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# Will I Teach Evolution?

## A Multiple Case Study of Prospective Biology Teachers

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## Abstract

The purpose of this multiple case study was to examine the impact of a biology-focused science methods course on prospective teachers' preparedness to teach evolution and to explore factors that influence their intentions to teach evolution. The researchers sought to understand the interplay between prospective teachers' personal and contextual issues (including acceptance of evolution and views of the nature of science) on their anticipated plans for teaching evolution. Participants included 3 female and 2 male students. Data collection utilized *VNOS-C* questionnaire, *Measure of Acceptance of Evolution* instrument, semi-structured interviews, and instructor and student journals. Profiles were created for each participant, and analyzed to identify cross-case themes. Findings indicate the development of prospective teachers' instructional plans for teaching evolution was mediated by their views of the nature of science and their understanding of evolution. As a result of course activities, there was a shift in the nature of prospective teachers' concerns about teaching evolution; however, although each of the prospective teachers personally accepted the theory of evolution, concerns about their future students', parents', and colleagues' acceptance of evolution played a significant role in their decision whether to teach evolution in their future classrooms.

## Introduction

Charles Darwin's theory of evolution by natural selection is considered one of the greatest scientific contributions of the nineteenth century (Bronowski, 1973). Despite its role as the foundation of modern biology, evolution is not widely understood and accepted by the general public. In a 2004 Gallup poll, 45% of the general public agreed with the statement, "God created man pretty much in his present form at one time within the last 10,000 years" (Newport, 2004).

Public schools have been placed in the center of the creation-evolution debate as special interest groups attempt to influence science curriculum. In 2003 and 2005, legislative bills were introduced in Missouri mandating the teaching of Intelligent Design. In 2004, an evolution disclaimer provision was added to a bill governing textbook purchases in Oklahoma, while Ohio's Board of Education approved a lesson plan, "Critical Analysis of Evolution." More recently in Dover, PA, it required a District Court judge to overrule the Dover Public School Board's mandated policy requiring the teaching of intelligent design as part of the biology curriculum. Consequently, "biology teachers face the demanding challenge of crafting a learning environment that mediates colliding agendas" (Meadows, Doster, & Jackson, 2000).

What effect does this controversy have on prospective biology teachers? Do they feel prepared to teach evolution in this politically charged environment? Science teacher educators play a critical role in the preparation of high school biology teachers. This case study of 5 prospective biology teachers examined the effect of a secondary science methods course that was designed specifically to address issues related to teaching evolution. The study explored the prospective teachers' views of the nature of science, acceptance of the theory of evolution, as well as their concerns and future plans regarding teaching evolution.

## Theoretical Framework

Prospective teachers' beliefs about teaching are well established prior to entering teacher education programs (Pajares, 1992). Many of these beliefs are formed during the prospective teacher's K-12 classroom experiences (Ball & McDiarmid, 1996). These beliefs are important to consider because teacher beliefs have been show to "play a major role in defining teaching tasks and organizing the knowledge and information relevant to those tasks" (Nespor, 1987, p. 324). Nespor proposed that beliefs play such an influential role in teaching because "the contexts and environments within which teacher work, and many of the problems they encounter, are ill-defined and deeply entangled, and that beliefs are peculiarly suited for making sense of such contexts" (p. 324). For high school biology teachers, evolution teaching may represent one of the most deeply entangled problems they will encounter.

We draw on both the teacher belief and teacher knowledge literature. Shulman (1986) proposed a professional knowledge base for teaching and identified teachers' subject matter knowledge as the missing paradigm in educational research. In defining subject matter knowledge, Shulman drew on Joseph Schwab's definition that includes knowledge of both the substantive and syntactic structures of a discipline. Shulman proposed pedagogical content knowledge (PCK) as a component of this knowledge base, defining it as "what goes beyond knowledge of subject matter per se to the dimension of subject matter for *teaching*" (p. 203). Based on her work with Shulman, Grossman (1990) proposed a model of teacher knowledge that included the following components: knowledge of subject matter, pedagogical knowledge, knowledge about context and pedagogical content knowledge. Magnusson, Krajcik and Borko (1999) expanded on this model

to develop a model of PCK for science teaching with the following components: orientations for teaching science; knowledge of science curricula; knowledge of students' understandings of science; knowledge of instructional strategies; and knowledge of assessment of scientific literacy. We find both of these models to be useful heuristics for conceptualizing a professional knowledge base for teaching. Additionally, we draw on a situative perspective of learning, which views learning as "(a) situated in particular physical and social contexts; (b) social in nature; and (c) distributed across the individual, other persons, and tools" (Putnam & Borko, 2000, p. 4). Using this perspective, the context in which teacher learning is situated becomes an important factor to consider. In this study, we examine the prospective teachers' learning within a secondary science methods course.

## Review of the Literature

What is the current status of evolution teaching and learning in the United States? Unfortunately, many biology teachers are not teaching evolution. Separate studies conducted in Minnesota and Indiana indicated that 40% of biology teachers spend little or no time teaching evolution (Moore, 2004). Because such a large percentage of teachers avoid teaching evolution, many students are never exposed to this scientific theory. This is evidenced in a 2004 Gallup poll that surveyed teen-agers (age 13-17) about Darwin's theory of evolution. The results indicated that 30% of the teens thought that evolution was just one of many theories and was not well supported by evidence, while 33% of the teens said they didn't know enough about evolution to say if it was well supported by evidence or not (Mason, 2005). The results are alarming because it indicates that close to two-thirds of American teen-agers do not understand the importance of the theory of evolution.

Why do so many biology teachers avoid teaching evolution? Griffith and Brem (2004) found that biology teachers decide not to teach evolution as a coping strategy to avoid the many stressors associated with evolution teaching. Internal stress occurs when teachers' personal beliefs conflict with the theory of evolution (Meadows, Doster & Jackson, 2000; Moore, 2000). A significant number of teachers hold creationist views as evidenced in the number of teachers who believe creationism should be taught in public schools: 39% of teachers in Ohio, Pennsylvania, and South Dakota; and 30% of teachers in Georgia (Osif, 1997). A second type of stress, situational stress, involves conflicts with students, parents and other teachers about evolution teaching (Griffith & Brem, 2004). This source of stress was confirmed in an informal survey of science teachers conducted by National Science Teachers Association (NSTA) in March, 2004. Of the 1,050 respondents, 31% felt pressured to include creationism, intelligent design, or other nonscientific alternatives to evolution in their science classroom (NSTA, 2004). When asked to identify the source of the pressure, teachers indicated students (22%) and parents (20%) as the primary sources. Thirty percent of the respondents felt that they were pushed to de-emphasize or omit evolution and cited students and parents (18% each) as the source of this pressure. Griffith and Brem (2004) identified a third stressor, external stressors connected to school administrator and community pressures to eliminate evolution teaching.

Knowledge of the legal history of biology education in the United States provides teachers with a strong defense against these external stressors. The U. S. courts have consistently supported the teaching of evolution and rejected the teaching of creationism in public school science classrooms. Unfortunately, not all biology teachers are familiar with this legal history. A survey of biology teachers in Minnesota indicated that 27% of the teachers thought that they may lawfully give equal time to creationism when teaching evolution. Only 41% of the surveyed

teachers knew that the courts had evaluated creation science and found it lacking in scientific merits. Twenty-nine percent of the teachers thought it was still a crime to teach evolution in some areas of the country (Moore, 2004). Moore recommends that prospective teachers become familiar with the legal history of evolution education in the United States as well as the position statements of professional science organizations, as both are important resources for resisting pressures to teach non-scientific alternatives to evolution. However, policy may in some cases indirectly contribute to teachers' decisions not to teach evolution. For example, public opinion has influenced state-level policies with some states choosing to omit evolution-related items from their state assessments. "Since evolution is not included on the exam, and because resources (including teachers' salaries) are often linked to scores on the exams, many teachers do not teach about evolution" (Moore, 2000, p. 18). A lack of accountability, as measured by state assessments, allows teachers in some states to choose not to teach evolution.

Additionally, teachers may lack sufficient subject matter knowledge to teach evolution effectively (Crawford, Zembal-Saul, Munford, & Friedrichsen, 2005; Griffith & Brem, 2004). In a survey of Indiana high school biology teachers, only 39% of the respondents had completed a course in evolution (Donnelly, 2006). Teachers' lack of understanding of the nature of science (NOS) is another consideration. For example, Rutledge and Warden (2000) found a strong positive correlation between high school biology teachers' understanding of evolutionary theory, understanding of the nature of science, and their acceptance of evolutionary theory. Without an understanding of the nature of science, biology teachers may fail to understand the role of theories in science (Farber, 2003). A survey of Oklahoma life science teachers found that only 57% of respondents viewed evolution to be a unifying theme in biology (Weld, 1999). Results of the survey indicated there was a positive correlation between coursework in nature or philosophy of science and the attitude of evolution as a unifying theme.

