching of evolution is important. The public, including many science teachers, hold strong misconceptions surrounding biological evolution and, if these misconceptions are not addressed, the troublesome public education controversy surrounding biological evolution will continue (Alters & Alters, 2001; McComas, 2008; NCSE, 2008). If evolution education experiences like those in BETAL are revealed as assisting beginning teachers to deal with the public-education controversy and teach biological evolution in their classrooms, perhaps similar experiences should be provided for prospective biology and life science teachers, and their impact further studied.

CHAPTER 2. LITERATURE REVIEW

Evolution is the unifying framework for the science of biology. Evolution provides a level of understanding linking form and function, ethology, biogeography, genetics, and almost every other aspect of the life sciences.
(McComas, 2008, p. 18)

Biological Evolution

A unifying theme

The theory of biological evolution explains the process by which life diversifies, producing the number of species that are, or have been in the past, on Earth. Evolution of new species is the result of the prevailing environment acting on individual members of a species ("natural selection"), thereby determining which individuals are most likely to survive long enough to reproduce. The genetic information in these reproducing individuals becomes more prevalent in subsequent generations, potentially leading to the development of distinct species (Colbert, 2009). The theory of evolution does not provide an explanation for the origin of life but, rather, addresses how life diversified afterwards (Gould, 1987; Rice et al., 2010). Without this framework of biological evolution, biology concepts are simply a collection of disparate facts (Alters & Alters, 2001). This is what Dobzhansky (1973) referred to when he wrote that nothing in biology makes sense except in the light of evolution.

Omitting biological evolution from the secondary science curriculum denies students an understanding of how all life is inter-connected, how life is intertwined with the physical environment, and of what is perhaps the most unifying idea in science. Alters and Alters (2001, p. 112) offered three major reasons why students must learn about biological evolution: (1) when students learn disparate facts without the thread that ties them together, they miss answers to biology’s underlying why questions; (2) without it they cannot understand the processes based on this science such as insect resistance to pesticides; and (3) they will not come to understand evolutionary connections to other scientific fields and thus not be able to attain scientific literacy.

A public education controversy

The controversy surrounding the teaching of biological evolution is an education controversy rather than a controversy in the biology/life science field. According to Hildebrand et al. (2008), science education controversies are distinguished in two ways from science controversies. First, science education controversies emerge outside of the science field. Second, science education controversies grow directly out of the consideration of non-scientific ideas.

Using these distinctions, the teaching of biological evolution clearly fits as a science education controversy. For example, concerns regarding the teaching of biological evolution in the classroom generally come from individuals outside the scientific community (e.g., administrators, parents, and politicians) or, perhaps, a rogue scientist who has ulterior motives for misrepresenting the overwhelming evidence supporting biological evolution. In addition, much of the controversy surrounding the teaching of biological evolution education involves asking for equal time or the inclusion of other non-scientific ideas, such as “intelligent design” (Johnson, 2006).

Biological evolution has become a public education controversy because it offers a naturalistic explanation of how life developed from a common ancestor(s) into the wide diversity one observes today. This scientific explanation does not rely on the existence or guidance of a supernatural being. Therefore, people who have misconceptions about the nature of science assume that evolution denies the existence of a god. Science does not make claims one way or the other about the supernatural. Rather, it seeks naturalistic explanations for phenomena—ideas that help us make sense of nature that can be tested. Yet, despite this distinction, opponents still push for the exclusion of biological evolution from science curricula or the inclusion of non-scientific ideas into science curricula. This is so despite the fact that “there is abundant and consistent evidence from astronomy, physics, biochemistry, geochronology, geology, biology, anthropology, and other sciences that evolution has taken place” (NSTA, 2003).

With overwhelming scientific evidence supporting biological evolution, the fact that many professional science educator organizations such as NSTA (2003) and NABT (2008) support the teaching of biological evolution is not surprising. The National Science Education Standards (NRC, 1996) include biological evolution in their content standards, and the American Association for the Advancement of Science (AAAS) (2006) adopted a statement supporting the teaching of biological evolution and voicing concerns about the various rulings against teaching biological evolution. Many other position statements supporting biological evolution and biological evolution education have been published by professional science organizations, science teacher education organizations, and religious organizations (National Center for Science Education, 2008).

Nevertheless, the history of biological evolution education is long and controversial. Prior to the 1950s, biological evolution was “noticeably absent” from biology textbooks (Bybee, 2001). In response to the Cold War and fear that American students were falling behind those of other nations, the U.S. Congress passed the National Defense of Education Act in 1958. Bybee notes that this act resulted in significant money targeted for science education reform. One result was the Biological Sciences Curriculum Study, which established a set of high-school biology textbooks that stressed biological evolution. While these textbooks were a step in the right direction, by no means did they end the battle over teaching biological evolution in the K-12 classroom.

Opposition to the teaching of biological evolution has taken on many forms, such as asking for the removal of biological evolution from the classroom, arguing for equal time for non-scientific ideas, or seeking the requirement of disclaimers in textbooks addressing biological evolution (Bybee, 2001). For example, in the late 1960s, Arkansas passed a statute that prohibited the teaching of human evolution in public schools. This was later invalidated in 1968 by the U.S. Supreme Court (Epperson v. Arkansas) as being unconstitutional (Matsumura & Mead, 2007). In 1981, the governor of Arkansas signed a bill requiring equal time for “creation science” and biological evolution (Aguillard, 1999). This bill also was found unconstitutional by the U.S. Supreme Court in 1982. A similar statue, prohibiting the teaching of evolution unless accompanied by instruction in “creation science”, passed in Louisiana was also later found unconstitutional in 1987 (Matsumura & Mead, 2007). More recently, opponents have promoted intelligent design as an alternative “scientific” explanation to biological evolution (Boston, 2005). The most notable case was in Dover, Pennsylvania, where teachers were required to make statements about intelligent design being a viable alternative to biological evolution and provide students access to the book, *Of Pandas and People* (Humes, 2007). This, too, was overturned in 2005 by a U.S. District Court judge. In the judge’s ruling, intelligent design was identified as having creationist roots and described as not being science (Matsumura & Mead, 2007).

With widespread support for biological evolution from science education organizations and science education reform documents, one would expect to find biological evolution being taught in all life science/biology classrooms. Unfortunately, this is not the case.

Current State of Biological Evolution Education

Research in schools

Clearly, the overwhelming confidence in biological evolution and its place in the science curriculum expressed by science organizations, science education organizations, and many religions are not shared by the general public in the U.S. How does this play out in the K-12 classroom? Unfortunately, students are the losers in this battle.

Numerous studies conducted across the nation have revealed that many teachers are teaching biological evolution or at least mentioning biological evolution. Unfortunately, while biological evolution is sometimes being taught in K-12, the percentage of teachers who teach it is less than one might expect for a concept as fundamental as biological evolution. Eve and Dunn (1990) conducted a study in which questionnaires were mailed to 387 biology teachers across the nation. Their results showed that 38% of the teachers agreed with the statement that “there are sufficient problems with the theory of evolution to cast doubt on its validity.” This finding illustrates that misconceptions concerning biological evolution are present among secondary school biology teachers.

Weld and McNew (1999) revealed that 33% of the biology teachers they surveyed do not think evolution is central to biology and place little or no emphasis on evolution in their classrooms. The teachers surveyed were chosen from the NSTA membership list; the same NSTA that, in 1997, first published their position statement (which was later updated in 2003) strongly urging the inclusion of evolution in curriculum.

While several recent studies (Bandoli, 2008; Bilica & Skoog, 2004; Moore & Kraemer, 2005) focused on biological evolution education in one or two states, Berkman, Pacheco, and Plutzer (2008) attempted to gain a clearer picture of the teaching of biological evolution across the nation. Of the 939 teachers surveyed nationally, only 2% claimed they did not cover “general evolutionary processes”. Unfortunately, the percentage jumps to 17% when narrowed to human evolution (Berkman et al., 2008). While the percentages reported seem better than previous studies, “general evolutionary processes” is a vague phrase that may have been misinterpreted by respondents. Some respondents may have agreed that they were teaching “general evolutionary processes” when in fact they do not teach biological evolution. While teachers may be teaching a “general evolutionary process,” if they never mention the theory of biological evolution or help their students make the connection to other concepts in biology, they are not teaching biological evolution. Along with lower-than-expected percentages of biology teachers teaching biological evolution, a substantial number of science teachers include non-scientific ideas in their curriculum. Moore and Kraemer (2005) revealed the results from surveys sent to biology teachers in 1995 and 2003, regarding their attitudes toward the teaching of biological evolution. Over this period, the percentage of teachers including creationism in the classroom increased from 16% to 20%. Not only did the percentage increase, but the time spent on creationism also increased. Bowman (2008) surveyed students at major universities in eight different states with regard to what had been taught in their high school biology classes. In response to “My high school biology class taught ...,” 30% of students reported creationism was taught while 19% said that intelligent design was taught. However, the percentage of students who may have been taught both intelligent design and creationism was not reported. Teaching creationism and/or intelligent design as good science is unlawful (Bowman, 2008; Matsumura & Mead, 2001; Moore & Kraemer, 2005), and those teachers who do so are acting unprofessionally and misrepresenting the science of biology. Additional findings with regard to the current state of biological evolution education are provided in Table 1.

Table 1. Findings on the teaching of biological evolution relevant to this study

Study	Relevant Findings
Aguillard, D. (1999). Evolution education in Louisiana public schools: A decade following: Edwards v. Aguillard. *The American Biology Teacher, 61*(3), 182-188.	Of 91% surveyed certified to teach Biology; 50% or more of teachers allocated five or fewer class periods to biological evolution; 16% allocated more than 7.5 class periods to evolution topics; 36% think evolution should be taught as a separate unit; 29% think evolution should be integrated throughout; 13% reported presenting more information than covered in the textbook; study found a significant and positive correlation between emphasis placed on evolution and college semester hours in biology and number of college courses specifically dealing with evolutionary theory.
Berkman, M., Pacheco, J. S., & Plutzer, E. (2008). Evolution and creationism in America's classrooms: A national portrait. *PLoS Biology, 6*(5), e124.	A total of 939 teachers nationally surveyed in 2007. Hours spent covering general evolutionary processes: 1-2 hours: 9%, 3-5 hours: 25%, 6-10 hours: 26%, 11-15 hours: 18%, 16-20 hours: 11%, more than 20 hours: 9%.
Bowman, K. (2008). The evolution battles in high-school science classes: Who is teaching what? *Front Ecol Environ, 6*(2), 69-74.	Surveyed students at eight major public universities. 92% said evolution was taught in their high school biology class, 30% said creationism was taught, and 19% said intelligent design was taught.
Moore, R. and Cotner, S. (2009). Rejecting Darwin: The occurrence & impact of creationism in high school biology classrooms. *The American Biology Teacher: Online Publication. 71*(2).	Surveyed students in introductory biology courses at the University of Minnesota. Groups were split into biology majors and non-majors. 12-13% of students said they were not taught evolution or creationism. 18-23 % said they were taught creationism, and 2-3% only were taught creationism. 65-68% were taught evolution and not creationism.
Moore, R. and Kraemer,K. (2005) The teaching of evolution & creationism in Minnesota. *The American Biology Teacher, 67*(8), 457-466.	2 randomly selected biology teachers at the 2003 NSTA conference and 10th annual Biology and Life Science Teachers' conference in 2003 were surveyed. 107 completed the survey. 19% spend 0-2 hours, 25% spend 3-5 hours, 20% spend 6-10 hours, 19% spend 11-20 hours, and 17% spend greater than 20 hours on evolution related concepts. Results were compared with a prior survey in 1995. In 1995, 69% reported teaching evolution, which increased to 88% in 2003 survey. Satisfaction with the treatment of evolution in textbook was 75% in 1995 and 84% in 2003.
Moore,R. (2007). What are students taught about evolution? *McGill Journal of Education, 42*(2), 177-188.	In a 2003 to 2006 survey 1,441 undergrad students at University of Minnesota; 54% of those who attended public schools had courses that emphasized evolution but not creationism; 34% of those who attended private schools had courses that emphasized evolution but not creationism; 20% of public schools taught both creationism and evolution; 20% surveyed were not taught evolution or creationism; 51% of those at a public school that were taught creationism reported that they were taught that creationism is a scientific alternative to evolution;

In addition, State science education standards too often ignore or downplay biological evolution. Lerner (2000) conducted a study to analyze states' biological evolution standards. Each state's standards were given a grade from A to F.

Findings revealed that 31 states had satisfactory to excellent standards regarding biological evolution, while 19 were less than satisfactory and, in the case of Iowa, (where most of the current researcher's participants taught), no grade was given. At the time of Lerner's study, Iowa did not have any state standards to evaluate teaching biological evolution.

Bandoli (2008) surveyed university students in introductory biology courses at state universities in Indiana and Ohio. These states were chosen because they are neighboring states. While Indiana received an A, Ohio received an F for their state standards. Bandoli also found that the coverage of evolution was not influenced greatly by state standards. Approximately one fourth (25%) of the university students surveyed in both states said that evolution was emphasized in their first biology course. Approximately 42% of university students surveyed in each group (41.8 % in Indiana and 44.2 % in Ohio) said their teachers "gave approximately equal emphasis to evolution and creation to explain the diversity of life" and just over 30% (30.1% IN and 30.9% OH) stated evolution was not mentioned or mentioned but not covered. These findings are consistent with conclusions from Bowman (2008), that geographic location influences the teaching of biological evolution more than state standards do.

Why does a discrepancy exist between what science organizations, science teacher organizations, and most religious organizations promote in regard to the teaching of biological evolution and what is actually being taught? In order to answer this question, looking at the public's views on biological evolution is necessary.

Public views

In February 2009, the Gallup organization conducted a poll via telephone interviews. The findings revealed that almost two-fifths (39%) of Americans said they "believe in the theory of evolution," one fourth (25%) said "they don't believe in the theory of evolution," and (more than one third (36%) had no opinion either way (Newport, 2009). Gallup polls conducted from 1982 to 2006 indicated the percentage of adults over 18 years old that believe "God created human beings pretty much in their present form at one time within the last 10,000 years or so" has stayed quite constant at 44% to 46% (Newport). In 2005, the U.S. was ranked second to last in a list of 34 countries, regarding their citizens' acceptance of biological evolution (Miller, Scott, & Okamoto, 2006).