Researchers argue that "[s]cience teachers without more complex understanding of NOS will likely lack the pedagogical content knowledge required to teach evolution for scientific understanding" (Eick, 2000, p.1). However, research conducted over the past several decades has consistently indicated teachers lack views of NOS consistent with the reforms (see, for example, Abd-El-Khalick & Lederman, 2000). Teacher education programs have met with limited success in addressing this problem, in part because their efforts have often been focused on single semester interventions in pedagogy courses. This poses a significant challenge in impacting views that are tightly held and resistant to change, as well as in promoting retention of improved views (Akerson, Morrison, & Roth-McDuffie, 2006). Researchers have found that with proper attention to NOS, content courses can serve as a fruitful venue for enhancing learners' views (Brickhouse, Dagher, Letts, & Shipman, 2000). Thus, the biology courses in which teachers learn evolution, as well as the pedagogy courses in which they learn to teach evolution, can be powerful sources of their PCK.

## Purpose of the Study

As future science teachers prepare to enter the teaching profession, they will undoubtedly face a host of issues and challenges in deciding whether they will teach evolution. Science teacher educators play a critical role in preparing prospective teachers to teach evolution (Good, et al., 1992). Based on recommendations in the literature, the first author re-designed her secondary science methods course to address issues and concerns related to teaching evolution. The course

included attention to the nature of science; confronted prospective teachers' misconceptions related to natural selection; provided information on legal aspects of teaching evolution; familiarized prospective teachers with science professional organization's position statements; engaged prospective teachers, as learners, with an inquiry-based, natural selection software; and highlighted a variety of additional evolution teaching resources.

The purpose of this study was to examine the impact of the science methods course on prospective teachers' preparedness to teach evolution and to gain a better understanding of the factors that influenced their intentions to teach evolution. The study included a focus on prospective teachers' views of NOS, specifically the nature and role of theories in science. The researchers sought to understand the interplay between prospective teachers' personal and contextual issues (including NOS views) on their anticipated plans for teaching evolution. We focused our study on three questions:

1) In what ways did the course impact prospective teachers' views of the nature of science and acceptance of the theory of evolution?
2) In what ways, if any, are their views of the nature of science and their understanding and acceptance of evolution related to their concerns and plans for teaching evolution?
3) In what ways did students' experience in the course address these concerns and impact their plans and intentions to teach evolution?

## Context of the Study

The participants were prospective teachers in a secondary science methods course at a large Midwestern university. This was the final course of a three-course sequence completed prior to student teaching. Each course has a required field experience, in which students observe in secondary science classrooms for a minimum of 24 hours a semester. The secondary science methods courses typically are not discipline-specific, as prospective science teachers from all science disciplines are enrolled. The methods courses are organized around three themes: the nature of science, science learning and science teaching.

The first course focuses on the nature of science and science learning. This course introduces students to aspects of NOS, with an emphasis on: 1) the difference between theories and laws; and 2) the social construction of scientific explanations. To support NOS understandings, students engage in a NOS card sort (Coburn & Loving, 1998) and read *T. rex and the Crater of Doom* (Alvarez, 1998). Regarding science learning, students are introduced to inquiry, students' prior conceptions and conceptual change. They complete two projects related to science learning. In the first project, students explore their own science learning in an inquiry-oriented moon investigation. In the second project, they interview high school students' eliciting their ideas about a specific natural phenomenon. Based on the interview data, students design a conceptual change-based lesson. At the end of the course, each student writes a teaching philosophy that focuses on the nature of science and science learning through claims supported with evidence from class readings and activities.

The second methods course continues the focus on science learnin*g*, and begins an intensive exploration of science teaching. NOS was not as significant a focus of this course, but was implicit throughout. As science learners, students engage in a water quality study, which is designed around the first three phases of the 5-E Instructional Model (Bybee, 2002). To focus on

science teaching, students design lessons for the elaboration and evaluation phases. As part of the science teaching emphasis, the course focuses on instructional strategies, teaching resources and curriculum analysis. To support these understandings, they compile a resource file for teaching a specific topic and engage in a curriculum analysis project. At the end of the course, students revised their teaching philosophy project, adding claims about science teaching.

The study took place in the third methods course, which focuses on curriculum planning and assessment (i.e, science learning and teaching). The major course project is to design a one-week instructional unit based on the 5-E Instructional Model (Bybee, 2002). In this particular cohort of prospective teachers, all of the individuals were seeking certification in secondary biology. Because of the unique make-up of the cohort, the course instructor (first author) tailored the course content to address biology teaching, with an emphasis on evolution. (That semester, the instructor also included units on teaching osmosis, cell division and genetics.)

The evolution component of the course was designed to support the development of students' understandings of subject matter knowledge (SMK) and pedagogical content knowledge (PCK) for teaching evolution. To foster discussions of substantive and syntactic aspects of SMK, the students read *The Beak of the Finch* (Weiner, 1994) and took turns leading weekly discussions of the readings. The students also read selected chapters from *Teaching about Evolution and the Nature of Science* (National Academy of Science, 1998). Students completed the *Conceptual Inventory of Natural Selection* (Anderson, Fisher and Norman, 2002) and portions of Bishop and Anderson's (1990) instrument. Follow-up discussions of their responses were used to reveal the prospective teachers' own misconceptions as well as commonly held misconceptions that their future students might have.

To support prospective teachers' development of PCK for teaching natural selection, they engaged, as learners, in a 5-E unit. The 5E Unit focused on specific science curricula and instructional strategies for teaching natural selection. For the exploration and explanation phases of the 5E unit, PTs engaged, as learners, with *The Galapagos Finches* software (Tabak, Sandoval, Reiser, & Steinmuller, 2000). The software allows students to analyze a sub-set of Peter and Rosemary Grant's finch data to construct evidence-based explanations for why finches were dying in the drought of 1977. The software includes scaffolds to aid students in using the theory of evolution by natural selection to analyze the data set. For the elaboration phase, students used the TB software (Sandoval, Reiser, Judd & Leider, 2000) to analyze genetic mutations that led to the evolution of drug-resistant strains of TB. During the 5E unit, peer review and alternative assessments were used to develop prospective teachers' knowledge of assessment. To further develop prospective teachers' knowledge of instructional strategies, they explored additional web-based resources for teaching evolution. To gain a deeper understanding of issues related to evolution teaching, students read a variety of articles from the *American Biology Teacher* and the *Proceedings of the 1992 Evolution Education Research Conference*. Throughout the semester, students recorded their ideas, questions, and concerns about teaching evolution in their journals. See Tables 1 and 2 for a complete summary of the evolution-related course activities and readings.

## Methodology

### Case Study

In this paper, we present a multiple case study (Stake, 1995; Yin, 1989) of five prospective biology teachers (3 female/ 2 male). The individual is our unit of analysis, allowing the

boundaries of each case to be their own experience in the course. Using this approach strengthens the results by allowing repetition in the cases to increase the robustness of the theory (Yin, 1994). Case study also provides us with richness and depth in analysis for each participant, a method congruent with our goals and purposes for understanding prospective teachers' ideas about teaching evolution. All three authors participated in the data collection and analysis.

**Data Collection**

Individual cases were constructed using multiple methods of data collection (questionnaire, interview, and collection of artifacts) to develop a robust understanding of the participants' views of the nature of science, understanding and acceptance of evolution, and concerns about teaching evolution. Primary data sources consisted of questionnaires and interviews conducted prior to and upon completion of the semester in which students enrolled in the course. Understanding of the nature of science was assessed using the VNOS-C (Lederman, Abd-el-Khalick, Bell & Schwartz, 2002), a 10-item open-ended questionnaire. Semi-structured interviews were used to probe students' concerns about teaching evolution, as well as solicit further elaboration of written responses to the questionnaire. Participants' acceptance of evolutionary theory was assessed using the Measure of Acceptance of the Theory of Evolution (MATE) instrument (Rutledge & Warden, 1999), a 20-item Likert-scaled questionnaire. The MATE contains 20 questions, and is scored with a possible total of 20-100 points. Both instruments were administered pre- and post-course. In addition to these, secondary data included classroom artifacts such as student journals and instructor teaching plans. These were collected over the course of the entire semester.