Miller et al. (2006) revealed that approximately one-third of American adults reject the concept of evolution. One reason is that biological evolution has become politicized in the U.S. Unlike other countries studied where no political party had taken a stance on biological evolution, in the U.S. the Republican Party adopted creationism as part of their platform in the second half of the 21st century (Miller et al., 2006). Many individuals have strong views against biological evolution even though they do not really understand the idea:

> A majority of Americans, regardless of their religious convictions or churchgoing habits, are in the same position... They don't understand what evolutionary theory is about, while at the same time they express disbelief in its principles — that is, they have opinions about evolution, but very little knowledge. (Humes, 2007, p. 29)

Because of misunderstandings about biological evolution and the nature of science (McComas, 2008), the history of biological evolution education has been fraught with controversy. Although the U.S. Supreme Court has ruled it illegal to teach religious ideas in school (Moore, 2004), some biology teachers still incorporate creationism (Moore, 2007) in their curriculum, and school boards across the country argue back and forth over inclusion of biological evolution and religious ideas (Humes, 2007).

Approaches in K-12 education

Even when biological evolution appears to be addressed in the science curriculum, this does not ensure that biological evolution is taught adequately (Hermann, 2008; Hildebrand et al., 2008). Hildebrand et al. (2008) identified four instructional approaches to teaching biological evolution: avoidant approaches, corrosive approaches, teaching about controversy (not to be confused with "Teach the controversy" pushed by intelligent design proponents), and proactive approaches.

Teachers who adopt the avoidant approach simply omit or downplay any discussion of biological evolution from their curriculum. For example, teachers may put off discussion of biological evolution until the end of the school year (if time permits) or omit aspects of biological evolution (such as human evolution) that the public finds most contentious.

Corrosive approaches to teaching evolution are those that corrode the relationship of the students with the teacher, students with the curriculum, or students with both (Hildebrand et al., 2008, p. 1047). Corrosive approaches include telling students they “don’t have to believe evolution”, or teaching biological evolution “dogmatically” and denying the existence of any public education controversy. These approaches tend to cause more issues for the teachers than avoidant approaches. Students may feel that the teacher does not care about their thoughts or feelings. Cases where teachers tell students “they don’t have to believe biological evolution” open a host of problems concerning the nature of science and scientific knowledge. By introducing the use of the word, “believe,” many misconceptions regarding the nature of science are conveyed. First, the word “believe” is problematic because “believe” can have different meanings depending on the context it is used. For example, in science education research, the use of “belief” implies the judgment may or may not be based on scientific evidence (and even that usage isn’t consistent among researchers) (Southerland, 2001). Second, are students to “believe” other science ideas, but not biological evolution? If so, this implies that biological evolution does not have the same level of veracity as other well-accepted science ideas have.

Using the term “believe” in connection with a scientific theory, such as biological evolution, can reinforce the misconception that scientific theories are simple guesses without any evidence to support them. Third, if the students are told they do not have to “believe” biological evolution, then why are they learning it? Why do scientists think it’s an important concept? Why can they not ‘believe’ in biological evolution, but they are not given the same option for atoms or cells? This treatment will only serve to reinforce the publicly perceived conflict between science and religion rather than help students reach an understanding that there is no conflict between the two.

Teaching about the controversy is an approach that seeks to engage the students' thoughts and feelings about the concept of biological evolution. This approach includes strategies like encouraging students to discuss their understanding of evolution and of the non-scientific explanations about the diversity of life. Unfortunately, Hildebrand et al. (2008) warned that this approach reinforces the dichotomy between science and religion by presenting the ideas against one another. Doing so also involves discussions of non-scientific ideas in a science classroom. Perhaps most importantly, this approach may inappropriately imply that a controversy exists in the scientific community regarding the veracity of biological evolution.

The last approach described is proactive. With a proactive approach, the teacher is aware of the public education controversy and plans lessons to address the causes of misconceptions. Rather than teach about the controversy, the teacher focuses on including the nature of science in the curriculum. This approach is aimed at helping students understand science's approach to understanding the natural world, the value of that approach, how science differs from other ways of knowing while not devaluing those other ways, why biological evolution is a well-accepted science idea, and why a controversy should not exist about the teaching of biological evolution as a sound scientific idea.

Hermann (2008) also identified four instructional approaches: avoidance, advocacy, affirmative neutrality, and procedural neutrality. His approaches considerably overlap those described previously, but there are some subtle differences. Advocacy approaches to teaching biological evolution are those that “move student thinking on evolution to be more in line with the scientifically accepted understanding of evolution” (p. 1018). This approach addresses the issue without discussing alternative views to biological evolution and does not address biological evolution as a controversial issue in science education.

Affirmative neutrality describes an approach that “occurs when the instructor presents a controversial issue from a variety of vantage points without emphasizing which vantage point they support” (Hermann, 2008, p. 1022). This approach acknowledges biological evolution education as a controversial issue, but enables the teacher to minimize discussions that may limit understanding of the concept. Procedural neutrality is similar except that alternative views are drawn out of the students or materials. Within this approach, lessons including instruction on the difference between science and religion would be found.

BETAL instructors strongly promoted accurate nature of science instruction to mitigate the education controversy surrounding biological evolution. BETAL did not encourage its participants to teach non-science ideas in their classrooms, and provided information about ideas such as intelligent design only to help the participants gain an understanding of the public education controversy and the ideas their students or coworkers might bring up in class or in the workplace. Accurately and explicitly teaching the nature of science was conveyed as “key” for planning curricula for teaching biological evolution. The NOS helps students understand what science is and how scientific knowledge is developed. This approach is important for helping students understand that the controversy surrounding biological evolution is not among the scientists, but rather takes place in the public arena. Due to the heavy reliance on nature of science instruction, the approach BETAL promoted is similar to the proactive approach described by Hildebrand et al. (2008). In addition, the understanding of intelligent design and other ideas without having explicit instruction on alternative ideas seems to fit Hermann's (2008) procedural neutrality approach. Procedural neutrality was chosen because the teacher doesn't introduce the alternative views, but rather alternative views are brought up by students.

Biological Evolution and the Nature of Science

> *There are clear and compelling reasons to teach our students about scientific inquiry and the nature of science. And we can do this within the context of biological evolution* (Bybee, 2001, p. 311).

If we want biology teachers to be proactive in their teaching of biological evolution, then the nature of science must be accurately and effectively teaching incorporated into the science curriculum (Clough, 1994, 2006; Khishfe & Lederman, 2006; Scharmann, 2005). Unfortunately, misconceptions regarding the nature of science are quite prevalent. These misconceptions about the nature of science are held by the public, the students, and the science teachers, themselves (McComas, 2008). Thus, while accurate NOS knowledge will likely increase students' willingness to learn about and understand biological evolution (Clough, 1994), biology teachers must first come to understand the nature of science.

Why is an explicit and accurate understanding of the nature of science important for those who teach biological evolution? Understanding the NOS illuminates why biological evolution is science and creationism or intelligent design are not. Teachers are thus also able to articulate why they should include biological evolution in their curriculum and should not include ideas such as intelligent design. Many teachers are unable or unwilling to face any conflicts that may arise while attempting to teach biological evolution and instead avoid teaching evolution all together (Hermann, 2008; Hildebrand et al., 2008). Armed with accurate NOS knowledge, teachers can use explicit nature of science instruction in their classroom to help reduce much of the resistance they may face from students and others (Clough, 1994, 2006).

Much of the opposition to the teaching of biological evolution comes from a misunderstanding of the nature of science (Bybee, 2001; Trani, 2004). People inappropriately assume that science is in conflict with religion and that one must choose one over the other (Trani, 2004). Consequently, that many students resist learning about biological evolution is not surprising. Clough (1994, 2006) addressed some NOS ideas that may reduce resistance to biological evolution education. The first is to make a clear distinction between biological evolution and the origin of life. A common misconception among those who are opposed to evolution education is that biological evolution makes claims about the origin of life. Science teachers should make clear that biological evolution explains the diversity of life, not how life began (Gould, 1987).

Other nature of science concepts to incorporate into the teaching of biological evolution include: that scientific knowledge is not “fair” or decided through voting, that science relies on naturalistic explanations, that anomalies in science do not result in the dismissal of theories, and that scientific knowledge is falsifiable and can change. That science relies solely on naturalistic explanations is at the heart of the rationale that ideas such as creationism and intelligent design should not be included in the science classroom. Ideas that involve supernatural events or deities relate to things above nature and, thus, beyond the realm of science (Clough, 1994, p. 412). Naturalism is the idea that reality is formed only by natural processes. If modern science is going to use "empiricism, rationalism, and skepticism to discover and corroborate its knowledge claims," then naturalism is a necessity in the "understanding and practice of science" (Schafersman, 2002). This is not to say that scientists can't hold beliefs in a supernatural being, but when working in science these scientists seek out naturalistic explanations. This NOS concept illustrates how science is different from other ways of studying and knowing the natural world, such as religion.

Ideas in science must be falsifiable and are subject to change when new evidence is presented or former evidence reinterpreted. Scientific knowledge is continually subjected to testing (direct and indirect) and thus has the opportunity to change. However, one piece of evidence that does not fit does not mean a scientific idea will be abandoned. Rather, this new piece of evidence may inspire additional research or thinking regarding the scientific idea, but not outright dismissal of the idea.

An important NOS topic to address is the meaning of particular language in science. For example, the word "theory" does not have the same meaning in science as it does in everyday conversation. While "theory" in everyday usage may mean “guess” or “speculation”, in science the word refers to an explanatory framework. This distinction is important to make so that students do not think of evolutionary theory as a speculative idea. Along with the need to emphasize the careful use of language in science, teachers should focus on students’ understanding and acceptance of evolution as a well-supported science idea. Attempting to have students *believe* in evolution wrongly sets it up as a religious idea. As mentioned earlier, the use of belief in the science classroom can be problematic and serve only to reinforce misconceptions regarding biological evolution and the nature of science.

Teaching the nature of science in the classroom can help students understand the enterprise of science and how science explains the world around us. In order to gain an understanding of the world around us, individuals may need to use different ways of knowing (National Academy of Sciences, 1998). Science is one way of knowing about the world around us. While scientific explanations may contradict explanations from other ways of knowing, that does not mean that scientific explanations are more valuable. Science answers different questions than theology does. If students can gain this understanding of science, they will know that biological evolution does not mean they have to abandon their religious beliefs.

Efforts at Improving Biological Evolution Education

Many position statements from science education organizations (NABT, 2008; NCSE, 2008; NRC,1996; NSTA, 2003) and journal articles regarding recommendations for teachers (Scharmann, 2005) are directed at improving evolution education. Some books, such as *Investigating Evolutionary Biology in the*

Laboratory (McComas, 2008), exist as well. Unfortunately, while the publications mentioned show an extensive effort by researchers to reform biological evolution education, those same publications need to be read by teachers. However, without appropriate background knowledge, teachers may not be able to implement or fully understand the recommendations. The National Science Teachers Association's (2003) position statement includes background information aimed at helping teachers understand some nature of science issues as well as the legal issues surrounding the teaching of biological evolution. The National Association of Biology Teachers' (2008) statement on evolution teaching presents information supporting the theory of evolution and argues that to teach biology in a "scientifically honest manner requires that evolution be taught in a standards-based instructional framework with effective classroom discussions and laboratory experiences."

In 1995 and 2003, Moore and Kraemer (2005) surveyed teachers about their teaching practices of biological evolution. In 1995, only 34% of teachers surveyed agreed that their undergraduate methods class prepared them to teach evolution; and, in 2003, only 38% agreed. This means over half of those surveyed were either not sure or disagreed that their undergraduate methods prepared them to teach biological evolution.

Khourey-Bowers (2006) described one such attempt to help pre-service teachers. A university secondary science methods course implemented a structured academic controversy (SAC) activity. "SACs are designed to engage students in controversy and then guide them to seek an agreement" (p. 44). This SAC was implemented for 11 undergraduate pre-service science teachers covering the topics of evolution, origin of life, quantum physics, and genetics. The goals were to “provide an examination of dominant perspectives on the nature of science, the nature of religion, and the existence and location of boundaries between these disciplines” (p. 45). After small-group and large-group discussions, the pre-service teachers came to a consensus that their future students should learn the scientifically accepted concepts and, while respecting diverse views is important, those other views need not be taught. This method of instruction is similar to one reported by Mead and Scharmann (1994) who posited that structured controversy can be used to engage students in biology for the purpose of teaching biological evolution. Mead and Scharmann provided a sample lesson that included structured small group discussions, similar to the procedure used by Khourey-Bowers (2006).

Biology Education Teaching and Learning (BETAL)

Biology Education Teaching and Learning (BETAL) was a learning community at Iowa State University from Fall 2002 through Fall 2007. BETAL was originally conceptualized by a biology professor at Iowa State University (ISU). Frustrated by his incoming introductory biology students’ lack of understanding regarding biological evolution, this faculty member wanted to better prepare future science teachers to teach biological evolution.. Prior to the inception of BETAL, he had not addressed the needs of pre-service teachers and their preparation to teach biology. The biology faculty member initiated conversations with two science educators in the Curriculum and Instruction Department at ISU. Both science educators were involved in the preparation of pre-service science teachers and the coordination of the Master of Arts in Teaching (M.A.T.) Science Education graduate program (College of Human Sciences, 2009). Through these conversations, the BETAL seminar was developed and initiated in Fall 2002.

According to the BETAL syllabus: “BETAL is a learning community dedicated to aiding in the development of excellent life science teachers at the middle school and high school levels.” The BETAL learning community grew to include several faculty members (Table 2) from the Biology and Science Education departments at Iowa State University. The involvement of these faculty members was instrumental in the success of BETAL.

From its beginning, evolution education was a primary goal for the seminar course. The BETAL faculty expected that if pre-service biology teachers better understood biological evolution and how to teach it effectively, then future incoming college students would be better prepared for introductory biology. As BETAL was taking shape, discussions with the two science educators resulted in the inclusion of a variety of topics that would be useful for pre-service biology teachers. As it gained momentum, BETAL became a collaboration among several science departments on campus (Biology, Curriculum & Instruction, Geology, Chemistry, and Physics). Over time, other science education topics considered to be controversial in the public’s view were included. This change reflected the number of BETAL participants who were endorsed to teach science subjects beyond biology.