**Data Analysis**

We began analysis at the conclusion of data collection, utilizing three forms of triangulation (multiple researchers, multiple methods of collecting data, and multiple sources of data) to enhance the validity of our findings. Qualitative data were transformed into electronic format and organized for analysis using NVivo qualitative analysis software (QSR International, 2002). Open coding of data was carried out independently by the researchers, who then met to compare analyses and finalize the coding schema. Agreement on specific codes was reached through consensus and comparison of multiple data sources across each case. Open codes were then collapsed into categories. For example, we created a category "How to Teach Evolution" that included the following individual codes: "Follow the Book," "Teaching Beliefs Versus Understanding," "Fitting in With the School," and "Theme or Unit." Quantitative data from the MATE questionnaire were analyzed to generate four scores for each student (Ingram & Nelson, 2006): a pre-course total; a post-course total; a normalized gain score, and a Wilcoxon Signed Rank score. With a small sample size, we used the Wilcoxon Signed Rank test, a nonparametric alternative to a t-test to identify significance between the pre- and post-MATE scores.

For each participant, we constructed pre- and post-semester profiles. Each of the initial profiles were constructed by a single researcher, and then negotiated and revised by the research team. Profiles were then member-checked for validity by participants. Summary profiles, written in narrative form, captured individual participants' experiences and learning over the course of the semester. Generation of the summary profiles enabled cross-case comparison on multiple levels. Assertions or themes were generated by the researchers. We then created a table summarizing individual profiles according to each of our categories, and used the table as an analytic tool to

test our assertions across all cases. This process enabled us to modify and continually retest our assertions to ensure the level of inference was appropriate.

In the sections that follow, we present our interpretations. First, we present background on the five participants. Next, we provide in-depth cases for each. Following that, we present three cross-case themes that characterize patterns and trends among the participants.

## Interpretations

### Introduction to the Cases

Of the eight students enrolled in the course, five agreed to participate in the study. The two male participants were both nontraditional students. Gary, who is in his mid-30s, had previously earned an undergraduate degree in psychology. Adam, who is in his late-20s has worked full-time and attended the university for the past ten years, earning a degree in communications. Neither had yet taken the required evolution course at the time of our study. The three female participants, Elizabeth, Sybil, and Samantha, were all traditional students in their early 20s and were majoring in biology education; however, Sybil was also double-majoring in biology. All three had previously completed the required evolution course.

MATE scores from the beginning of the semester indicated a range of acceptance of evolution for our participants, as shown in Table 3. Possible scores range from a high of 100 to a low of 20. Among the group, Elizabeth had the lowest acceptance of the theory of evolution with a score of 63. It should be noted, however, that comments she made to the interviewer about finding herself giving the "science education" answer to this questionnaire led us to believe that her actual acceptance of evolution was lower than that measured by the MATE.

All participants' MATE scores increased following completion of the course; however, this change between pre and post scores was not significant. Whereas Gary's initial score of 99 limited his potential for increase, the other four participants had normalized gains ranging from 24 to 46%.

**Table 3. Students' acceptance of the theory of evolution**

| Participants | MATE (Pre-course) | MATE (Post-course) | Normalized Gain | Wilcoxon Signed Rank |
|---|---|---|---|---|
| Samantha | 79 | 86 | 0.33 | 4 |
| Gary | 99 | 100 | 1.00 | 1 |
| Elizabeth | 63 | 72 | 0.24 | 5 |
| Adam | 84 | 90 | 0.38 | 1.5 |
| Sybil | 87 | 93 | 0.46 | 1.5 |
| Average | 82.4 | 88.2 | 0.48 | Total: 13 |

Wilcoxon Signed Rank Test for n=5, alpha=5, and one-sided is 17. This total of 13 indicates no significant difference.

These findings indicate the course had little, if any, impact on these students' acceptance of evolution. Their level of acceptance when they began this methods course did not significantly increase. In turn, we found that their acceptance of evolution was not necessarily a good predictor of prospective teachers' intentions to teach evolution. In the vignettes that follow, we provide an in-depth description of each of the participants' background, experiences in the

course, and future plans in regard to teaching evolution. Following the vignettes, we provided an analysis that draws together themes across all five cases.

***Gary***

After working in psychiatric hospitals for several years following his bachelor's degree, Gary decided to return to college to become a secondary biology teacher, working toward earning both a master's degree and certification to teach. Gary has possessed a strong interest in science since childhood, and indicated his parents and the media were the primary influences on his early ideas about evolution:

> I've always been drawn to science. Both my parents have a large interest in it, and I just grew up watching NOVA and PBS, Discovery Channel, thought everybody did [laughing]. . . . NOVA and all those [programs] put in my head when I was growing up that [evolution] was just another part of biology, another system at work and nothing special. (Interview 1, lines 415-428)

As Gary learned more about biology, he also learned more about the nature of theories:

> I'd always thought of…law as being something that are hard fact, proven time again—there's no doubt whatsoever—and theory was just somebody's idea, you know? And as I took more biology I realized that theory didn't have the same use as it does in regular society. So now I realize that theories are used to explain things that happen, laws are just a description of what's occurring. (Interview 1, lines 157-164)

Gary's college coursework reinforced his view of evolution as a major, underlying theme in biology. This view was reflected in his approach to teaching evolution while serving as a teaching assistant (TA) for a general biology laboratory for majors:

> When I'm TA-ing at the university—just, instead of making a point to teach a block unit on evolution, I just show students how evolution works in all the other aspects of biology.... (Interview 1, lines 329-331)

As the sole graduate-level student of the five participants, Gary was the only person to have prior experience teaching evolution. However, he did not make a strong association between his college-level experience (where he experienced no opposition to teaching evolution) and his future K-12 context. Given his background, Gary did not view evolution as a controversial subject. When a friend, who taught public school, told him she had been verbally attacked for teaching evolution, however, Gary's views changed:

> Well, it really was maybe the *key* moment that opened my eyes to realize that it WAS a bigger issue than just, a topic in biology. That, it meant so much to so many people, both for and against it… to me it was just another part of biology. (Interview 1, lines 367-370)

Based on his friend's experience, Gary realized he could face similar opposition to his teaching of evolution. He began the semester with this concern. Over the course of the semester, Gary developed an awareness that he needed to be sensitive to students who might feel their religious beliefs were threatened by evolution:

> I was raised without a religion, I don't subscribe to an organized religion so, I learned that, um—through talks and class discussion that its going to hard for

> me…I'm gonna have to work at being a little bit more, um, *gentle* when it comes to evolution instead of just you know, spitting it out there. (Interview 2, lines 335-339)

Although he realized a need for sensitivity, he firmly believed that evolution should be taught:

> I believe its just its a foundation for biology…. I don't see how you could leave it out. It just—it's such an *important* part of biology, that I couldn't imagine *not* teaching it. (Interview 2, lines 412-414)

Furthermore, he was adamant that creationism has no place in the science classroom:

> It would go against everything that I—I feel like I would contradict myself everyday if I, according to law, have to give equal time [to creationism]…I would have to tell the students why something evolved and then tell them why it didn't right afterwards! (Interview 1, lines 399-402)

Gary did not consider creationism to be a scientific theory, which he defined as an explanation for a scientific law.

> I was taught that theories explain while laws are descriptions. Gas laws in chemistry describe what will happen in given circumstances. The theory of evolution explains why it happens. (Pre: VNOS-C, Item #5)

However, what Gary meant by "explanation" in science depended on whether the context was "hard science" or "soft science," a distinction he made in relation to his own experiences doing psychological research:

> Psychology, a soft science, uses a lot of interpretation in their research. There are false or misleading situations designed to [elicit] a particular human response. Biology, the hard science of which I have the most experience with, uses observation and much less interpretation to formulate its results. (Pre: VNOS-C, Item #1)

Consistent with the negative way in which Gary viewed interpretation, he indicated that the use of creativity and imagination were not appropriate when conducting research in science:

> Creativity and imagination have connotations not suited for the scientific world. I do not believe I would trust a study with a lot of creativity or imagination in it. I think of creativity and imagination as something AWAY from reality—something, abstract, something more in the lines of art or music—something that just doesn't really belong [in science]. You think of art—and you ask a hundred people what a painting means, they're gonna interpret it in different ways. (Interview 1, lines 218-224)

This rejection of creativity and imagination was reflective of his belief in a single, universal reality—a reality which science seeks to describe.

> I think that's what humans—there's a drive in humans to find that, to find out…the truth, or facts, or whatever you want to call it. (Interview 1, lines 259-260)

In this sense, Gary assigned an elevated status to scientific knowledge. He believed that truth exists, and that science, rather than religion, is the way to that truth.