Table 2. Biographical information of the BETAL faculty

Name	Degrees & research focuses	BETAL involvement
Biologist	B.S. Biology, M.S. Botany-Plant Anatomy, Ph.D. Botany-Plant Molecular Biology. Research: student learning of biology, evolution education, nature of science understanding (Colbert, 2009)	Founder of BETAL. Main professor responsible for the seminar course. Created syllabi and coordinated with other faculty. Major professor for biological evolution education component.
Science Educator	B.A. Biology, M.A.T. Science Education, Ph.D. Science Education. Research: Effective science teaching and science teacher education; Nature of science and its implications, Biological evolution public education controversy (Dept. of C & I, 2010)	Professor for science methods course and nature of science course. Collaborated in creation of BETAL and promotion. Made connections to BETAL in other courses as well as incorporate NOS into the BETAL seminar. Collaborated in evolution education component of BETAL.
Science Educator	B.A. Liberal Studies, M.A. Education, Ph.D. Curriculum & Instruction Science Education. Research: Science Education, elementary teacher preparation, Science teacher decision-making, Nature of science and technology and their impacts on science learning (Dept of C and I, 2010)	Professor in science education. Spoke to BETAL students about successful field trip experiences and professional organizations for science teachers.
Biologist	B.A. Biology, M.S., PhD. Zoology. Research: Invertebrate Neurobiology (Drewes, 2005)	Dedicated to in-service teacher training, low cost materials for biological exploration, bioethics particularly dissection
Biotechnology Outreach Coordinator	M.S. Education in Curriculum and Instruction, Science Education emphasis. Research: producing bioscience activities and curriculum for K12 classroom teachers (Zeller, 2010)	Shared teaching experiences in high school classroom (24 years experience). Discussed Iowa school system organization and low cost biotechnology activities.
Biology Academic Advisor	B.S. in Psychology, ISU (Biology minor), M.A. in Psychology/Behavioral Genetics, University of Colorado-Boulder (Hix, 2010)	Handled various administrative duties. Coordinated BETAL students' attendance at the Iowa Science Teachers conference. Purchased teacher start-up kit supplies. Compiled articles and activities into booklet for students.

To participate in BETAL, students were required to be enrolled concurrently in the secondary science methods course. The BETAL seminar made numerous links to topics being discussed in students' methods course and vice versa. BETAL followed a two-semester format, with the fall semester focusing on general topics for pre-service teachers, and the spring semester focusing on biological evolution education and other potentially controversial science topics in the secondary school biology curriculum. BETAL also provided a teacher start-up kit each semester that contained useful materials for a beginning biology teacher.

A brief discussion of the fall semester is presented in the current research to provide a deeper understanding of the concept of BETAL. This study primarily focused on the biological evolution component during the spring semester of BETAL. The fall semester (Appendix B) focused on incorporating service learning into the classroom, how to run successful field trips, and introduced students to professional organizations and conferences. The students were required to participate in a service learning activity and/or a field trip. In addition, BETAL also paid the registration fees and provided transportation to the Iowa Academy of Science's yearly science teachers' conference.

The spring semester of BETAL (Appendix C) was concerned with addressing science topics that are perceived to be controversial in the public's view. Early in the spring semester, BETAL seminars concentrated on the teaching of biological evolution and on raising the participants' awareness about issues regarding biological evolution education. This section typically lasted approximately six weeks.

In one of the first classes of the semester, students were asked to come prepared to discuss the following questions:

1. What was your pre-college experience regarding learning evolutionary theory?
2. How has your college-level experience built on your understanding of evolutionary theory?
3. What would you predict as the percentage of your future students who would agree with the following statement: “God created human beings pretty much in their present form at one time within the last 10,000 years of so”?
4. What concerns, if any, do you have about teaching evolution?

The discussion of these questions enabled the facilitators of BETAL to get a sense of the students’ background in biological evolution education and identify concerns the students had with teaching biological evolution.

Early in the seminar, students read articles and engaged in discussions about the public’s views on biological evolution and creationism. One item that was discussed was the poll results from 2004 that asked a random sampling of approximately 1,000 adults if they thought certain Bible stories (Red Sea, Creation, Noah) were “literally true." Students also discussed the creation story in Genesis. These discussions and others were necessary to make the students aware of the types of beliefs of their own students who would be entering the classroom, as well as the beliefs of fellow teachers, administrators, and parents.

Discussions and readings (Table 3) addressed evidence supporting biological evolution. During this time the students participated in some activities addressing natural selection that could be used in their classrooms. One goal was to provide the students with resources and support for teaching biological evolution topics. Myths and fallacies about biological evolution perpetuated by those against the teaching of biological evolution were also addressed. Further effort was directed at dissecting the claims of Intelligent Design (D) proponents, and discussing why ID is not science.

Table 3. Readings and resources used in BETAL

Readings/Resources	Topics Covered
Defending Evolution in the Classroom by Alters and Alters (2001)	Perceived challenges to evolution teaching; Why students reject evolution; Questions and answers about teaching evolution
Public Acceptance of Evolution. *Science*. J. Miller, E. Scott, and S. Okamoto (2006)	Americans' acceptance of evolution compared to other countries
Was Darwin Wrong? *National Geographic.* D. Quammen (2004)	Evidence supporting evolution; History of Darwin
Denying Evolution: Creation, Scientism, and the Nature of Science by M. Pigliucci (2002)	Creationist fallacies, Intelligent Design, Nature of science, Legal battles
Countering the Wedge: A multi-pronged, multi-year strategy to oppose creationism and intelligent design in the science curriculum of public schools. Pigliucci, Baum, and McPeek	Defending the teaching of biological evolution
The Essential Role of the Nature of Science in Learning about Evolutionary Biology. M, Clough. 2006	Nature of science, Public education controversy

During the prior fall semester, before the evolution education component of BETAL, most BETAL participants also took part in a Nature of Science course that was taught by one of the science educators. This enabled the BETAL facilitators to build on the students' understanding of what science is and what is not science, and make connections to the education controversy surrounding biological evolution. As previously discussed, the Nature of Science is crucial to the effective teaching of biological evolution (Clough, 2006; Scharmann, 2005).

The evolution education portion of BETAL concluded with a written assessment asking the students to respond to the following questions:

1. What obligations, or responsibilities, do you feel regarding teaching evolution in the science classroom? Why?
2. What reservations do you have about teaching evolution in the science classroom? Why?
3. Over the past several weeks what aspects of your thinking about teaching evolution and creationism/intelligent design in science classrooms have changed? What aspects remained the same? Why?
4. In what way(s), if any, do you imagine this portion of BETAL may aid in your development as a biology/life science teacher?

Answering these questions required students to take a stance on teaching biological evolution and provide reasons for their decision. The purpose was to solidify the knowledge students gained through the six weeks. Students were also able to re-voice any concerns they had about teaching biological evolution. The last two questions provided feedback to the BETAL facilitators about what students gained from their BETAL experience.

Overall, the discussions encouraged students to become more comfortable talking about a topic that many find difficult to discuss. By examining these issues, students were able to formulate reasons supporting the importance of teaching biological evolution, and not teaching non-science ideas such as creationism or ID. Students also formed friendships with fellow BETAL participants and facilitators, and created a support system. This support system gave the students others to rely on when they were struggling teaching. Along with this support system the students were also given access to many resources for teaching biological evolution. One resource was a booklet of articles (Appendix D). Other resources were provided in the teacher start-up kit the students received as participants in BETAL.

CHAPTER 3. METHODOLOGY

The BETAL learning community at Iowa State University was designed to help secondary biology teachers in their first years of teaching. One of the goals of BETAL was to increase the numbers of secondary biology teachers teaching biological evolution (Colbert, 2009). This study was conducted to ascertain the biological evolution teaching practices of former BETAL students and compare their practices to those of: 1) former ISU students who did not participate in BETAL, and 2) national data on practices of biology teachers. This comparison will enable us to determine if participation in BETAL is associated with higher levels of teaching biological evolution.

Research Questions

The study was conducted to answer the following questions regarding the biological evolution teaching practices of former ISU students who had taken part in the second semester of BETAL, those who did not take part in the second semester of BETAL, and data from prior national studies.

What differences, if any, exist between groups in:

1. the amount of time spent teaching biological evolution concepts?
2. how they cover the concept of biological evolution?
3. how they assess biological evolution concepts?
4. the type and number of resources used in teaching biological evolution concepts?
5. the connections made to the nature of science and biological evolution?

Research Design

This study used qualitative research methods to gain an understanding of the participants' biological evolution teaching practices. Qualitative research methods were used because they can provide an in-depth description (Adler and Clark, 2008) of the participants' teaching practices. Because of the small sample size, the use of open-ended interview questions enables the interviewer to gather detailed information from each participant regarding their biological evolution teaching practices, which would be difficult with quantitative methods. The ability to develop or modify follow-up questions, depending on the answers to previous questions, allows for clarification and elaboration from participants during the interview process (Adler and Clark, 2008). Thus, due to a small sample size and the desire for an in-depth look at the teaching practices of participants a naturalistic inquiry approach was chosen. With this approach the interviews became the main data source, with teaching artifacts used as an important source of data triangulation (Maxwell, 2004).

Participants and recruitment

To recruit participants, a number of e-mail correspondences were sent, describing the study, what participating would entail, and inviting those contacted to participate. Initial response was low (3 of 25). To gain enough participants for the study, a second request was sent to a larger population, including former students who had graduated in the past five years. Respondents who expressed interest in taking part in the study were mailed consent forms with self-addressed stamped envelopes for each participant to read, sign, and return. Respondents were also asked to provide materials they used in their teaching of biological evolution and to prepare to spend an hour to participate in an interview.

Former ISU secondary science education students who currently taught or had recently taught a course addressing biological evolution were recruited. Participants were past ISU Secondary Science Education students who had participated in the evolution education component of BETAL, as well as those who had not participated in the evolution education component of BETAL. Seven participants who met the above criteria agreed to participate in the study.

Table 4. Demographic summary of the participants

Participant	Gender	Degree	# of Years Teaching.	BETAL Experience	State Teaching	Type of School
1	M	BS: Physics	3	none	Iowa	Private Christian school in a suburb
2	F	BS: Biology	2	none	Iowa	Small rural school; ~90 students
3	M	MAT BS: Biology	3	Both sem.	Illinois	Large suburban school; predominately white
4	M	BS: Biology	2	both sem.	Iowa	1800 students; diverse backgrounds; suburban; rural,
5	F	MAT BS: Anthropology Environmental Science	1	fall sem. only	Iowa	Large school district; students with varying SES backgrounds
6	F	MAT BS: Genetics	1	both sem.	Iowa	Large school; mixed SES statuses
7	M	MAT BA: Biology	5	both sem.	Iowa	Large suburban school; high SES status

As shown in Table 4, four of the seven study participants took part in the evolution education component of BETAL and three did not. Four participants were male and three were female. Four participants had completed the ISU graduate level Master of Arts in Teaching (MAT) secondary science teacher education program and three completed the undergraduate version of the secondary science teacher education program. ISU's MAT program is an intense 15-month graduate program for those with a bachelor's degree in science who wish to earn their license to teach. The two programs have similar coursework (two semesters of science methods, a nature of science course, multicultural education, educational psychology, foundations of education, technology in education, and practicum experiences), although the graduate versions have additional work to complete for each course. The MAT program also differs from the undergraduate program by requiring an advanced science pedagogy course after student teaching (College of Human Sciences, 2009).

Two of the undergraduate students (Participants 2 and 4) earned a bachelor's degree in biology. Participant 1 only took one biology class at the college level while earning an undergraduate degree in physics. All teachers except Participant 3 teach in the state of Iowa, while Participant 3 teaches in Illinois. The types of schools represented varies, with a majority teaching in larger school districts with a diverse student population. Teachers 3, 4, 6 and 7 make up the BETAL evolution education group, while teachers 1, 2 and 5 make up the non-Betal evolution education group.

Data sources

Teaching materials

For this study, teaching materials were requested from participants. Teaching materials were described as including lesson plans, worksheets, lecture notes, PowerPoint presentations, handouts, overheads, assignments, and assessments. These materials were requested because they are what the students see and written materials convey powerful messages about science and how it works (Aikenhead, 2009). These artifacts are important to collect because participants may not realize the message their teaching materials are sending to the students, and therefore may over- or under-report their evolution teaching practices as experienced by the students. Thus, the materials serve an important role in providing triangulation for the conclusions drawn from other data sources. Two of the seven participants (Participants 2 and 5) did not provide any teaching materials. Participant 2 did not teach biological evolution and, thus, did not have any teaching materials to provide. Participant 5 agreed to provide teaching materials later, but did not. That participant was contacted several times in attempt to gather materials, but to no avail. Other participants did provide teaching materials. However, the number of teaching materials varied greatly between participants. For some participants, the lack of teaching materials hindered data analysis and weakened the ability of the researcher to make confident claims about the results.

Interviews

Interviews are a second data source in this study. A semi-structured interview format (Appendix A) was designed so that specific questions could be asked of all participants, to enable comparisons, while providing flexibility for follow up questions (Adler & Clark, 2008). The interview process was used to gather information about the participants, in addition to their thoughts and rationales behind their biological evolution teaching practices. Each interview lasted around an hour and was digitally recorded and then transcribed for later analysis. Interviews took place in settings chosen by the participants to help ensure that they felt comfortable answering questions about biological evolution-- a topic that a large percentage of the public considers controversial. Interview settings included coffee shops and a library.

As mentioned previously, self-reported data have limitations. The assumption must be made that participants are answering in a way that is consistent with what really occurred (Adler & Clark, 2008). “It can be problematic when the respondent wants to present a good image or tries to conform to what are perceived to be the researcher’s expectations” (p. 229). In this study, participants may have felt the need to represent themselves in a way that was consistent with what was promoted in BETAL or by ISU faculty, especially considering the topic of biological evolution was involved. However, the use of classroom artifacts as well as interview data reduces the likelihood that teachers were misrepresenting their teaching practices.

Data Analysis

Research Question 1: How do these different groups compare in the amount of time spent on the concept of biological evolution?

To answer research question 1, responses to the following interview questions were examined:

- How long do you typically spend on evolution concepts?
- What time of the school year do you typically introduce evolution concepts?
- What are the pros and cons to doing it that way?

Responses to the first interview question were coded by the number of class periods that were spent teaching biological evolution concepts. Class periods were assumed to be 45 minutes long since none of the participants taught in schools with block scheduling. The number of class periods was converted to hours to allow comparison with other national studies reporting hours spent covering biological evolution. Teaching materials were examined and the number of artifacts were counted to provide triangulation with reported class hours spent on biological evolution concepts. Groups were then compared to determine if those who had enrolled in the second semester of BETAL showed any differences in the amount of time they spent teaching biological evolution.

Research Question 2: How do these different groups compare in how they teach biological evolution concepts?

To answer research question 2, responses to the following interview questions were examined:

- What time of the school year do you typically introduce evolution concepts; what are the pros and cons to doing it that way?
- How long do you typically spend on evolution concepts?
- Do you feel it is important to teach evolution concepts in your class?
- To what extent did you help reduce the evolution controversy for your students? How did you go about this?
- What resources do you use to develop your lessons and assessments on evolution concepts?

Analysis of teaching materials and interview transcripts utilized categories from Hermann (2008) and Hildebrand *et al*. (2008) (see Chapter 2) for instructional approaches regarding biological evolution instruction.