Gary's views of science influenced his perception of course activities during the semester. For example, when exploring the Finch software, he saw the value in the tool, and liked that students were asked to work with raw data. Nonetheless, he was concerned that students might be led astray by it:

> I still do not like the idea of having the students work a week or two on an incorrect trait. No matter what I want the students to get out of it, they want to know if they are right or not. The correct answer is beak size, even if you can make an argument for another trait. (Journal Entry, 11/17/04)

Despite his concerns about this particular piece of software, Gary felt that, overall, the course addressed many of his concerns about *how* to teach evolution:

> I feel much better about teaching evolution now than in the beginning of the semester. I was worried that the class would focus more on the idea of evolution than the actual teaching of it. I was happy to see that there was a good mix. (Journal Entry, 12/6/04).

He believed the resources shared in class provided him with a good place to start in planning lessons. However, he still had lingering questions about whether to begin with macro/micro evolution, and how much time to devote to different topics within evolution during a school year. These concerns were things Gary believed could only be addressed with more "practice" or opportunities to actually attempt these tasks in student teaching.

Gary's commitment to teaching evolution was evident in the beginning of the semester. His experience in the course served to affirm his commitment. At the conclusion of the semester, Gary shared the way in which he planned to be "proactive" in regard to teaching evolution in his future position:

> I plan on hopefully getting myself in a community that's progressive thinking—again, maybe moving back to Southern California or somewhere, putting myself in a situation where I don't have to make that a big deal in my life. If, for some reason—I know things change—and something DOES come up like that, I would have a hard time NOT teaching it, just because of the way I believe. And the way I believe in teaching it, trying to work it into every PART of biology. It would be hard to pull that out and not be able to teach the students how things have changed… (Interview 1, lines 314-321).

Despite this desire to teach in an ideal situation—in which there was support for teaching evolution, Gary did recognize that his students' acceptance of evolution might differ from his own. During the semester, Gary became more aware of the need for sensitivity in dealing with students who believe in creation. His experience in the course and his observations in the field informed his instructional goals for teaching evolution—for students to *understand*, rather than to accept evolution. In doing so, he hoped to avoid controversy.

***Elizabeth***

Elizabeth, and articulate and reflective young woman, described herself as a fundamentalist Christian, which she defined in the following way, "Basically, I believe what the Bible says about God" (Interview 1, line 121). She had many reservations about enrolling in the Evolution course as part of her program requirements. Elizabeth explained, "I thought evolution was a scary idea that threatened my moral fiber" (Interview 1, line 83). Elizabeth was concerned that

she would be perceived as a "brainwashed Christian" and made fun of in the class, so she decided to enroll in the same section as a friend from her church. (Interview 1, line 141) Their conversations helped her sort through personal conflicts between evolutionary theory and her religious beliefs.

> [My friend] and I would frequently talk about how does this mesh with our belief? And so, that was a pretty good support system . . . . We talked about should I ask kids to believe something or change their value system or just present facts and leave it alone? (Interview 1, lines 97-103)

To her surprise, Elizabeth found the instructor to be sensitive to diverse viewpoints such as those she and her friend held. "When we met with the evolution teacher to talk to him, he would OPENLY discuss his religious beliefs and science beliefs, and how sometimes they're totally disjointed and sometimes they support each other" (Interview 1, lines 103-106).

The same semester, Elizabeth was enrolled in the second science methods course. In this course, the instructor discussed a state legislative bill recently introduced that would have required equal time for creationism. Elizabeth struggled to personally make sense of the evolution course and the political events that were occurring.

> I started doing independent research about intelligent design. How does that mesh with what I believe, how does that mesh with my family [pause] and is that an appropriate label for science? And so, I had conversations with my family, but they're really not scientific people . . . . So they're just kind of, well this is what the Bible says, this is what we believe, and I guess it could happen other ways. God's BIG and they're not really interested in discussing points of view on science. So I felt the best conversations I had about teaching evolution were in my [second] science methods class. (Interview 1, lines 67-77)

Of the five participants, Elizabeth expressed the strongest religious convictions and had the lowest score on the MATE at the beginning of the course. However, she entered the third methods course having already resolved personal questions regarding her religious beliefs and teaching evolution. Although religion played an important role in her life, it was not her exclusive lens for understanding the world (Journal Entry, 10/27/04). She viewed science as another lens, with its own limitations. "Science is unique in the fact that the scientific approach can only answer questions that are based on the natural world. That is, questions that are opinion-based, concerning morality, and/or do not have root in the physical world, cannot be scientific questions" (Pre: VNOS-C, Item #1). Elizabeth found comfort in learning about the nature of science, which helped her differentiate between religious and scientific viewpoints. In doing so, she was reassured that science was not a threat to her religious beliefs.

During the course, Elizabeth demonstrated evidence of both a strong content background and good understanding of the nature of science. An analysis of Elizabeth's pre-instructional VNOS questionnaire indicated that she viewed science from a socio-cultural perspective. She didn't think that scientists relied on a single method and she viewed creativity and imagination as being involved in all aspects of doing science. When asked to define a species, Elizabeth viewed the concept of species as a human construct and stated that the definition of a species is "determined by the group that's determining them" (Interview 1, line 293). In her pre-instructional VNOS answers, Elizabeth demonstrated a good understanding of scientific theories. "A scientific theory is a series of interconnected statements used to give meaning to a general topic . . . . Theories

guide the way science knowledge is categorized . . . they are umbrella ideas. They help to connect all these ideas" (Pre: VNOS-C, Item #5).

Though Elizabeth had resolved many of her own personal dilemmas regarding her religious beliefs and evolution, she still had concerns about teaching evolution. These initial concerns were more pragmatic in comparison to those of her peers, and focused on how and what to teach her students about evolution:

> I'm not really sure what the NSES Standards are [pause] I just thought it said evolution is a category you need to teach so I don't know if I'm supposed to teach microevolution, macroevolution, like just the idea of it or interweave in all my lectures. The evolution class I took in college was a whole semester long and there was so much information that I wouldn't know what is most important. . . . I wasn't taught evolution in high school, so don't have a model to follow off of. . . . I wish I had a reference point in a high school setting, how it is suppose to be done or the depth. But since I've never really SEEN that before or really even talked to anybody about how they did it, I don't if know it's suppose to be a month long, or two weeks or if you just hit the high spots. . . . Maybe like, I wish I had a reference point for . . . in a high school setting, how it goes, like, how it, how its supposed to be done, or the depth. But since I've never really SEEN that before, or like, really even TALKED to anybody about how they did it . . . (Interview 1, lines 9-26)

Though her understanding of evolution was strengthened in the evolution course, Elizabeth still struggled to translate this knowledge into the context of teaching high school biology. Because her own high school teacher had not taught evolution, she did not have a model to follow. The evolution course had been an entire semester devoted to the theory, which she did not anticipate as providing an appropriate model for teaching a high school biology course. Despite this, she did have some tentative ideas about approaching teaching evolution as an underlying theme, similar to how she saw it as a theme within the disciple of biology. However, she was very hesitant in her response as evidenced below:

> I think that I would use it [thematic approach] (pause) well, I don't know, (pause) I'm not sure (pause) maybe if (pause) I'm not sure how (pause) guarded I'm going to be my first year of teaching. And actually, I think I'm going to teach middle school, so I'm not sure if I'll have a textbook to follow and if evolution is a chapter in the textbook, and that's what all the teachers do at my school and expect you to do, I guess I'd do it like that . . . but I'd like to choose a textbook that kind of integrates it. (Interview 1, lines 47-52)

At the end of the course, Elizabeth was again asked how she planned to teach evolution. She replied:

> Um, I'd say like, as much as I have in other units like if its two or three weeks, um and like, a week of almost all like solid activities are labs, and then I think that um, throughout the year like, if learn about something and, especially it'd be helpful if it was in the teacher's manual this correlates, um I'll like explicitly bring up like, this is evidence for evolution, especially when we talk about genetics or – (Interview 2, lines 423-427)

At the end of the course, Elizabeth's approach to teaching evolution was very similar to what she stated at the beginning of the course. She visualizes a separate unit, but thinks she will make connections to evolution throughout the year.