Participants' data were coded, and responses were tallied for each category to determine an overall category classification. If a participant had a majority of tallies in one category, it was classified as that category. For those who had two or more categories with similar numbers they were labeled as both (Table 5). Groups were then compared to determine if taking part in the second semester of BETAL revealed any differences in their classifications.

Table 5. Teaching category coding scale

Code	Category
A	Avoidant (Hildebrand et al., 2008 and Hermann, 2008)
B	Corrosive (Hildebrand et al., 2008)
C	Teach about controversy (Hildebrand et al., 2008)
D	Proactive (Hildebrand et al., 2008)
E	Advocacy (Hermann, 2008)
F	Affirmative Neutrality (Hermann, 2008)
G	Procedural Neutrality (Herman, 2008)
H	BETAL-promoted approach

Research Question 3: How do these different groups compare in how they assess biological evolution concepts?

To answer research question 3, assessment artifacts were examined from each participant's teaching materials. Additionally, answers to the interview question "What resources do you use to develop your lessons and assessments on evolution concepts?" were examined. Assessments were coded using criteria developed by Marzano (2006). Marzano divided assessments into three types. Type I assessments are comprised of basic details and processes. These assessments rely on simple recall and are relatively easy for students. Type II assessments involve slightly more complex ideas and require the student to generate a response rather than simply recall information. Type III assessments ask students to make inferences and applications that go beyond what was taught in class (Marzano). Oftentimes, assessments include one or more of the described types. Assessments were coded and tallied for each participant. Groups were then compared to look for differences.

Research Question 4: How do these different groups compare in the type and amount of resources used in teaching biological evolution concepts?

To address research question 4, the following interview questions were examined:

- What resources do you use to develop your lessons and assessments on evolution concepts?
- To what extent did BETAL (or other experiences) make a difference in your teaching of biological evolution?
- What supports and/or constraints do you feel in your building about teaching evolution concepts?
- Have you taken any courses/workshops/presentations/etc. on how to teach evolution concepts?
- What difficulties have you faced when teaching evolution concepts?

Teaching materials were also examined to look for any citations to sources, to determine if any materials used in BETAL were being used by the teacher. To code these data, a multi-level coding system was used to examine the type of resource and whether or not the resource was provided through BETAL (Table 6). One of BETAL's aims was to provide students with resources for teaching biological evolution. Each participant's codes were tallied and groups were compared to determine if there were any differences.

Table 6. Resource coding scheme

Resource used	BETAL-provided resource	Other source
Website	1a	2a
Book for teachers	1b	2b
Book for students	1c	2c
Book, historical example	1d	2d
Video	1e	2e
Article for teachers	1f	2f
Article for students	1g	2g
BETAL resource other	1h	
District provided other		2h

Research Question 5: How do these different groups compare in the connections made to the nature of science and biological evolution?

To answer research question 5, the following interview questions were examined:

- To what extent did BETAL/other experiences make a difference in your teaching of biological evolution?
- To what extent did you help reduce the evolution controversy for your students?
- How did you go about this?

Teaching materials were examined for explicit references to NOS and connections to the education controversy surrounding the teaching of biological evolution. As shown in Table 7, data were coded according to the nature of science topics identified by Clough (1994; 2006). These topics were coded because they can help decrease students' resistance to biological evolution education. Groups were then compared to determine if participation in the second semester of BETAL showed any difference in which, if any, topics were discussed.

Table 7. NOS coding scheme

Code	NOS Idea
N1	Distinction between biological evolution and origin of life
N2	Use of language in science
N3	Functional understanding rather than belief
N4	Scientific knowledge is not fair nor is it decided democratically
N5	Science provides naturalistic explanations
N6	Anomalies in science don't mean automatic dismissal
N7	Science is falsifiable

Limitations of Study

Due to the study design, the findings should be interpreted with caution. First of all, the number of participants that agreed to take part was small. The overall population (around 120) to draw from was small. Then the population was further limited by how many graduates only had been teaching for a few years and were teaching biology/life science. Four participants agreed to take part that fit the narrow criteria. This limits the ability to generalize the findings to the entire population of BETAL Evolution Education learning community participants.

Another limiting factor is the controversial nature of the subject picked for the study. Biological evolution has a public education controversy (Hermann, 2008) surrounding it that greatly affected this study. It may have limited the number of people that choose to participate. As well, it may have influenced participant’s interview responses to be more in line with what they thought was wanted (Adler and Clark, 2008). In addition, it limits the ability to generalize the findings to other science topics that are less controversial in nature.

The study design itself was limiting, because classroom observation was not part of the experimental design. The lack of observational data means there was a heavy reliance on self-report data. There may have been more going on in the classroom than the participants realized. While participants may have been teaching one way, perhaps another message entirely was conveyed to students. Self-report data is inherently troubling due to relying on the integrity of the participant (Adler and Clark, 2008). Assumptions need to be made that participants are replying in a manner consistent with their actual teaching practices. The collection of teaching artifacts was designed to help mitigate this affect, but with the low return of teaching artifacts, interview data became the main source of information.

Summary of Methodology

In summary, this study seeks to determine if any differences exist between students who enrolled in the BETAL evolution education seminar and their peers who did not, both nationally and in the ISU program. Two data sources were collected: teaching artifacts and interviews conducted with BETAL evolution education and non-BETAL ISU graduates. These data were compared with national data concerning biological evolution education. Qualitative methods were selected due to the need for detailed descriptions of teaching practices and the small number of participants who were willing to take part in the study.

CHAPTER 4. RESULTS

The purpose of this study was to determine whether the evolution education component of BETAL had an effect on its participants' teaching of biological evolution. Because few programs like BETAL appear to exist, determining its impact on participants' teaching practices is important. A positive impact, despite the significant limitations of this small study, may imply that more programs like BETAL should be in place.

This research study utilized two types of data collection. First, teaching materials used in the teaching of biological evolution were requested from participants and analyzed. In addition, a semi-structured interview was conducted with each participant, either in person or via email (participant three was teaching in another state). Both sources were examined and coded to answer the research questions.

Data and Analysis

The seven participants were divided into two groups based on their BETAL experience. Four individuals (participants 3, 4, 6 and 7) completed the evolution education component of BETAL, whereas the other three individuals (participants 1, 2 and 5) either did not participate in BETAL, or, in the case of participant five, only took the first semester portion which concentrated on professional development topics. However, all seven participants did take part in a separate Nature of Science course as either undergraduate or graduate students.

BETAL evolution education participants

Of the seven study participants, all but Participant 3 were teaching in Iowa. Participants 3, 4, 6, and 7 completed the evolution education component of BETAL and all four reported that they teach biological evolution in their classes.

Participant 3 was in his third year of teaching and taught biology in a large high school (approximately 3,100 students) in a suburb of Chicago, IL. The student population at this school is predominantly white (74%), with only 9% of the total population labeled as “low income.” When asked about any constraints that interfered in the teaching of biological evolution, Participant 3 reported feeling “nothing but support to teach concepts the way I see fit”. The opposition to teaching biological evolution he reported came from a few experiences with students arguing that it shouldn’t be covered.

Participant 4 was in his second year teaching and taught 10th grade biology in a suburban high school (approximately 1,800 students) in Central Iowa. Students come from a variety of backgrounds (suburban, rural, and urban). The student population is predominantly white in ethnicity. Participant 4 did not feel any constraints towards teaching biological evolution. However, some of Participant 4’s coworkers have expressed feeling uncomfortable teaching biological evolution or that they only spend a short time on biological evolution to avoid conflicts. This participant also experienced concerns among his students about learning about biological evolution.

Participant 6 was in her first year of teaching and taught general biology and an advanced biology course in a urban high school (approximately 1,700 students) in Central Iowa. The school has a fairly large Hispanic population and the socioeconomic status of the students varies widely, with about 33% on the free and reduced lunch program. Participant 6 noted that the only resistance she received regarding evolution education was from students who “refuse to learn it due to not wanting to believe it”. Other teachers and the administration are supportive of the teaching of biological evolution and the participant had never received a negative word from parents.

Participant 7 was in his fifth year of teaching and taught biology in a large suburban high school (approximately 1,900 students) in Central Iowa. Students were from a predominantly high socioeconomic status. Participant 7 reported that all the other biology teachers at his school also taught biological evolution and the school administration was very supportive regarding the teaching of biological evolution. Participant 7 reported some student resistance to learning about biological evolution, but none from parents.

Non-BETAL evolution education participants

Three participants (1, 2, and 5) did not participate in the spring BETAL learning community where evolution education was addressed. Two of the participants (1 and 5) reported that they teach biological evolution, and one participant (2) did not.

Participant 1 was in his third year of teaching at a small private Christian school located in the suburbs in Central Iowa. The school includes all grades from kindergarten through 12. Participant 1 is the only science teacher at the school and teaches all the science courses, from 7th–12 th grade. The majority of the students are from high socioeconomic backgrounds. The students are predominantly white and the class size is approximately 10 – 15 students. Participant 1 reported that some parents had voiced support for the teaching of biological evolution, but he also had parents who voiced concerns about the teaching of biological evolution. However, the administration was supportive of including biological evolution in the science curriculum and helped Participant 1 write stan*dards for biological evolution.* Participant 1 also had faced student resistance, with students questioning why they were having to learn about biological evolution.

Participant 2 was in her second year of teaching, taught high school biology, and was the only participant that did not teach biological evolution. Participant 2 taught biology in a small rural high school of approximately 80 students in North Central Iowa. Students come from a rural background and are predominantly white. When asked about constraints, Participant 2 mentioned that coworkers voiced many misconceptions about science (nature of science concerns such as what science is and what science is not) and were skeptical of biological evolution. Participant 2 felt the administration was supportive, but the previous teacher in her position did not teach biological evolution and so Participant 2 followed suit. The school did not have any standards for biological evolution at the time of the interview. When asked if biological evolution was important to teach, Participant 2 said she thought so and wanted to include it later: “maybe in advanced biology courses”.

Participant 5 was finishing her first year of teaching environmental science in an urban high school (approximately 2100 students) in Central Iowa. Students come from middle to low socioeconomic statuses. The high school has a fairly large minority population. This teacher does teach biological evolution. Constraints felt by Participant 5 included coworkers' comments and reactions by students in class. No other teachers at the high school teach biological evolution, not even the biology teachers. Coworkers were vocal about not believing in biological evolution and not wanting to teach it. Student reactions included voicing not wanting to learn about biological evolution because they did not believe it.

Findings Based on the Research Questions

The five research questions focused on how the two groups compare on different aspects of their biological evolution teaching practices. Comparisons also are made with national data as reported in other studies about the current state of biological evolution education.

Research Question 1: Amount of time spent teaching biological evolution

During the semi-structured interview, participants were asked how much time they typically spent on biological evolution concepts and what time of year they introduced biological evolution. These answers were coded, and number of class periods they reported were converted into hours for comparison to national data. A forty-five minute class period and five periods a week were assumed for the calculation based on hours (Table 8).

For the non-BETAL evolution education group (participants 1, 2, and 5), converting the number of class periods into hours resulted in an average of 8.75

hours of class time spent teaching biological evolution. When looking at BETAL evolution education participants (participants 3, 4, 6, and 7), they self-reported spending on average about 14.6 hours on biological evolution (participant 6's two classes were counted separately). Teaching artifacts were then compared to self-reported data concerning class time spent teaching biological evolution.

Table 8. Time spent teaching biological evolution concepts

Participant	Teacher	Class time for biological evolution (self report data)	Class hours for biological evolution*	Artifacts provided (#)
Non-BETAL	1	one month	15 hrs	One page syllabus with discussion topics and assessment questions (1)
	2	Did not teach biological evolution	0 hrs	None to provide (0)
	5	3 weeks	11.25 hrs	Not provided (0)
BETAL	3	4+ weeks	15+ hrs	Assessments, articles, lab activities (10)
	4	3-4 weeks	11.25-15 hrs (avg. 13hrs)	100 slide power point, lab activities, articles(12)
	6	2 weeks (biology) 6 weeks (upper level biology)	7.5 hrs 22.5 hrs	Research project, discussion topics, layout of unit, articles (5)
	7	one month	15 hrs	File folder of daily lesson plans, assignments, and test (25)

* Calculated assuming 45 minute class periods and 5 days a week.

Triangulating data sources about the time spent teaching biological evolution was problematic for the non-BETAL evolution education participants. Participant 1 reported spending one month teaching biological evolution, but only provided a one-page list of topics discussed and assessment questions. Participant 1 did not provide actual evolution instructional artifacts and instead wrote up a syllabus for the unit. Thus, Participant 1's self-reported data only can be compared to the syllabus provided. The unit syllabus provided by Participant 1 indicates that biological evolution and genetics were taught together. When examining the syllabus, Participant 1 appears to have spent a month teaching genetics topics and making connections to biological evolution throughout, rather than one month explicitly on biological evolution.

Participant 5 described lessons and activities used during the teaching of biological evolution, but did not provide artifacts to back up the self-reported data. Thus, non-BETAL evolution education instructional time is based solely on self-report data and should be viewed with caution.

All BETAL evolution education participants did provide instructional artifacts from their evolution education unit. Participant 7 provided the most teaching materials. Participant 7 provided a file folder full of daily lesson plans, assignments, and assessments. The amount of daily lesson plans (Figure 4) matched with Participant 7's claim of spending approximately one month (assumed to be 20 class periods) teaching biological evolution topics. Participant 4 provided the second highest amount of teaching materials. In the teaching materials provided was a PowerPoint presentation that the participant mentioned using portions of throughout the entire unit on biological evolution. Along with the PowerPoint, lab activities, article readings, and reflections were provided. The amount of materials provided was adequate for the self-reported time spent of three to four weeks.

BETAL Participant 3 also provided teaching materials, although the amount of teaching materials this teacher provided did not seem adequate to confirm the self-reported time spent on biological evolution. The lab activities and articles seemed enough to support a teaching time of a few weeks, but not a month. Participant 3 was the only participant who taught in a state other than Iowa. Participant 3 attached some teaching artifacts to an email, but only provided artifacts that were in electronic formats. Participant 3 was encouraged to mail physical copies of teaching artifacts along with the consent form, but the participant did not do so.

During the interview, Participant 6 mentioned quickly grabbing a few things to provide for the study. Most of the artifacts were articles she had her students read and one was a general layout of the unit. The general layout was a list of topics (Natural selection, Darwin's voyage, Fossil examples, "Superbugs"), but didn't have any time breakdown for the topics. Participant 6 also provided a description of a research project that the students complete. Due to so few artifacts provided from Participant 6, the reported amount of time spent teaching biological evolution of two weeks for the lower level course seemed adequate, but (depending on the amount of time allowed for the student's to complete their research projects), the six weeks reported for the upper level course seems overestimated.