Some of Elizabeth's pragmatic concerns were addressed in the course. When asked what she had learned in the methods course, Elizabeth summarized her experiences in the following way:

> I learned practical activities I could use in the classroom. . . . And so I think it gave me context for like how to teach evolution like, how would you teach the nature of science, we could use this activity or this activity. And this is what kids might say, this is what YOU might say, and I also learned a little bit more about how teachers should be very clear on like definitions, that they give their students and not to personify like or, like to say, a species NEEDS to or WANTS to like, to give attributes that don't really make sense in evolution. (Interview 2, lines 286-295)

Elizabeth identified the teaching resources and evolution teaching websites as the most helpful part of the course. She emailed her former high school biology teacher to share teaching resources from the course. Elizabeth also enjoyed reading the book, *Beak of the Finch,* but she disliked the Finch software. She explained her reaction to the software in this way:

> I think I missed the point completely in uh, the Finch software. Like, I thought it was only, like, as far—since I'm a logical, kind of logical, thinker, like, I got a perfect score on it, but, like it didn't—I didn't get the evolution in it. I just, like, put things in order how they made sense. It didn't help me learn evolution at all. (Interview 2, lines 322-326)

Although Elizabeth valued practical classroom activities and believed that NOS activities should precede the teaching of evolution, she failed to see the purpose and value of the Finch software.

At the end of the course, Elizabeth felt more prepared to teach evolution, although she saw a discrepancy between the information given in the methods course and what secondary biology teachers taught, as evidence in this quote:

> I'm more prepared than I was before. I've talked to, I kind of did informal interviews with some biology teachers that, like were teachers at my school, and then one of my field placements, and I kind of, that experience gave me like a practical like, this is really what people do. And then, I listened to [course instructor] talk about, like her experiences and provide all the resources and those are kind of like IDEALLY what teachers do, so I kind of saw the contrast between those, and I kind of tried to see where I fit between those. (Interview 2, lines 337-343)

Elizabeth left the course wishing that she would have the opportunity to teach evolution during her student teaching, and expressing the need to see how classroom teachers teach evolution. During the semester, she contacted the mentor teacher with whom she would be working. The mentor teacher indicated that evolution was not a major underlying theme in their biology course. It was taught as a separate unit and Elizabeth's student teaching schedule would not coincide with the evolution unit. While Elizabeth felt more prepared than at the beginning of the semester, she struggled with a disconnect that she perceived between what she learned in the methods course and what actually occurred in high school biology classes.

***Adam***

Adam, who had already earned a bachelor's degree in communications, decided he wanted to be a high school principal, and so in 2003 he began working toward earning a teaching certification in secondary biology at the undergraduate level. In the semester he was enrolled in the final methods course, Adam still needed to take all but one of his required biology courses, including the evolution course.

Growing up, Adam's family did not attend church regularly. As such, he described himself as "more spiritual than religious" (Interview 1, lines 27-28). To Adam, evolution and creation are compatible ideas:

> I don't go to church often but when I do, I just kinda take from it what I take from it. I don't subscribe completely to any theology necessarily. . . . So, however we learn things here on earth, like through science, I don't think it conflicts with God because ultimately God is responsible for putting all this evidence in front of us to discover. . . . So, I don't really see a conflict between it, I see the scientific evidence, which I can't refute with anything, but since I have more of a broader, spiritual kind of look. . . I feel that God is responsible for everything around us. (Interview 1, lines 32-39)

Nonetheless, Adam separates religion from science in the curriculum:

> I don't really see a conflict between evolution and creationism- but at the same time I don't really feel that it's the science classroom's place to have creationism in it. (Interview 1, lines 10-13)

Given he personally saw no conflicts between evolution and creation, Adam began the semester without anticipation of much difficulty in teaching evolution. However, he did acknowledge the possibility that if he ended up teaching in a rural area or a "religious conservative community" he might offend someone by teaching evolution (Interview 1, line 709). Thus, like Gary, his goal was to teach students to understand, rather than believe in evolution as "truth":

> I don't think I would treat it as some BIG deal. I would put forth that this is part of the class and I'm not asking you to say this is the absolute truth—but I would emphasize that, in the field of science, this is what scientists believe. (Interview 1, lines 162, 288-291)

This is consistent with his stated belief that "science is a way of knowing, just as religion and philosophy are different ways of knowing" but stands in contrast to his personal merging of scientific and religious views (Interview 1, lines 75-76).

> I'm not really religious but I am somewhat spiritual, and I never really saw why there has to be, you know its this or that I never saw why you couldn't just combine the two together. (Interview 2, lines 322-325)

Despite any of his expressed intentions toward teaching evolution, Adam didn't have a clear plan for *how* he would teach it. Like Elizabeth, he didn't remember learning about evolution in his high school biology courses, and thus had no models of what teaching evolution in a high school setting might be like. As a result, his plans at the start of the course were to rely on his textbook for guidance:

> I would follow whatever textbook I'd picked out, the way it introduces in relation to the other subjects, interdependence of organisms, things like that, ecology stuff, somewhere it slips in and I think, at this point, they [textbook authors] could handle the transition better than I could, just trying to create something. (Interview 1, lines 158-162)

In this sense, Adam viewed the textbook as the curriculum, and authority on how he should teach science, including the theory of evolution. While Elizabeth also emphasized using the textbook as a guide, she did not as strongly express the belief that it was the ultimate guide for how she would teach evolution as Adam did.

Adam's future teaching of the theory of evolution may be influenced by his views of science, and indeed his understanding of *scientific theory*, which he defines as "the explanation for a scientific law." He describes theories as the "ultimate goal" of science, yet acknowledges that these are subject to change "when new information is obtained or when old theories are proven wrong" (Post: VNOS-C, Item#5-6). In this sense, theories are still somewhat incomplete, but working models and useful tools:

> I believe the structure of the atom is not known for certain. The properties and behavior of atoms are known to a better extent, and this knowledge allows for practical representations of an atom's structure. It may not be completely certain, but it is sufficient for a scientist's [sic] purposes at this stage of atomic theory. (Post: VNOS-C, Item #4)

On the other hand, Adam views laws as absolute and unlikely to change:

> A law cannot be proven false in my—in how I describe a law. There's not guesswork involved, it's just a plain observation. For me, a law is just the description of what happens, and that doesn't change. (Interview 1, lines 443-445, 466-467)

Thus, he had only an incomplete understanding of the tentativeness of scientific knowledge, despite his differentiation between theories and laws as forms of knowledge. According to Adam, as scientific knowledge develops, society gets closer to knowing reality, a "truth" which he views as universal:

> I believe science is universal. It's evidence and law are fact [sic]. Cultural and social values direct us to different areas of science, but the science is universal. What we do with it is often not. (Pre-VNOS, Item #10)

Though Adam views subjective influences as inherent to the conduct of science, he views these in a negative light. In this sense, subjectivity detracts from our ability to know the truth.

> …ultimately, if there are two different explanations for the same phenomenon—maybe they're special cases, but I I'd say someone does have to be wrong, or BOTH might be wrong. (Interview 2, lines 234-236)

This epistemological stance is inconsistent with his stated goals for teaching students to *understand*, rather than *believe* in evolution as "truth," given the status of universality he assigns to scientific knowledge.

Adam's views of the nature of science became a source of dissonance for him in the methods course. Despite his indication that theories were tentative works in progress, it became clear that

he did, indeed, view evolution as certain. When the class discussed the debate surrounding the definition of "species," Adam's own understanding was called into question, and as a result, he questioned scientists' understanding of evolution:

> The question I always had—and no one would ever answer and it wasn't in any of the books we read or any articles, and whenever I bring it up people always change the subject—is that (laughing) no one understood the definition for species. …and reading this book (*The Beak of the Finch*), people defined something as a species which I would just classify as a variation of something, and even regarding evolution, even though I've read more about it now, I actually believe in it less, after reading all this material because no one is able to pin point or put their finger on it or just stand up and say *This is what a species is!* And I think the whole *basis* of evolution for me, is the development of the new species or, taking one species and evolving it into another eventually if, if they can't define what a species is, then I—I don't understand! A lot of… some of the Finch breeds and things we were looking at, um… they were supposed to be specific species but I don't see the difference. That's like—to me it was like equating… a human being having different ethnicities. To ME, by the Finch definition, that would be, everyone would belong to a different species….(Interview 2, lines 154-166)

This experience, and the frustration he felt in response to it, had a profound influence on Adam's perceived usefulness of the course in helping him teach evolution:

> Um (long pause)… I honestly can't think of new things I learned that—that I would use in teaching evolution. If anything I became more confused, less convinced of evolution throughout the class…. I wasn't aware that it was such an, an *uncertain* kind of thing that, everybody was, you know *conflicted* over what exactly IS evolution and, what constitutes evidence for evolution and what a species is and all these different things—things that when I came into class I already just assumed; you know, species is <u>this</u>, evolution is <u>this</u>… I just assumed it was TRUE, just because it's *science*. And just reading through all this stuff, um… I mean, I still *believe* in it of course, BUT, I don't feel as strongly about it as I did before I came into the class. There's a lot of holes in it….(Interview 2, lines 298-310)

Unlike the others, Adam ended the semester *less confident* about teaching evolution, because he was less confident in the validity of the theory itself. It should be reiterated, however, that Adam was one of the two students who had not yet enrolled in the required evolution course and the majority of his science coursework. The elevated status he assigned scientific knowledge (certain, universal truth) and his lack of in-depth understanding of the theory of evolution itself functioned as critical barriers to his learning in the methods course.

Despite his lessened confidence in evolution, Adam remained as confident about teaching evolution as he felt initially:

> I feel just as comfortable, teaching [evolution] as anything else, and I felt that way before I came into the class…. I honestly don't have any [concerns]…. I think as long as you go in and treat it as science, and—you know, you can answer questions students have without making a big speech about it—I don't see what

> the problem is. I mean you're gonna be backed up by the school board or otherwise they won't allow you to teach it so. (Interview 2, lines 384-385, 414-418)

***Sybil***

Although Sybil earned an excellent grade (A) in the methods course, she was uncertain as to whether she would seek a high school teaching position. During the study, Sybil worked part-time as a technician in a medical laboratory. She enjoyed the laboratory work and considered pursuing a master's degree in biology.

In the initial interview, Sybil expressed a great deal of enthusiasm for evolution, which she identified as her favorite biology topic. The professor in her evolution course had cultivated her interest:

> We had a really small class and our teacher [worked] with lizards and salamanders and so he would actually show us experiments he did over the course of five years to show microevolution, and I thought it was really interesting . . . (Interview 1, lines 50-53)

Although Sybil and Gary both considered themselves to be scientifically oriented, Sybil's interest in science did not appear to be fostered by interactions with her family or friends.

> I'm not friends with any very biologically-minded people, so nobody really wants to listen to me talk about it. When I was taking the [evolution] class, I'd go home to my mom and say, 'Hey, isn't this really cool?' and she'd be like 'Yeah' (disinterested tone). (Interview 1, lines 163-165)

Of the five participants, Sybil and Gary demonstrated the most enthusiasm and interest in evolution.

While a student in the methods course, Sybil did not share any religious views she may have held. Her exclusion of religion from class conversations paralleled her commitment to a separation between church and state. Sybil stated that she would personally find it difficult if she were required to teach creationism, as required in the proposed legislative bill.

> I know they've been proposing teaching creationism as well as evolution and I was trying to figure out how you could do that and, the only thing I can think of that would be O.K. with me personally as a teacher, would be, like concurrently, while you were teaching evolution in your science class, in your social studies class you could be reading the text of certain cultures that had to do with… (Interview 1, lines 575-590)

When asked why she wouldn't teach both evolution and creationism in a science class, Sybil replied,

> I personally have problems teaching creationism because nobody's been able to show me a scientific FACT that I could show my students or any scientific experiments that we could do to like PROVE creation, but with evolution I can show my kids pictures of birds' beaks or we can go observe salamanders but we can't go observe creationism. . . . the only proof that creationists have to go on is what they've read in the books that they worship, . . . considering, at least in the public schools, we try to keep religion separate from state, I personally would be

> extremely uncomfortable teaching something like that. (Interview 1, lines 596 – 617)

Like Gary, Sybil saw a clear distinction between religion and science, and used her understanding of the empirical nature of science as a rationale for excluding creationism from science teaching. However, unlike Gary, Sybil held misconceptions about the function and relation of theory and law. According to Sybil, scientific theories were speculative and uncertain ideas: "I think of scientific laws as a given, and theories as still… *theoretical*. Somebody could still come along and disprove it" (Interview 1, lines 350-355).

Yet, this did not affect her assessment of the validity of the theory of evolution. She explained,

> I'm totally all about evolution and stuff, but it's still called a THEORY so I still go along with it because its not-- they haven't said Oh this is . . . you know, they can't say EXACTLY what happened yet, so they just know MOST of the story. (Interview 2, lines 172-174)

Though she expressed the belief that such theories become laws, this should not be interpreted as a view of scientific knowledge as absolute. Sybil clearly acknowledged the tentativeness of scientific ideas:

> You can't really <u>prove</u> anything, but you can, like—<u>not</u> disprove it so many times that everybody takes it to be true. (Interview 1, lines 357-358)

However, she did believe scientific knowledge reflects a universal truth. Thus, when scientific knowledge changes, it is because we are accumulating new knowledge or correcting current knowledge to more accurately reflect the truth. This was similar to Adam's belief that science helps us discover the truth about the world.

Despite Sybil's enthusiasm for learning evolution, she initially expressed several concerns related to teaching evolution. She was concerned about teaching evolution "correctly, so that the kids will actually understand" (Interview 1, lines 57-58). Additionally, Sybil was concerned about the controversy surrounding evolution teaching. This concern reflected her awareness of current political events, rather than her own experiences:

> Since I don't think I had to learn [evolution] for a test or anything in high school it was never—the controversy was never brought up. And in college, it was an optional class so everybody <u>wanted</u> to take the class, so there was never any controversy. We didn't even talk about it really I mean—the most controversy was last semester in my science education class . . . the conversation was kind of getting heated. So that's the most experience I've had dealing with [the controversy], so it kind of scares me. (Interview 1, lines 137 -144)

At the beginning of the semester, Sybil didn't feel prepared to address this concern. "If a kid in my class asked me, 'But the Bible says this…' I don't even know how to answer a question like that!" (Interview 1, lines 124-125). Sybil felt that her own high school experiences had not prepared her to deal with controversy surrounding the theory of evolution:

> Honestly, if we covered [evolution] in high school, it was really short—it was like less than two weeks. It wasn't really something we were allowed to talk about. I think we covered it, and it wasn't even in our book. It was kind of an aside, like

> ‘This is really cool, but you don’t have to know it for the test or anything.’ (Interview 1, lines 105-109).

Nonetheless, Sybil relied on this high school experience as a model for how she planned to teach evolution. In the initial interview, Sybil stated that she planned to teach evolution as a shorter, separate unit within her future biology classes.

Sybil indicated she felt better prepared to teach evolution as a result of the methods course, in part because she had developed a rationale for teaching evolution at the secondary level. She referred to several course readings from the *American Biology Teacher*, “We read a lot about teachers, how they dealt with it, like teachers that WOULDN’T teach evolution, teachers that WOULD teach evolution, so I have a basis for teaching evolution myself” (Interview, 2, lines 433-435). In addition, Sybil gained insights into learning evolution. She became familiar with common student misconceptions related to evolution. Sybil reflected on Bishop and Anderson’s (1990) paper, “It helped me think about what students are thinking when they come into my class” (Interview 2, lines 504-505). Sybil also felt she increased her own subject matter knowledge of evolution.

As a result of the course, Sybil also became familiar with teaching strategies and resources for teaching evolution. She particularly enjoyed the web-based games and simulations illustrating evolutionary concepts. In class, the instructor discussed the strategy of emphasizing understanding rather than acceptance and belief in evolution. However, Sybil questioned the value of this particular strategy in her course journal:

> I’m not sure I quite agree with the ‘teachers should commit to teach for understanding, not belief’ comment made on p. 47, though [referring to a course reading]. It sort of goes against what I believe learning to be, which is about permanently changing a way of thinking. For students to understand evolution, but not believe it, would go against a lot of motivations that I hold as a teacher. It begs the question, “what’s the point?” (Journal Entry, 11/7/04)

In general, though, Sybil felt that she had learned useful evolution teaching strategies. In her course journal, Sybil summarized what she had learned in the course:

> I feel much more prepared at the end of the semester than I did at the beginning about teaching evolution in high school. I feel like I understand evolution better, and I understand the attacks on evolution better. I feel like I know better how to present evolution is such a way as not to turn off any of my students from it. However, only time will really tell if I’m prepared . . . (Journal Entry, 12/6.04)

Although Sybil believed the methods course helped to prepare her to teach evolution, she still had lingering concerns related to her lack of teaching experience. She was upset when she learned that her student teaching mentor did not teach a unit on evolution. Like Elizabeth, Sybil felt she was missing an important opportunity. For student teaching, Sybil was assigned to a small high school in a rural community. Because of perceived community opposition to evolution, the mentor teacher used a less direct approach when teaching evolution. Sybil explained this approach, “[The mentor teacher] said she just kind of would pepper it throughout the semester, like she has skulls on one of the shelves and students just look at them and think of ideas about why they change over time” (Interview 2, lines 635 – 637). Sybil was quite

disappointed that she would not be able to teach evolution during her student teaching, especially since she had never observed evolution being taught in any of her field experiences.