When looking nationally, one prior study (Berkman et al., 2008) revealed that "overall teachers spend 13.7 hours devoted to general evolutionary processes, with 59% devoting between three and fifteen hours of class time" (p. 922). In a survey of Minnesota biology teachers in 2003, Moore and Kraemer (2005) found that 64% of those surveyed spent between three and 20 hours devoted to evolution-related concepts. Aguillard (1999) surveyed Louisiana teachers regarding how many class periods were allocated to biological evolution and found that only 16% allocated more than 7.5 class periods, with the highest percentage being 41% allocating 2.5 to 5.0 class periods. Comparing this to the reported time spent by BETAL evolution education students (14.6 hours), it appears that they fall on the high end of ranges found nationally. However, this comparison is made with caution, due to the lack of triangulating data from teaching artifacts.

In addition to how long they spent teaching biological evolution, participants were asked what time of year they taught the concept (Table 9). Both of the non-BETAL evolution education participants who teach biological evolution do so at the transition of first and second semester. Participant 1 taught biological evolution with genetics and that section ends the first semester, although Participant 1 claims biological evolution topics get touched on throughout the rest of the course.

Participant 5 used biological evolution to begin the second semester of the environmental science course. This course was new that year at the district and the participant was not happy with the placement. That position was chosen because it was handy at the time. In a traditional biology course, Participant 5 said they would teach an abbreviated version of biological evolution at the beginning of the year and then revisit it more in depth after talking about DNA.

Table 9. Time of year biological evolution was taught

Participant	Teacher	Time of year	Satisfied with placement?
Non-BETAL	1	Near the end of first semester(December)	Yes - fits nicely after genetics
	2	Doesn't teach biological evolution	NA
	5	Beginning of second semester (January)	No, would like to include in earlier in an actual biology course
BETAL	3	Late March/beginning of 4th qtr	Somewhat - good have genetics background, bad time crunch last qtr
	4	February/March	No - not sure where would like it, but thinks it's too late in the year
	6	May for general biology October for advanced biology	Yes - have background to understand
	7	End of first semester (December)	Yes - background is there and can touch on it all second semester

BETAL evolution education participants seemed mostly to teach biological evolution midway through the second semester. The latest in the year that biological evolution was taught was May. Participant 6 liked the placement as it "worked to bring everything together and reveal how biological evolution fit with everything else." However, Participant 6 mentioned it would have been better to teach evolution sooner, but this was not possible due to restrictions with the school's curriculum. Participant 6 taught biological evolution in October in an advanced biology course. Participant 7 was similar to the non-BETAL participants and taught biological evolution at the transition of first and second semester.

Considering the publicly controversial nature of biological evolution, when teachers do teach it they teach it at the end of the school year as a way of avoiding trouble (Hildebrand et al., 2008). By teaching it at the end of the school year there is often not a lot of time to go into a lot of depth. This could also be true of teaching it at the end of the first semester. It's disappointing to see that, while biological evolution is a topic crucial to understanding biology concepts, teachers put if off until later in the school year, rather than use it as a unifying theme throughout the school year. Participant 5 (non-BETAL evolution education) was the only one that stated they would start teaching it at the beginning of a biology course. BETAL evolution education participants tended to teach it earlier than is found nationally (Berkman et al., 2008), but it was still placed well into the school year. However, students need an accurate understanding of the nature of science to be able to grasp fully the importance of biological evolution in biology. So perhaps this later placement in the school year by BETAL participants was a byproduct of first helping their students understand the nature of science.

Research Question 2: How participants cover the concept of biological evolution

To address question 2, categories were used from Hermann (2008) and Hildebrand et al. (2008) in order to classify participants' treatment of biological evolution in their classrooms. Interview data and teaching materials were coded and subsequently tallied to determine categories for each participant (Table 10).

Table 10. Classification of instructional approaches toward evolution

Participant	Teacher	Category
Non-BETAL	1	Corrosive (Hildebrand et al., 2008)
	2	Avoidant (Hildebrand et al., 2008 and Hermann, 2008)
	5	Proactive (Hildebrand et al., 2008)
BETAL	3	Teach about controversy (Hildebrand et al., 2008) Affirmative neutrality (Hermann, 2008)
	4	Teach about controversy (Hildebrand et al., 2008) Affirmative neutrality (Hermann, 2008)
	6	Teach about controversy (Hildebrand et al., 2008) Procedural Neutrality (Hermann, 2008)
	7	Teach about controversy (Hildebrand et al., 2008) Procedural Neutrality (Hermann, 2008)

Non-BETAL evolution education members showed the widest range of categories. Participant 2 choose not to teach biological evolution in the biology classroom. This places Participant 2 in the avoidant category of instructional approaches. The reasoning for not including biological evolution was that the science teacher who was replaced by Participant 2 did not teach it and the school did not have any standards for biological evolution. Participant 2 felt biological evolution was important to include but still chose to not teach it. Participant 2's colleagues shared negative opinions about the teaching of biological evolution. For example one colleague said they were "skeptical" of biological evolution. Due to negative comments from colleagues and the lack of prior biological evolution education, the apparent consequence was Participant 2's choice to not teach biological evolution.

Participant 1 fell mostly into the corrosive (Hildebrand et al., 2008) category of teaching biological evolution. Participant 1 reported including some nature of science instruction regarding the difference between models and theories. This was done mainly through class discussions. Participant 1 described models as “tools scientist use to help them understand science concepts” and theories were described as explanations. However, Participant 1 said he shied away from the use of theory and law in his classes and instead would use models. “It helps me in the classroom, prevents the argument of ‘it's only a theory’”. Participant 1's main goal in teaching biological evolution was to present it as a model that scientists use. Participant 1 claimed purposely to avoid having class discussions about any controversy surrounding the teaching of biological evolution because it “brings up emotions”. Instead, the reported focus for the unit was the evidence behind biological evolution and how biological evolution is a model scientists use to explain how living things change.

Participant 1 also reported including some information about creationist ideas (a genesis story) during the same unit. Participant 1 would read the genesis story to the class after students had received instruction on biological evolution. Participant 1 stated this was used to discuss “how science explains things differently” and to present multiple sides of the story. As Participant 1 teaches in a private Christian school, the fact that creationism was only included briefly was surprising. Although, considering the students also participate in religion classes, Participant 1 may have felt it wasn’t necessary for more instruction.

Participant 1’s teaching artifact supports the same categorization. The one artifact provided was a two-page outline of topics covered, goals for the unit, and assessment questions. One of the topics discussed was listed as “Creation versus Evolution.” The outline continued with: “Don’t make a big deal about the argument. I give model of evolution, read creation account of genesis, and discuss NOS”. While this shows acknowledgment of the controversy and could support a different categorization, Participant 1 was categorized as corrosive for two reasons. By making the statement that Participant 1 avoided class discussions about the education controversy and “don’t make a big deal about it,” the teacher ignored the role that public education controversy has on the students’ thoughts and perceptions. In addition, by teaching biological evolution as a model, it downgrades biological evolution’s importance to the field of biology and presents it as merely an idea or tool. This likely reflects Participant 1’s lack of background knowledge, which is not surprising considering the teacher earned a bachelor’s degree in physics and only completed one college biology course. This lack of biological content knowledge would make effectively teaching about biological evolution difficult.

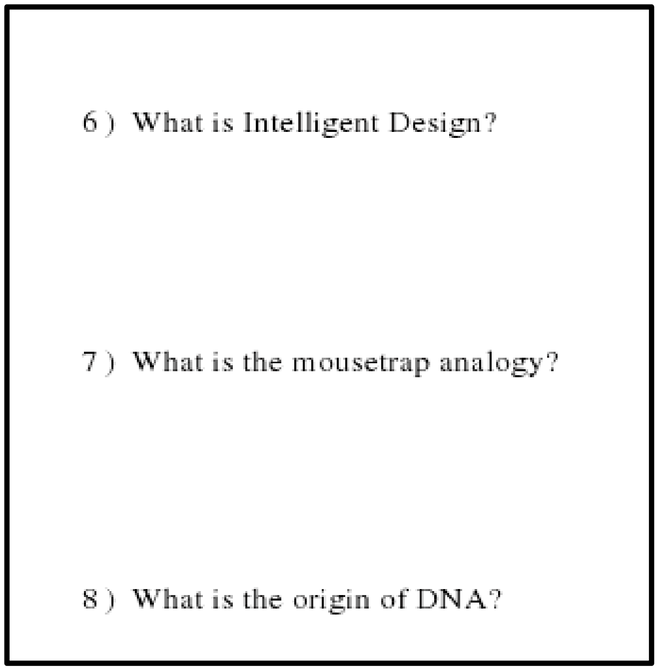
Participant 5 (non-BETAL) was categorized in the proactive (Hildebrand et al., 2008) approach to teaching biological evolution. However, this participant did not provide teaching materials for analysis, so categorization was based solely on interview data. This participant taught biological evolution in what was a new environmental science course at the school. According to Participant 5’s interview data, explicit nature of science teaching was incorporated in the course from the beginning. Participant 5 claimed to start off the year by distinguishing science from other ways of knowing and the difference between natural and supernatural explanations. One activity Participant 5 described using was a tube activity, which is similar to a black box activity. This activity was used to illustrate that scientists rely on naturalistic explanations rather than supernatural explanations. The description was based on using an analogy comparing science to a sport: “Every sport has their own rules to follow and so does science,” Participant 5 said. This analogy was presented in an article (Clough, 2004) provided in the nature of science course that all participants took part in. Participant 5 revisited these differences before starting the unit on biological evolution and continually brought it back up while the unit was progressing. Because of the reported deliberate decisions regarding highlighting the nature of science and showing how science is one way of knowing, Participant 5 was categorized as proactive. However, without any teaching artifacts to support or negate this categorization, determining the appropriate evolution education teaching category is unreliable.

All BETAL evolution education participants fell somewhat into the category of teaching biological evolution while incorporating the education controversy. Participants 3 and 4 mentioned teaching their students about intelligent design. Participant 3 would have class discussions regarding what intelligent design is and why it isn’t science, mainly focusing on ID’s reliance on a supernatural explanation.

Participant 4 also included information about intelligent design by watching the film “Evolution: Fossils, Genes, and Mousetraps.” From the film’s description:

"Ken Miller discusses the controversy surrounding the teaching of evolution, presents compelling evidence for evolution and reasons why "intelligent design" is not scientific." (HHMI, 2006). Participant 4 also reported during the interview that their focus was to show how intelligent design is not science. According to Hildebrand et al. (2008), including non-science ideas can "create an environment where science and non-science ideas are placed into a form of competition" (p. 1049). Taking time to distinguish intelligent design from science falls into the affirmative neutrality (Hermann, 2008) category because, while the participants are presenting an alternative view, they are limiting the discussion to why it is not science. While this also may seem consistent with the BETAL-promoted approach, BETAL did not promote teaching the idea of intelligent design, but rather merely presented it for its own participants' understanding.

During the interview process, Participant 4 mentioned telling the students that it was necessary for them to understand evolution for the class. This, on its own, could have placed Participant 4 into the corrosive (Hildebrand et al., 2008) category. However, one of Participant 4's teaching artifacts (Figure 1) was a worksheet for the Ken Miller video "Evolution: Fossils, Genes, and Mousetraps," that discusses how science and religion should not be a battle. This supports the choice of classification of "teach about controversy," as it shows instruction about non-science ideas and addressing the controversy with their students.



6) What is Intelligent Design?

7) What is the mousetrap analogy?

8) What is the origin of DNA?

Figure 1. Teaching artifact submitted by Participant 4

Participants 6 and 7 both were categorized in the “procedural neutrality” (Hermann, 2008) approach and the “teaching about controversy” (Hildebrand et al., 2008) approach. Participant 6 taught two levels of biology courses. In the advanced biology course, Participant 6 described taking an active approach at presenting the controversy around biological evolution. During the interview, Participant 6 said that the controversy has “little to do with science and more with the philosophical interpretation of the evidence,” and described spending time teaching from a philosophical approach. Participant 6 mentioned wanting to help her students “understand the controversy as well as the basic arguments behind all sides of the fence”. These statements support classification in Hildebrand et al.’s (2008) “teach about controversy” category. In the lower level biology class, Participant 6 did not mention spending as much effort towards reducing the controversy for the students. When examining Participant 6's teaching artifacts, one artifact provided was a description of a research paper (Figure 3) given to the advanced biology course. The students are asked to research yes or no questions related to evolution that they find interesting. Students are to research both sides of the issue and present information. The students then are asked to judge which side has the better argument. This assignment could cause comparisons of non-science and science ideas. While good when illustrating what science is and what it is not, the problem here is that the students likely lack the necessary knowledge and understanding to make accurate judgments of the evidence. This artifact supports the categorization of "procedural neutrality" because the alternative perspectives come from the students rather than being predetermined by the teacher.

Participant 7, on the other hand, explicitly stated not teaching any alternative ideas, but would comment on them briefly if brought up by students. Participant 7 incorporated nature of science instruction to help the students understand the differences between theories and laws in science. Early in the year the participant discusses what a theory is in science ("a tested explanation") and how it's different from society's use ("a guess"). Then when starting the unit on biological evolution, this participant brings it back up with a discussion of evolutionary theory and what that means in biology. Participant 7 also said he has a poster on the wall with what hypothesis, theory, and law mean in science; that is there for the students to see all year long. However, these decisions do not completely encompass the proactive approach (Hildebrand et al., 2008). For example, Participant 7 invited students' questions and thoughts about biological evolution in class. While this can be a good approach to illustrate what science is and what science is not, it can be problematic, depending on how the participant handled it. Without classroom observations of this occurrence, knowing how these discussions went and how the participant steered them is not possible. For these reasons, Participant 7 was categorized into the teach about controversy (Hildebrand et al., 2008) category and into the procedural neutrality (Hermann, 2008) category. Procedural neutrality was chosen because any alternative views to biological evolution were brought up by the students and not presented by the instructor.

No national studies were found that used the biological evolution teaching categories suggested by Hermann (2008) or Hildebrand et al. (2008). However, when looking at the current state of biological evolution education, the following research results need to be considered. Berkman et al. (2008) attempted to remedy the “lack of (a) systematic and coherent account of how instruction varies from teacher to teacher across the nation as a whole” (p. 921). What Berkman et al. revealed, when surveying teachers nationally, is that 25 % include instruction on creationism or intelligent design. However, in a follow-up question, they found that only half of that 25% agreed that creationism and intelligent design were scientifically valid alternatives to biological evolution. Berkman et al. determined that teachers including these non-scientific ideas were doing so to “challenge the legitimacy of these alternatives” (p. 922). While this study did not address nature of science topics explicitly, it does show that a small percentage of teachers nationally would fall into the avoidant (Hildebrand et al., 2008 and Hermann, 2008) category, and a slightly higher percentage fall into the teach about controversy category (Hildebrand et al., 2008).