When Sybil was asked about her future plans to teach evolution, she was quite hesitant in her response, "If they let me (soft laugh). I hope so, but I don't even know at this point, if or when I will be teaching, so theoretically I DO hope to teach evolution, I'll be kind of upset if I can't" (Interview 2, lines 648 – 650). When asked how much time she would spend teaching evolution, Sybil responded similarly to her initial ideas at the start of the semester,

> Maybe a couple of weeks, no more than that probably, though. . . . Even though I think evolution is really interesting and they might, too, I wouldn't want to use up all that time on things that they probably should be learning for some of their standardized tests or their college prep tests. . . . I could recommend books they could read outside of class. (Interview 2, lines 667 – 682)

Later in the interview, Sybil referred to her own high school biology experiences. "I'm sure he [high school biology teacher] didn't spend THAT much time on it, because I don't actually remember learning it at all, until college" (Interview 2, lines 743 – 744).

When asked what aspects of evolution she would teach, Sybil said she would focus on microevolution because it was easier for people to understand and she would just briefly discuss macroevolution. She didn't think she would teach human evolution because she didn't want to "turn off" student with strong religious beliefs (Interview 2, lines 688 – 698). Sybil other concern focused on the possibility of being confronted by angry parents. "I'm sure I'll get them if I teach any sort of evolution, no matter what, including natural selection, I'm sure I'll get angry parents and that's another concern of mine. I don't know how to deal with parents" (Interview 2, lines 723 – 725). Because of her lack of experience teaching evolution, resistant students and angry parents remained her primary concerns.

***Samantha***

Samantha had a strong Catholic upbringing, but unlike Elizabeth, she felt her faith did not stand in opposition of her acceptance of the theory of evolution:

> For a long time I believed that Catholics didn't believe in evolution AT ALL, and I was taught that yeah, we do—it's just that you have to believe that God created those first organisms and at some point he put a soul in humans…I'm really glad that the Catholic Church does teach evolution because otherwise I don't know which side I would take…basically I take the religious side more because I have that faith. (Interview 1, lines 70-73, 26-29)

Like Adam, she was able to merge both her religious and scientific perspectives into a coherent whole.

Samantha indicates that while she may have learned some things from her family conversations around the dinner table, in regard to evolution, she didn't really learn "factual things" until she was taught about evolution in school (Interview 1, line 97). Unlike the other four participants, Samantha attended a Catholic high school and a public university, experiencing both the inclusion and exclusion of teaching creationism along with evolution. As she explained,

> I think religion plays a huge role [in teaching evolution] because you are able to discuss it…I went to a Catholic high school and they taught us about evolution,

> but they taught it WAY differently than I learned it in college. Basically, the Catholic teaching of it agreed with the scientific teaching but it just included God in the description of evolution. (Interview 1, lines 7-11)

Of the five participants, Samantha was the only individual who indicated support of teaching both evolution and creationism together. However, she stressed that her decision to do so would highly be influenced by whether she chose to teach in a public versus private institution.

Though Samantha merged her personal views of science and religion, she understood the political separation of church and state. This caused some anxiety for her about teaching in the public schools. "I'd just be afraid of saying the wrong thing—of, accidentally bringing religion into it somehow or having something I said taken the wrong way" (Interview 1, lines 17-19). At the end of the course, Samantha was still undecided about whether she wants to teach in a public or private school.

Whereas she was uncertain about whether to teach, she was equally uncertain about her rationale for teaching evolution.

> I guess just the biggest problem I'll have is if its NOT required of me to teach, whether I'll do it or not, but I think its good to teach because it will come up in conversations and in college it'll probably come up in a few classes so I think its good that the students have at least SOME background of it. (Interview 1, lines 126-130)

The statement above reveals Samantha did not view evolution as a foundation of biology, but rather one of many topics that could be discussed within a biology course.

Samantha's statements about the theory of evolution must be interpreted with an understanding of how she views scientific theories themselves. Her responses to the VNOS indicate she holds a hierarchal view of theories and laws, describing theories as "incomplete" or only "somewhat correct":

> A scientific law is something that's been universally accepted by scientists and has evidence that only supports the fact, such as the law of gravity. A scientific theory is something that has evidence that both supports and contradicts the idea, and has not been universally accepted by scientists, such as the theory of evolution. (Pre: VNOS-C, Item #5)

To her, laws were reflective of a single, universal reality and "did not bring in personal feelings and beliefs." In this manner, scientific knowledge is viewed as objective and discovered, rather than constructed and theory-laden. Consistent with this, Samantha believes creativity plays a role in science, but not as a means for constructing knowledge, rather as a means for finding innovative ways to get closer to the truth.

> Creativity, I think, is coming up with a unique idea that's not the norm—something that wouldn't normally be the… way to do something. (Interview 1, lines 312-316)

In this sense, Samantha viewed science (objective facts) as distinct from religion (personal beliefs).

Despite her epistemological beliefs about science, she nonetheless felt that religious views such as creation and Intelligent Design could be included in discussions of evolution. Her experience

in the methods course strengthened her personal views of teaching creation science with evolution. She responded in her journal to reading the Supreme Court decisions with the following: "I do think that teachers should be allowed to discuss intelligent design and creation science, since understanding these will help students understand evolution better" (Journal Entry, 10/25/04). In response to the NABT position statement, she pushes the issue of leaving creation science out of the classroom. "Even if the teacher does not bring up creation beliefs, the students will! There's no way to get around them, creation beliefs must be addressed when teaching evolution" (Journal Entry, 10/25/04).

Following the methods course, Samantha felt better prepared to teach evolution primarily because she became more aware of her content knowledge through the module. She especially enjoyed learning about different religious views, questions the students might raise, and the controversy surrounding its teaching. (Interview 2, lines 218-226) "You need to think about these concepts in different ways to be able to teach students" (Interview 2, lines 415-417). Samantha felt that the best evolution teaching strategy is to focus on the evidence rather than beliefs and allow her students to form their own views of evolution. "I plan on just providing the evidence, the scientific evidence, and saying, you know even though this is the evidence you can interpret it however you WANT" (Interview 2, lines 255-256). While she appreciated the module, she was clear in emphasizing that her views of the nature of science have not changed. When asked if the course strengthened or changed these views, she responded:

> It [methods course] just strengthened them, REALLY all we talked about the majority of it was evolution and species and um genetics, things like that so it helped me reinforce the ideas I previously had and kind of clarified a few of them, it didn't really change my beliefs. (Interview 2, lines 182-185)

Following this methods course, Samantha seemed more confident in teaching evolution; however, her concerns remained about offending parents.

> I fear that I might have trouble dealing with parents who do not want their students learning about evolution. I would like to educate them about evolutionary concepts and show them the theory of evolution may not contradict their religious beliefs, but I don't know the best way to do that (Journal Entry, 12/6/04).

Samantha became more aware of the controversy surrounding the teaching of evolution and as such the need for sensitivity and teacher knowledge on her part.

When asked about her future evolution teaching plans, Samantha indicated that her plans were dependent on the context of her first teaching position. She deferred to the school context in making her decisions more that the other participants. Samantha indicated that she would teach evolution if the school wanted her to teach it. When asked how much time she would spend teaching evolution, she replied:

> I think that depends on how much the science teacher prior to me did, um if they spent weeks and weeks on it, I'll spend weeks and weeks on it if they did a week then I'll spend a week. I think it goes along with, how much the school wants me to teach, too, if there's a pre-planned curriculum then I really have no option. AND it depends on how long it takes me to teach the other concepts, I think it's important, and I would probably take at least a week on it I would think because I

> don't think you could go through all the different concepts in less than that so. Interview 2, lines 341-347)

Samantha did not draw on a strong rationale for teaching evolution, but rather on the need to fit in and do what would be expected of her at her new school.

**Cross-case Analysis**

Three themes emerged during our analysis of the cases, and highlight both similarities and differences between each of our participants. These themes, each of which has implications for science teacher education, are elaborated upon in the sections that follow.

***Theme 1: Prospective teachers' views of the nature of science influenced their learning in the methods course, specifically with regard to learning to teach evolution***

As assessed by the VNOS-C, none of the participants demonstrated change in their views of the nature of science over the course of the semester. We argue then, that the course did not shape their views of NOS, but that rather their views of NOS shaped how they experienced the course. Specifically, prospective teachers' understanding of the nature of science 1) framed their understanding of evolution and its status as a theory, 2) provided a basis for addressing issues of religion and science, and 3) informed their decisions to approach teaching evolution as a theme of biology versus a unit in the curriculum.