Research Question 3: How participants assess the concept of biological evolution

Assessments regarding students' understanding of biological evolution were examined and coded according to the classification by Marzano (2006). A majority of the data came from the teaching materials collected from each participant, although some participants described assessment activities during the interview process. Assessments were coded according to the types (I, II, III) of questions and processes they asked the students. Type I questions are simple recall type questions such as definitions or fill-in-the blank type questions. Type II questions require the students to put more thought towards answering the questions. Examples would include completing a Venn diagram, or short answer style questions. Finally, Type III questions go beyond what is taught in the classroom. Type III questions require students to create or synthesize new information together. While analyzing assessments, questions were not coded individually but rather assessments as a whole were coded. For example, if a lab activity asked the students to define some vocabulary and complete a Venn diagram, the assessment was coded once each as type I and type II. Then the number of each type was calculated for each participant (Table 11).

Table 11. Assessment coding data

Participant	Teacher	Type of Assessment and Number of Artifacts
Non-BETAL	1	Type I - 3 Type II - 5 Type III - 0
	2	Not applicable - participant doesn't teach biological evolution
	5	No teaching materials provided
BETAL	3	Type I - 2 Type II - 4 Type III - 1
	4	Type I - 4 Type II - 4 Type III - 0
	6	Type I - 3 Type II - 3 Type III - 1
	7	Type I - 2 Type II - 3 Type III - 1

In order to evaluate the types (I, II, III) of questions used to assess biological evolution, formal assessments such as worksheets and exams were examined. Examples of assessments provided included lab activities, a chapter test, and a research paper topic. Only Participant 1 provided teaching materials in the non-BETAL evolution education group. Participant 1 provided a list of assessment questions (Figure 1) that was used throughout the unit to assess students. Some of the questions were simple recall of definitions and others required more thinking by the students. None of the questions provided could be classified as type III. One assessment question may have been a type III style question (“Why is evolution a theory (or model) and not a law?”) but, with Participant 1 stating that the focus of the unit was models in science, it was classified as type II since the distinction of type III questions is that the student goes beyond what was taught. Participant 5 described some of the used with students, but without the actual artifacts to evaluate, the types of questions being asked could not be coded.

BETAL evolution education participants showed a variety of assessment types. All BETAL participants had some simple recall questions, usually vocabulary terms, and then progressed to more complex type II assessments. Participant 4 used an M & M activity while talking about natural selection. One of the questions on the lab sheet asks the students to tell what method they used and how well it compared to others in the class. This was coded as a Type II question because the question required students to do more than simply write down what they did. Later, in the same assignment, participant 4 asks the students to do some graphing of information and afterwards asks how the graph would change if various conditions were altered (Figure 2). As this question goes beyond what was performed in the activity this question was coded as Type III. Participant 6 also had a Type III (Figure 3) assessment as a research paper:

> *They do a research paper based on a yes or no questions related to evolution that they find interesting. They are to research both sides of the issue and present them in a factual basis, then make a judgment call about which side has the better argument.* (Participant 6 Interview)

This was classified as a Type III because to complete the assignment students needed to go out and find information not given to them in class. It also asked students to make judgments, which would entail students putting together information from a variety of sources. However, the appropriateness of the assignment is questionable. As described in the interview, students make a judgment about which side has a better argument. This is worrisome because the students may choose to research science versus religion type of questions, and since the teacher says they stress evaluating evidence, that may be unknowingly making students feel their religious beliefs are less worthy or not as good as science. The students also lack the background knowledge to make appropriate judgments on the presented evidence and are likely to side with non-science ideas. This process could reinforce the students' beliefs in non-science ideas and cause them to cast aside the scientific explanations.

Type I and type II style assessments are used much more frequently (Marzano, 2006) by teachers in K-12 classrooms than type III assessments. Type I and II are often easier to grade and take less time to create. Type III assessments can often go in unintended directions, as they are more open-ended. Considering that teachers don't spend much time covering biological evolution in any depth (Berkman et al., 2008), assessing biological evolution may similarly stay at the "surface" level.

Evolution Paper: Evaluating information

You will be writing a paper dealing with evolution and/or natural selection.

1. Choose a topic from the list below (you may pick your own, but it must be approved by me).
2. Narrow down the topic to a smaller part.
3. Determine a question related to that topic within evolution you wish to address (typically making it a yes or no question will help you, sample questions below)
4. Gather evidence for and against the question
5. Write you paper

Sample questions: [Be creative and use what you are interested in to write your question]
Does the fossil record of whales support evolution?
Does protein similarity put doubt into our understanding of evolution?

Possible Broad Topics:
Fossil record (transitional fossils)
Homology, either fossil or protein
Genetics
Geologic Time
Anatomy (Vestigial Organs)

Possible websites to start with- be careful you know the bias of the website

Against
http://www.intelligentdesign.org/science.php
http://www.answersingenesis.org/home/area/qa.asp (This is strict Creationism)
http://www.scienceagainstevolution.org/newsletters.htm

For
http://www.nps.gov/archive/dino/dinos.htm
http://www.pbs.org/wgbh/evolution/library/index.html
http://evolution.berkeley.edu/evolibrary/search/topicbrowse2.php?topic_id=46

Figure 2. M & M teaching artifact used by Participant 4

Part II. Graph
Using lined paper or an excel document, create a graph that shows the number of M&M's that were found after the hunt. Use the data that was recorded by the class. Attach your graph to this lab when you are done.

Part II Questions

1) How would the graph change if this activity were done in the summer time?

2) What would the results have look like if Black or Brown colored M&M's had been introduced during this activity? What about a regular bag of M&M's?

Figure 3. Type III assessment - Participant 6

Research Question 4: Type and Number of Resources Used

Participants were asked during the interview process what resources they used in development of lessons on biological evolution. Responses were coded according to the type of resource and whether the resource was provided by BETAL, for those that participated in the BETAL evolution education component. Teaching materials were examined for any known resources, which were subsequently coded (Table 12). During the interview process, some participants who had taken part in BETAL had difficulty remembering whether or not they had gotten a resource used from BETAL. In those cases, the resource was compared to a list of known resources provided by BETAL. If the resource was listed or mentioned, the source was coded as being provided by BETAL. For example, Participant 4 provided a lab activity about bird beaks (Figure 4) that was used while teaching biological evolution. This activity was similar to one provided in the BETAL booklet (Appendix D), but the participant wasn't sure where they had gotten the activity. As this activity is a common one found in many sources, the activity was not coded as coming from BETAL, even though it may have.

Table 12. General resources used in teaching biological evolution

Participant	Teacher	Resources Used
Non-BETAL	1	Book for teacher, Websites, book for students
	2	None as participant doesn't teach biological evolution
	5	Websites, article for teacher, articles for students, video, book for students
BETAL	3	Website(BETAL), Video (BETAL), textbook for students, Article for students, Book for teacher, Information provided from a History of Science and Religion class
	4	Video, website, Book for students, Articles for students, Articles for teacher
	6	Book for students, article for students, websites (BETAL and other), Video (BETAL)
	7	Video, Article for students, Book for students(BETAL), Information from a class they took on Evolution

Hide and Go Beak
A Study in Species Competition

This exercise examines the competition among bird species for food in the same ecosystem. You will act as a representative of a species of bird with one particular beak form, and will compete with members of your group to "eat" foods. You will then analyze the information from the class to determine which foods were preferred by which beak forms, and which foods were most popular overall. You will also hypothesize about what might happen if there were changes in the food available

Figure 4. Lab activity description used by BETAL Participant 4

No study participant relied solely on the textbook for teaching materials. The two non-BETAL evolution education participants (1 and 5) used websites and books as resources for their teaching materials. Participant 1 decided the textbook was insufficient. This participant taught in a private Christian school and said the book contained very little concerning biological evolution. In addition, Participant 1 had taken only one class in biology in college and reported feeling less confident regarding biology teaching practices. Because of this, Participant 1 mentioned reading a book entitled, What is Evolution? The participant said the book went through the "current model" of evolution and provided some background information. Unfortunately, the participant could not remember the author of the book. Participant 1 also mentioned using the Internet for pictures, but did not provide any specific web addresses.

Participant 5, on the other hand, reported using the PBS Darwin resources website and showed portions of the PBS evolution movies. This participant was teaching biological evolution in an environmental science class. The textbook used for the class did not cover biological evolution so the participant needed to seek out other resources. Participant 5 also mentioned using articles personally written in the Iowa Science Teachers Journal and excerpts from Rachel Carson books for lessons.

The BETAL evolution education participants all reported using articles for their students to read and discuss. Participant 4 used an article that discusses how the director of science for the Texas Education Agency was forced to resign due to being suspected of being “insufficiently neutral” in the intelligent design and evolution debate. Participant 4 used this article when discussing intelligent design and how it is not science. Participant 6 used articles from Discover magazine and newspaper articles. The articles were focused on providing the students with information about biological evolution and as a basis for discussions in class. Participant 7 mentioned using a book called Voices on Evolution (NCSE, 2008) provided to them in BETAL (Figure 5) to foster discussion as well.

Part II. Graph
Using lined paper or an excel document, create a graph that shows the number of M&M's that were found after the hunt. Use the data that was recorded by the class. Attach your graph to this lab when you are done.

Part II Questions

1) How would the graph change if this activity were done in the summer time?

2) What would the results have look like if Black or Brown colored M&M's had been introduced during this activity? What about a regular bag of M&M's?

Figure 5. Teaching artifact used by BETAL Participant 7

Participants 3 and 6 used a PBS video on Evolution (PBS, 2001) provided to them in BETAL, the same video non-BETAL Participant 5 used. The other two BETAL evolution education participants (4 and 7) used videos as well. Participant 7 used a video on Darwin's voyage in the Galapagos and Participant 4 used a Howard Hughes Medical Institute video (HHMI, 2006) featuring Ken Miller talking to high-school students about evolution.

BETAL Participant 3 claimed their classroom textbook was actually “pretty good” but could not remember the author or publisher, only that it had a lizard eye on the cover. The participant failed to respond to later queries about what textbook they had. Participant 6 used the textbook mainly in the lower level biology class. The other two BETAL participants (4 and 7) mentioned they did not use the textbook much. Both had taken evolution courses while in college and mentioned using information from the courses for their curriculum. In regards to the textbook, Participant 4 said that biological evolution was “there,” but that he didn’t use the textbook much throughout the whole year. Interesting though, is that one of the textbook authors, Ken Miller, was the same Ken Miller in the video Participant 4 used during their unit. Participant 7 used the textbook as a general resource, but mainly relied on other sources.

Nationally Moore and Kraemer (2005) found 90% of the teachers surveyed in 2003 were satisfied with the treatment of biological evolution in their textbooks. Aguillard (1999) found that in Louisiana that 74% of teachers stated that their textbooks contained the right amount of information regarding biological evolution. Participant 3 said the textbook used by the student was “actually pretty good,” but still felt a need to supplement from other sources. Participant 6 did not comment on the textbook other than to say it was used as a resource for the lower level biology class. Participants 4 and 7 stated their textbook was used very little for biological evolution. Without careful analysis of a participant’s textbooks, not much can be concluded about the treatment of biological evolution in those textbooks. BETAL participants may have supplemented their textbooks as a general good teaching practice rather than due to dissatisfaction with how biological evolution was portrayed.

Research Question 5: Connections made to the Nature of Science

During analysis for research question 3, which addressed how groups compared in their coverage of biological evolution, a participant's connections to the nature of science factored into their classification (see Table 13). A major difference between the proactive approach and the teach about controversy approach (Hildebrand et al., 2008) is whether the teacher, while acknowledging the controversy, takes specific steps to include nature of science instruction to illustrate the "special qualities" of science, but doesn't take class time to teach about non-science ideas. All participants who taught biological evolution also included explicit instruction about the nature of science. For the purpose of data analysis, seven NOS-related concepts that were identified as helping reduce resistance to biological evolution education were initially coded for (Clough, 1994; 2006). However, through the coding process only four of the seven NOS-related concepts were identified. Those four were the use of certain language in science, science is falsifiable, stressing functional understanding rather than belief in biological evolution, and science relies on naturalistic explanations.

The use of certain language in science refers to what meaning is attributed to certain words, such as theory and law, in science and how that is different from the meaning attributed by society. That "science is falsifiable" encompasses how science ideas must be testable and subsequently can be altered due to evidence from said tests. However, one piece of evidence does not automatically result in the dismissal of an accepted concept. Stressing functional understanding rather than belief in biological evolution refers to “showing how the theory of evolution works” (Clough, 2006, p. 73). Teachers attempt to increase a student’s understanding of biological evolution, while not directly attacking any alternative beliefs they may hold. The last NOS concept is that science uses naturalistic explanations. This means that while doing science, scientists attempt to understand the world around them using naturalistic explanations. Even though scientists may hold beliefs in deities or supernatural events, they do not employ those beliefs when doing science (Clough, 2006).

Table 13. Participants’ NOS connections

Participant	Teacher	NOS ideas
Non-BETAL	1	Use of language in science; Science is falsifiable
	2	Not applicable; participant doesn’t teach biological evolution
	5	Use of language in science; Functional understanding rather than belief; science uses naturalistic explanations
BETAL	3	Functional understanding, rather than belief (Science uses naturalistic explanations)
	4	Functional understanding, rather than belief; Science is falsifiable (Science uses naturalistic explanations)
	6	Use of language in science; Functional understanding, rather than belief
	7	Use of language in science; Functional understanding, rather than belief

The two non-BETAL evolution education participants that teach biological evolution, both focused on the use of language in science (Table 13). Participant 1 used NOS instruction in regards to the meaning of theory and model throughout the teaching of biological evolution. Participant 1 focused on presenting biological evolution as a model that scientists use and then spent time discussing the terms, theory and law (Figure 5). Participant 1 described theories as explanations of science concepts and laws were described as being “rules of nature - like what goes up, must come down.” Participant 1 also listed a discussion topic about scientific models; how such models should represent evidence and are subject to revision.

Participant 5 emphasized the difference between natural and supernatural explanations, while addressing the use of language in science. To address the differences between naturalistic and supernatural explanations, Participant 5 reported using a black box tube activity early in the school year. This activity was reportedly brought up again prior to addressing biological evolution topics and touched on throughout the unit. However, Participant 5 did not provide teaching artifacts to support self-report data. BETAL Participants 3 and 4 may have also touched on the concept that science uses naturalistic explanations. Both participants mentioned discussing intelligent design with the purpose of showing how it is not science. Since neither of them provided artifacts that showed they addressed naturalistic explanations or mentioned naturalistic explanations during the interview, the NOS concept was not coded.

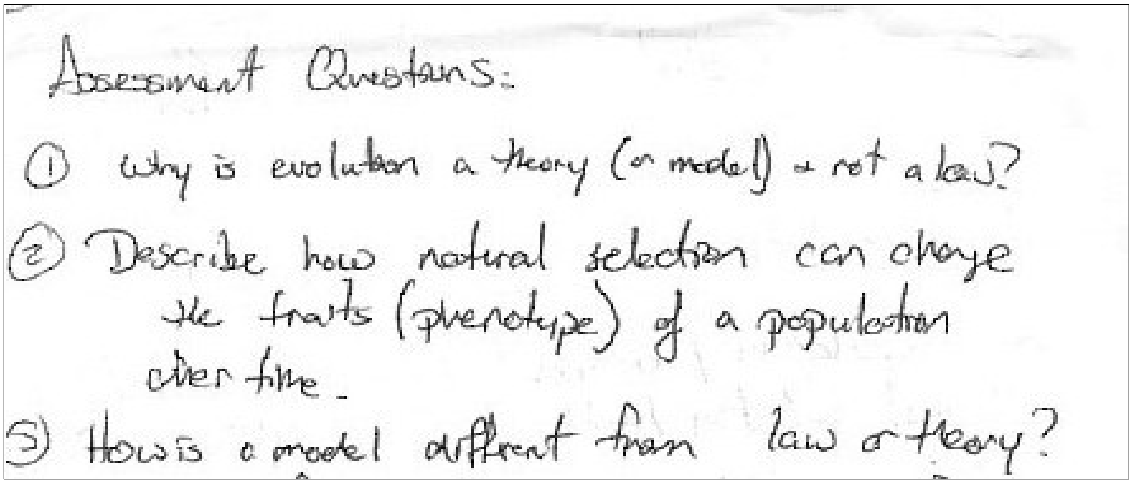

Assessment Questions:
① Why is evolution a theory (or model) & not a law?
② Describe how natural selection can change the traits (phenotype) of a population over time.
③ How is a model different from law or theory?

Figure 6. Questions on theory, model, law used by non-BETAL Participant 1

When looking at the BETAL evolution education group, Participants 3, 4, and 7 mentioned in their interviews that they tried increasing their students' understanding of biological evolution rather than changing the beliefs of their students. These three BETAL evolution education participants, during the interview, mentioned telling their students that they didn't want to change the students' beliefs.

> *I work hard to make students comfortable and reiterate that while this may challenge their religious beliefs, it doesn't have to, and I don't have any interest in crushing their beliefs.* (Participant 3)

> *I tell my students 'I don't want to change your beliefs, I want to give you an understanding of evolution' and I want to show them how biology couldn't exist without it.* (Participant 7)

> *I show a video where Ken Miller comes out and says it's not a battle with religion. I tell my students it's okay to keep their beliefs, but they need to understand evolution for the class.* (Participant 4)

Participant 6 also stated that, *"In the end, I wasn't out to change anyone's perspective (beliefs), I was out to teach them understanding of what is meant when* *certain things are said and to understand bias."* Participant 6 focused on the students learning to interpret information themselves. Discussions were held about various evidence, during which students were asked to leave religion out of the discussions, but rather focus on interpretation of evidence. Participant 6 explained she took this approach to help her students understand the public "controversy surrounding biological evolution as well as the basic arguments behind all sides of the fence." While this approach may be problematic due to students' abilities to interpret evidence or not, the participant aimed to increase students' understanding of biological evolution rather than using their personal beliefs.

Participants 6 and 7 addressed the usage of language in science. Participant 6 reported that class discussions were held specifically to address the differences in the use of the word "theory" in society and science.

> *Beyond that, it is a very hot topic in the media right now and my goal in teaching it is to inform them, so when they read a newspaper article they will have a clear understanding of what is meant and how to properly define and evaluate the information given.*

Participant 7 also mentioned focusing on discussing evolutionary theory and what a theory means in science. Participant 7 provided a teaching artifact that was a printout of PowerPoint slides. One slide gives three definitions: *"evolution: change over time", "theory: well supported explanation about the physical world", and "Evolutionary theory: a well supported explanation of how life has changed over time,"*

Participant 4 touched on the NOS idea that science is falsifiable. Participant 4 provided a PowerPoint presentation discussing how the ideas of biological evolution changed over time and influenced other scientists' thinking (Figure 6). Participant 4 reported that they tried to incorporate the history of science as much as possible, especially during the evolution unit. When asked what history they incorporated, Participant 4 reported discussing the ideas of scientists such as Lamarck and Wallace. These ideas were presented to "show what scientists thought before Darwin's ideas of natural selection were developed". The only teaching artifact that showed any history of science were slides from a PowerPoint presentation (Figures 7a and 7b).

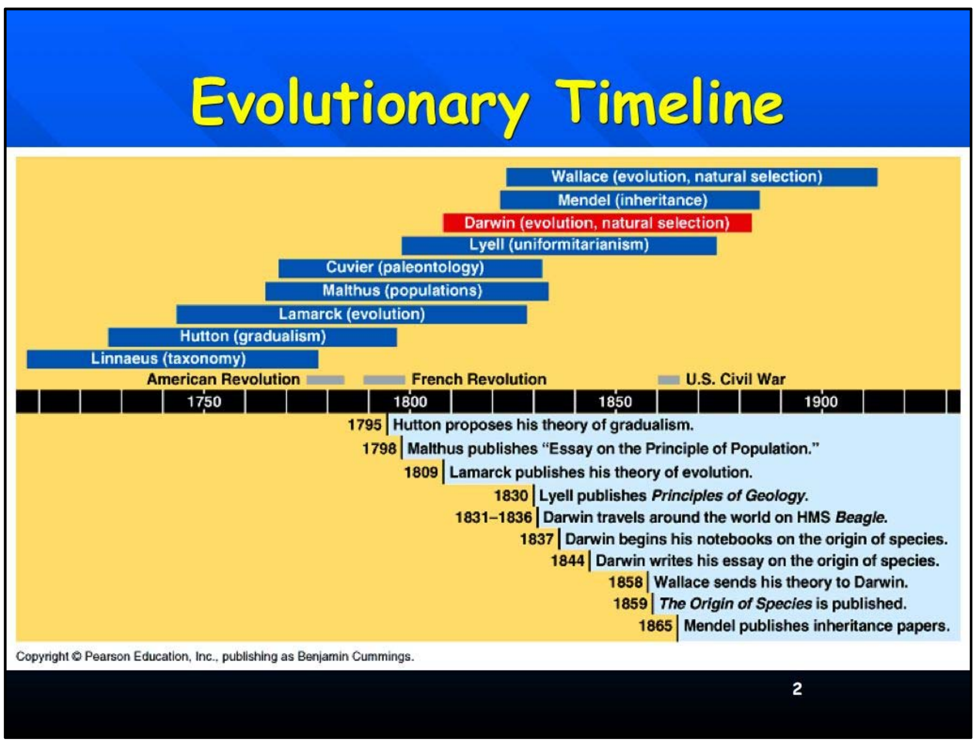


Figure 7a. PowerPoint excerpt 1 used by BETAL Participant 4

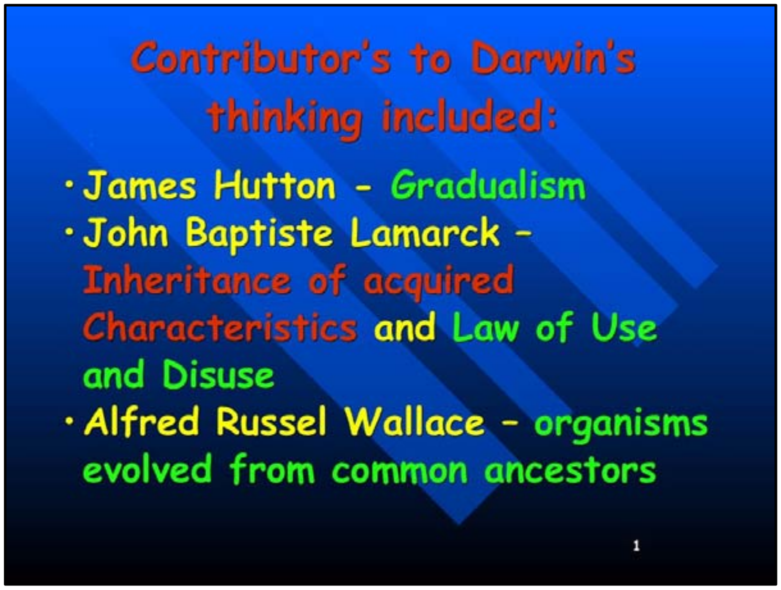


Figure 7b. PowerPoint excerpt 2 used by BETAL Participant 4

Nationally, what can be said about teachers' connections to nature of science and biological evolution teaching? Considerable evidence indicates that teachers, themselves, hold misconceptions about the nature of science (Abd-El-Khalick & Lederman, 2000; Eve & Dunn, 1990; Ryan & Aikenhead, 1992). When teachers make the choice not to teach biological evolution they are showing misconceptions regarding the importance of scientific theories. Scientific theories, especially biological evolution, provide frameworks for continued research in their fields (Clough, 2006). When teachers choose not to teach biological evolution for whatever reason, lack of background knowledge, outside pressure against it, or personal beliefs (Moore, 2009), they are denying students the ability to form a deep understanding of biology concepts.

When Moore and Kraemer (2005) surveyed teachers in 2003 they asked “Do you think that creationism has a valid scientific foundation?” The results showed 22% of participants chose “yes” responses. This illustrates the misconception that science and scientists can use supernatural ideas or deities to answer scientific questions. The same misconception can be held by science teachers who include instruction on non-science ideas. Studies (Bilica and Skoog, 2004; Moore and Kraemer, 2005; Berkman et al., 2008) continue to find teachers teaching non-science ideas such as intelligent design, which supports the idea that many teachers hold misconceptions about the nature of science. In a public science classroom, instruction on creationism is unconstitutional (Moore, 2007). While some of the teachers may be teaching these alternative ideas, intending to demonstrate their ineffectiveness or show what science is and what it is not (Moore, 2009), some teachers are teaching them as scientifically viable alternatives to biological evolution.

CHAPTER 5. DISCUSSION AND CONCLUSIONS

This study looked at the biological evolution teaching practices of seven Iowa State University secondary science education graduates. Four of the participants took part in the second semester of the Biology Education Teaching and Learning (BETAL) learning community and three participants did not. The second semester of BETAL set out to help its participants with the task of teaching biological education in the K-12 school system. The study was conducted to ascertain whether any differences in teaching practices existed among the four who did participate in evolution education BETAL experience and the three who did not participate in that experience. Five research questions framed the comparison regarding specific aspects of biological evolution teaching.

BETAL

The BETAL learning community seminar was first offered in Fall 2002. Over the years, the number of BETAL participants grew, as did the number of staff involved. During the five years BETAL met, approximately 121 students participated (Table 14). Taking part in the BETAL learning community was voluntary, and the seminar was directed primarily towards pre-service secondary biology teachers. However, students from other science disciplines often registered for BETAL. The BETAL learning community experiences were beyond that required of students in the secondary science teacher education program, yet they were linked to expectations and experiences in that program.

Table 14. Number of BETAL students per semester

Semester	Participants
Fall 2007	16
Spring 2007	11
Fall 2006	13
Spring 2006	11
Fall 2005	16
Spring 2005	7
Fall 2004	15
Spring 2004	~6
Fall 2003	10
Spring 2003	~10
Fall 2002	~6
Total	~121

The secondary science teacher education program these students participated in is very different from typical secondary science teacher education programs. All students completed a three credit “Nature of Science and Science Education” course that explicitly addressed the important of the nature of science in teaching biological evolution. Moreover, addressing the NOS in lesson plans and other aspects of teaching was conveyed and expected in the multiple science methods courses in the program. This means that students who participated in BETAL had multiple experiences regarding the value of the NOS for teaching, including addressing biological evolution. Faculty involved in both the secondary science teacher education program and BETAL were clearly dedicated to promoting the teaching of biological evolution. Thus, the biological evolution teaching practices of BETAL evolution education participants in this study cannot be attributed solely to the evolution education experiences in BETAL. That said, some interesting, yet tentative, conclusions may be stated about BETAL evolution education participants in this study compared to those who did not take part in the BETAL evolution education experiences.

Discussion and Conclusions Based on the Research Questions

Research Question 1: Amount of Time spent Teaching Biological Evolution

When comparing BETAL to non-BETAL evolution education participants, BETAL evolution education participants appear, on average, to devote more time to teaching biological evolution. The average amount of time BETAL evolution education participants spent teaching biological evolution is also higher than that reported in national data. Aguillard (1999) found that only 16% of Louisiana teachers surveyed allocated more than 7.5 class periods to teaching biological evolution concepts, where as all BETAL evolution education participants reported spending more than 7 class periods on biological evolution concepts. Moore and Kraemer (2005) found that 56% of Minnesota teachers surveyed devoted six or more hours to biological evolution concepts. BETAL participants spent from 7.5 to 22.5 hours on biological evolution concepts. However, not all BETAL evolution education participants provided enough teaching artifacts to verify their self-reported time spent teaching biological evolution. This could mean two of the four BETAL participants over-reported the amount of time they spend. However, even when comparing

BETAL evolution education participants with other studies using self-report data (Berkman et al., 2008; Moore and Kraemer, 2005; Aguillard, 1999), BETAL evolution education participants are spending as much and probably more time teaching biological evolution.

Research Question 2: How do these different groups compare on how they cover the concept of biological evolution?

When looking at the categories used for classifying participant's teaching approaches to biological evolution, a spectrum can be created with avoidant as one end and the pro-active (Hildebrand et al., 2008) as the other. BETAL was trying to promote an approach to teaching biological evolution that emphasized "nature of science" instruction. When looking at the study participants, BETAL evolution education students tended to fall closer to the proactive approach end and non-BETAL evolution education participants were closer to the avoidant end of the spectrum (with the exception of Participant 5).

Nationally, instruction on biological evolution varies widely. Moore (2005, 2007, 2009) has continually found teachers in Minnesota that are including instruction on non-science ideas such as creationism. In addition, there are still biology teachers that are not teaching biological evolution at all (Bandoli, 2008; Moore, 2007; Weld & McNew, 1999). Even among those who do address biological evolution, the time spent on biological evolution varies widely (Berkman et al., 2008), as does the depth of coverage. Considering the public's unfounded skepticism and frequent hostility regarding biological evolution (Newport, 2009; 2006), many biology teachers may simply be avoiding offending students, parents, and the larger community.

In contrast, all four BETAL evolution education students appear to devote significant time teaching biological evolution. Two of the four BETAL students did include teaching on non-science topics, but the instruction was geared towards discounting intelligent design as a scientific alternative to biological evolution. This inclusion of intelligent design may be due to BETAL faculty focusing on ID to help participants understand the recent battles around the inclusion of ID into science curriculum and why it should not be included.

Research Question 3: How do these different groups compare on how they assess the concept of biological evolution?

When looking at assessment techniques of both groups, many similarities were found. Both groups tended to ask more Type I and Type II questions. Type I questions are simple recall style questions such as vocabulary. Type II questions tend to take more thought on the part of the student. These questions would be “compare and contrast” type of questions or short answer questions. Type III questions are those questions that go beyond what is taught explicitly in the classroom. They would be application style questions that require students to apply their knowledge to new situations. Non-BETAL evolution education students did not provide any examples of Type III questions with their teaching artifacts. Three of the four BETAL evolution education participants had Type III assessments, but the overwhelming majority of assessments were Type I and II. Due to the low return of teaching artifacts, it’s not possible to say whether there was a difference between the two groups regarding how they assessed evolution or not. Considering that both groups experienced the same methods courses and general teacher prep program, a difference between the two groups' methods of assessing wouldn't be expected. In addition, the findings do seem to be consistent with assessment techniques in general.

Marzano (2006) pointed out that teachers most often use Type I and Type II assessments. Type III assessments are often more difficult to create and more difficult for the students, so they are avoided by teachers. That BETAL participants had Type III assessments may be more a factor of the science teacher education program than BETAL itself. However, that BETAL students found biological evolution an important topic to assess in multiple ways is positive.

Research Question 4: How do these different groups compare on the type and amount of resources used in teaching the concept of biological evolution?

All participants who taught biological evolution mentioned using resources other than or in addition to, the textbook for biological evolution. For example, BETAL evolution education Participant 7 used information gained from a course taken in college about biological evolution to create lessons and used the textbook very little. One of BETAL's aims was to support its participants by providing evolution education resources for use in the classroom. During the evolution education segment (Appendix C), BETAL faculty demonstrated activities that could be used in the K-12 classroom. Three of the four BETAL evolution education students said they used resources provided to them in BETAL, whereas one participant did not, saying he/she pulled information from prior coursework in evolution. There were no notable differences in the type of resources used by non-BETAL and BETAL evolution education participants.

Nationally, science teachers generally appear satisfied with their textbooks' treatment of biological evolution (Aguillard, 1999; Moore & Kraemer, 2005). In this study, 50% (2 out of 4) of the BETAL evolution education participants said their textbooks were good, although all four still supplemented and pulled resources from elsewhere. This more likely reflects the participants' pre-service teaching program's influence, rather than a dislike of the textbooks' treatment of biological evolution.

Research Question 5: How do these different groups compare in the connections made to the nature of science and biological evolution?

When looking at the nature of science concepts that the BETAL evolution education participants reported addressing, only one concept was common among the whole group. The NOS approach of stressing functional understanding for students rather than belief was mentioned by all BETAL participants. However, while this approach is thought to reduce students' resistance (Clough, 1994; 2006) to biological evolution education, it is by no means adequate enough on its own. BETAL evolution education participants 4, 6, and 7 reported instruction on other NOS concepts as well, but no participant reported teaching more than three.

Perhaps the BETAL participants under-reported their explicit NOS instruction in regards to teaching biological evolution or, perhaps like many teachers (Clough, 2006), the participants were "neglecting" the importance of NOS to effective science teaching. Although participants in both groups focused on the usage of certain words, such as theory and law, in science. non-BETAL Participant 5 was the only participant who described explicitly focusing on how science relies on naturalistic explanations – a crucial consideration for why creationism is not science.

Participants 3 and 4 may have addressed the same topic implicitly, but naturalistic explanations were not mentioned explicitly during the interview nor in any of the teaching artifacts. Because both non-BETAL and BETAL evolution education participants took a separate nature of science course, both groups received extensive instruction on the crucial nature of methodological naturalism in science. Perhaps the participants did explicitly and correctly address the nature of science, but did not connect that teaching with their teaching of biological evolution. The approach BETAL evolution education took in teaching its students to include biological evolution stressed functional understanding rather than belief. This same approach was taken with all science ideas. That is, for *all* science concepts, evidence, reasoning, and understanding were the objectives – not belief. “Belief” was a word that BETAL faculty thought best reserved for religion. BETAL evolution education also did not set out to change its students’ religious beliefs, but rather increase their understanding of biological evolution and its place in biology curriculum.

On its own, explicit nature of science instruction has been a topic of numerous studies. Overwhelmingly, explicit nature of science instruction is recommended (Khishfe & Lederman 2006). BETAL promoted using explicit nature of science instruction to reduce the education controversy for its participants’ future students. In hindsight, it would have been more advantageous to ask participants what nature of science topics they incorporated throughout the year leading up to and during their units on biological evolution rather than just focusing on during them. Nationwide, nature of science instruction can be troublesome due to teacher misconceptions and lack of nature of science training in pre-service teacher education programs (Abd-El-Khalick, 2000). If teachers hold misconceptions regarding the nature of science, they will often inadvertently pass these on to their students. That said, it is encouraging to see BETAL students using nature of science instruction in regards to their biological evolution teaching practices.

Limitations

This study was limited to the perceptions of seven practicing teachers of biology who participated or did not participate in the BETAL seminar, which addressed topics surrounding evolutionary biology, conducted at Iowa State University from Fall 2002 – Spring 2007. The study also addressed issues faced nationally by biology teachers about the teaching of biological evolution. The findings of this study support national findings, yet they may not be applicable to all BETAL participants due to the small sample size. Findings reported here are limited due to the low inclusion of teaching artifacts to support self-report data gathered during the interviews.

The lack of teaching artifacts and classroom observations raises concerns regarding the validity of findings. Relying on self-report data from the interviews can be troubling, as self-report data is inherently biased. This bias can be lessened by using a variety of data sources to triangulate findings (Maxwell, 2004). Assumptions were made that the participants answered questions in a way that accurately reflected their teaching practices. However, answers to interview questions may reflect quick responses rather than deep thought. Since the study addresses a controversial topic, participants may have felt compelled to present a certain image rather than to reflect honestly on their teaching practices (Adler and Clark, 2008). The teaching artifacts were necessary as a source of data that could be used to support or deny participant's interview answers. Because participants either did not provide teaching artifacts at all or did not provide all their teaching artifacts, data triangulation was difficult. This means this study relied on self-report data for the majority of its findings. Due to this and the small number of study participants, the findings of this research lack generalizability (Maxwell, 2004).

Another limitation is that participants had other classes in common, such as a nature of science course and science teaching methods taken in their secondary science teacher education program. Thus, the results found in this study could be due to a combination of effects from the other classes rather than solely from their BETAL evolution education experiences. However, an important part of the BETAL learning community was providing participants with a forum for discussing the teaching of biological evolution and increasing their awareness of the issue. Without this direct challenge to the students' ways of thinking, the tools gained from the other common classes might not have been applied to the topic of biological evolution.

Due to the small sample size, findings may not be reflective of the entire BETAL evolution education population. The researcher was only able to capture a small snapshot of the possible affect of the BETAL evolution education learning community upon its participants. With limited access to participants, this limitation was unavoidable. However, even though the snapshot is small, the findings are encouraging.

Findings are also limited because of the publicly controversial nature of biological evolution education. The participant’s own thoughts and ideas about the topic interfered with what they took away from the BETAL evolution education learning community. In addition, the results of that learning community would be different had it focused on non-controversial science topic. Thus, the findings lack generalizability to all science topics.

Conclusions

Although the sample was small, that all BETAL evolution education participants taught biological evolution is encouraging. While the percentage of science teachers that are teaching biological evolution is potentially on the rise (Moore & Kraemer, 2005), it is still not where it should be for such a unifying concept. While BETAL evolution education participants faced opposition to teaching biological evolution (e.g., students’ resistance, parent comments, and other teachers’ opinions), the BETAL evolution education participants continue to teach biological evolution despite the opposition. National data suggests that these social factors are an important cause in how and whether or not teachers teach biological evolution (Bowman, 2008). BETAL evolution education participants reportedly spent more time overall teaching biological evolution and also included ties to important nature of science topics while doing so.

However, that not one BETAL evolution education study participant was teaching biological evolution in a manner that entirely reflected that promoted in the learning community is noteworthy. Perhaps the teaching of biological evolution is so steeped in education controversy that pre-service teachers can never have enough preparation to face it. The BETAL evolution education experience seems to have made a positive impact in the teaching practices of its students, but clearly further effort and research is required to move the teaching of biological evolution where it needs to be.

Recommendations for Further Research

Further research is needed in at least two different areas related to this study. One recommendation would be studying how teachers' biological evolution teaching practices change as the time from graduation increases. Perhaps school climates that encourage or discourage the teaching of biological evolution year after year impact the teaching decisions and practices associated with biological evolution. Two out of the three participants that demonstrated teaching practices more in line with what BETAL promoted had graduated the year prior to the study; the third had the most teaching experience of the two groups.

Another recommendation for research would be to compare teaching practices of those who have taken a nature of science course with those who have not. There is much literature (Abd-El-Khalick, 2000; Clough, 1994,; 2006; Hildebrand et al., 2008; McComas, 2008; Scharmann, 1993) that mentions the importance of accurately portraying the nature of science in science curriculum. Considering how much of the controversy surrounding the teaching of biological evolution comes from misconceptions about the nature of science, NOS instruction seems to be a key component to improved biological education teaching practices. Because the two groups both participated in a separate nature of science course, the findings reported here may be due primarily to nature of science instruction.

More research is needed in comparing the pre-service teaching preparation of biology teachers. In addition to the nature of science course completed by all participants, two participants had completed a separate college course on biological evolution. A few participants were M.A.T. (Masters) students and others only held a bachelor’s degree. While some studies (Moore, 2004) have mentioned teacher preparation, a comprehensive comparison is needed.

In addition, any further research in this area of study should include classroom observation of the teachers during the teaching of biological evolution. One significant limitation with this study, and many of the national studies, was the reliance on self-report data. Most of the national studies use survey data obtained from teachers and/or students. By actually going into the classrooms and observing the teaching of biological evolution, researchers can gain a clearer picture of the current state of biological evolution education.

APPENDIX A. SEMI-STRUCTURED INTERVIEW QUESTIONS

Note: Various demographic questions such as degrees attained, date degrees earned, and where currently teaching were asked.

How many years have you taught biology and/or life science? How many sections of biology/life science have you taught?

Have you taken any courses/workshops/presentations/etc. on how to teach biological evolution concepts? If so, when, where, how many, etc.

What certain things did you take away from those courses/workshops/presentations/etc?

To what extent did BETAL (or other experiences) make a difference in your teaching of biological evolution?

What resources do you use to develop your lessons and assessments on biological evolution concepts?

What time of the school year do you typically introduce biological evolution concepts? What are the pros and cons to doing it that way?

How long do you typically spend on biological evolution concepts?

What supports and/or constraints do you feel exist in your building regarding the teaching of biological evolution concepts?

What difficulties have you faced when teaching biological evolution concepts from students, parents, fellow teachers, and/or administrators?

Do you feel it is important to teach biological evolution concepts in your class? Why/Why not?

To what degree are you satisfied/dissatisfied with how you currently are teaching biological evolution concepts? What are you satisfied/dissatisfied with? Why?

To what extent did you attempt to reduce the unease or resistance among students toward biological evolution education? How did you go about this?

APPENDIX B. SAMPLE OF FALL SEMESTER BETAL SYLLABUS

BETAL
Fall 2007

Bio 495: Issues in Secondary Biology Teaching
Syllabus

Meeting Time: 4:10 – 5:00 PM Mondays, Room N127 Lago

Date:	
Aug 20	Recruitment of BETAL Students from CI 418/518
Aug 27	Introduction to BETAL (Colbert)
Sep 3	NO CLASS (Labor Day)
Sep 10	Service-Learning: What is it and how do you do it?* (Colbert)
Sep 17	Organizing and executing successful field trips.* (Olson)
Sep 24	Teaching Biotechnology on Shoestring (Zeller)
Oct 1	Professional Societies focused on teaching science – the importance and value of such participation. (Clough, Olson, Zeller)
Oct 8	Discussion of service-learning and field trip experiences (Colbert, Olson)
Oct 15	NO CLASS – Iowa Science Teachers Fall Conference** (Hix – Thursday 18 October)
Oct 22	Discussion of Iowa Science Teachers Conference experience (Colbert)
Oct 29	Iowa school organization and administration (Clough, Olson, Zeller)
Nov 5	Discussion with practicing teachers (organized by Clough)
Nov 12	Discussion with practicing teachers (organized by Clough)
Nov 19	NO CLASS (Thanksgiving Break)
Nov 26	Bio 495 Evaluations due. Handout teacher start-up kits***
Dec 3	NO CLASS due to service-learning/field trip requirements

* Passing this class will require that you participate in either a service-learning activity or a field trip activity and write a reflection about your participation. You are (strongly) encouraged, but not required, to participate in both types of activities.

APPENDIX C. SAMPLE OF SPRING SEMESTER BETAL SYLLABUS

Biology 495 Syllabus

Date	Topic	Reading Material
Jan 8	Introduction (Colbert)	
Jan 15	MLK Day	

Unit 1 – Teaching Evolution – A Challenging Issue in Biology

Jan 22	Where we're starting from	Questions (below)
Jan 29	In the beginning… (Colbert)	Pigliucci, pg. 6-53; Science and Creationism
Feb 5	Natural Selection Activity (Hix)	Teaching About Evolution and Natural Selection
Feb 12	Creationist Fallacies (Colbert)	Pigliucci, pg. 72-80; 158-188
Feb 19	Intelligent Design (Colbert)	Pigliucci, pg 53-72
Feb 26	Dover and beyond (Colbert)	Resource Booklet

Unit 2 Teaching Challenging Issues in other Natural Sciences

Mar 5	Issues in Chemistry (Greenbowe)
Mar 12	**Spring Break**
Mar 19	Issues in Geology (Cervato)
Mar 26	Issues in Geology (Cervato)
Apr 2	Issues in Chemistry (Greenbowe)
Apr 9	Issues in Physics (Ogilive)
Apr 16	Issues in Physics (Ogilive)
Apr 23	Celebration and Start-up Kits

Questions for 22 January:

Please come to class on 22 January 2006 prepared to discuss the following questions:

1) What was your pre-college experience regarding learning evolutionary theory?
2) How has your college-level experience built on your understanding of evolutionary theory?
3) What would you predict as the percentage of your future students who would agree with the following statement:

   "God created human beings pretty much in their present form at one time within the last 10,000 years or so".

4) What concerns, if any, do you have about teaching evolution?

APPENDIX D. SAMPLE OF BETAL RESOURCES

Table of Contents from BETAL Booklet

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