Understanding of tentativeness and tolerance of the ambiguity of science was important to making sense of speciation. For example, Adam's frustration and confusion over the definition of species is reflective of his views of NOS. Entering the class with very strong beliefs about science as absolute "truth," Adam experienced cognitive dissonance when he read *The Beak of the Finch* and realized that scientists do not agree on a single definition of a species. Consequently, he began to doubt the theory of evolution. In contrast, Sybil, who fully acknowledged the tentativeness of science and tolerated ambiguity experienced no such conflict. Though she believed that theories might change, she recognized them as nonetheless useful explanations and working models.

An understanding of the epistemological differences between science and religion was helpful in negotiating personal concerns. For example, Elizabeth's understanding of the nature of science was a reassurance to her that evolution was not a threat to her personal religious beliefs. Recognizing science and religion as fundamentally different ways of knowing the world enabled her to resolve concerns by allowing her multiple "lenses" of understanding. Furthermore, it enabled her to view the nature of science as important to helping allay her own students' concerns. By teaching her students about the nature of science, she believed they would similarly be able to reconcile religious and scientific ways of knowing.

Like Elizabeth, Gary recognized epistemological differences between science and religion, though he was not religious and relied on science as his personal lens. For Gary and Sybil, their understanding of the nature of science served as a rationale for excluding creationism and Intelligent Design (ID) from the science classroom. In contrast, Samantha argued for teaching these religious views along with science. Because she felt scientific theories were speculations not yet accepted by the scientific community as valid, she viewed creationism, ID and evolution on equal footing in terms of their certainty. Though she differentiated between science and religion, she nonetheless believed that since students use both of these lenses, both should be discussed.

Participants' understanding of the nature of scientific theories was reflected in their future teaching plans. Some anticipated evolution would be a discrete unit within their curriculum, whereas others described it as an underlying theme. Although Adam had a good understanding of the difference between scientific theories and laws, his lack of biology content knowledge prevented him from thinking of evolution as anything but another chapter in a biology textbook. Samantha and Sybil completed evolution courses prior to enrolling in the methods course and exhibited strong understanding of evolution. However, they both held misconceptions about scientific theories and laws, viewing them as hierarchical. Although Sybil was enthusiastic about learning evolution, she still viewed it as "just a theory." Evolution, as a theory, did not hold a high status among other science concepts in the curriculum. Consequently, she planned to limit her teaching of evolution to a unit of a few weeks duration. Samantha, like Sybil, indicated she would use a unit approach, spending at least one week on teaching evolution.

In contrast to the others, Gary and Elizabeth exhibited both strong content knowledge and a good understanding of scientific theories and laws. Elizabeth indicated that she would teach a unit on evolution, but also approach evolution as an underlying theme in her course, bring up examples throughout the year. Gary entered the course viewing evolution as foundational to the study of biology, and he continued to embrace a thematic approach to teaching evolution. Within these cases, it appears that prospective teachers need both a good understanding of evolution and the nature of scientific theories in order to develop an approach to teaching evolution that presents it as an underlying theme and organizing principle for biology.

***Theme 2: Prospective teachers' experience in the course increased their preparedness to teach evolution by providing them with specific resources and strategies; and consequently, there was a shift in the nature of their concerns over the course of the semester.***

In the second methods course, students had discussed a proposed state legislative bill mandating the teaching of Intelligent Design. Thus, our participants entered the third methods course with an awareness of the controversy surrounding teaching evolution, and concerns about how it might affect them in their future careers. Gary was concerned about not being allowed to teach evolution in his future teaching position. He felt strongly that creationism did not belong in the science classroom, an opinion that was echoed by Adam. Sybil and Samantha were concerned that teaching evolution could lead to conflicts with their students' parents. Adam entered the course viewing teaching evolution as unproblematic, and when prompted, he voiced a single concern about "possibly offending" a student. In contrast to the others, Elizabeth's primary concerns revolved around her lack of familiarity with the scope and sequence of evolution concepts taught in high school. She felt a lack of direction and models for her own teaching because her high school biology teacher had avoided evolution.

Though initially Elizabeth alone voiced such pragmatic concerns about *how* to teach evolution, by the end of the semester, the nature of other participants' concerns had shifted to this focus as well. This is evidenced in students' interview responses regarding what they learned in the course. With the exception of Adam, all participants identified specific strategies and ways in which the course fostered their PCK for teaching evolution. For example, the course activities helped Sybil develop a rationale for teaching evolution in high school. She felt that she gained strategies for helping students understand evolution and that her own understanding of evolution deepened. Elizabeth also valued the practical teaching resources, sharing some of these resources with her former high school biology teacher. Gary, who described himself as nonreligious, gained an awareness of creationist viewpoints and the need to be sensitive toward his students'

religious backgrounds. Samantha felt she learned more about the controversy surrounding the teaching of evolution and creationism. Consequently, as a teaching strategy, Samantha planned to focus on scientific evidence for evolution.

Even though these prospective teachers felt more prepared to teach evolution as a result of the course, they nonetheless had a heightened awareness of additional resources and experiences they would need in order to be successful in doing so. Gary felt that he needed to sit down and write actual lesson plans before he would feel completely prepared to teach evolution. Samantha felt the need to actually teach evolution before she could feel fully prepared. Sybil and Elizabeth expressed that they needed a mentored experience teaching evolution in a secondary classroom, an opportunity that would not be available to them during their student teaching. Consequently, both Sybil and Elizabeth expressed a need to observe high school biology teachers teaching evolution. These four participants valued the course's practical teaching resources and strategies; however, they ended the semester with new concerns focused on pragmatic issues, including the need for secondary classroom teaching models; lesson planning and experience actually teaching evolution.

Unlike the others, Adam felt no more prepared to teach evolution than when he entered the course. This is because, however, he already considered himself prepared to teach evolution when he entered the course. Initially, Adam thought of teaching evolution as unproblematic, given he had no personal conflicts between his religious views and evolution. Additionally, because he had not yet taken much of his content coursework and the evolution course, he lacked understanding of evolution as a major organizing theme within biology. He viewed teaching as lecturing and equated the biology curriculum with the textbook. As such, when he entered the course he already felt prepared to teach evolution-- to Adam, it was simply a matter of following the teacher's guide. This significantly impacted his perceptions of the course material and its utility. As a consequence, Adam's concerns never shifted to focus on instructional issues, as the concerns of his peers did. Instead, his emerging concerns focused on the validity of the theory of evolution, as discussed in the vignettes. At the conclusion of the study, Adam indicated he was looking forward to taking the required evolution course, in order to address his concerns.

***Theme 3-Though each of the prospective teachers personally accept evolution, contextual factors related to their future students', parents', and colleagues' acceptance of evolution are anticipated to play a significant role in their decisions whether to teach evolution.***

Despite their acceptance of evolution, as measured by the MATE, a common theme throughout these five cases is the role of future teaching context in determining whether or not these prospective teachers will teach evolution. Each appears willing to adapt to the status quo of their new school, rather than stand firmly by their personal position with regard to teaching evolution. Sybil's future evolution teaching will depend upon what her colleagues advocate. For example, she indicated she would follow the precedent of other teachers in her school to decide the length of her evolution unit. While Sybil wants to "fit in" with her colleagues, and would alter her practice to do so, Gary's efforts to "fit in" involved seeking a progressive community in which his desire to teach evolution would be supported. He does not appear to want to change a school's viewpoint on the teaching evolution by imposing his own views; rather, he wants to choose an environment in which he could avoid controversy. Samantha planned to ask specific questions during job interviews to determine the school's policy on teaching evolution, not to determine whether she wanted to accept a position there, like Gary, but to find out the school's wishes as far as what to teach. Adam indicated he would leave his decision about whether and

how to teach evolution up to the textbook adopted by his school. Similarly, Elizabeth emphasized the role of the textbook in informing her how she was "supposed" to teach evolution. However; unlike the others, Elizabeth expressed uncertainty about her future teaching plans. At the conclusion of the semester, she indicated she was considering seeking additional certification in English education. This late career decision could reflect her desire to avoid controversy as well, by avoiding teaching evolution altogether.

All of these prospective teachers, in different ways, are trying to "fit in" as new teachers while avoiding becoming the target of controversy. These generally compliant attitudes towards the teaching of evolution inform us that as these teachers enter the profession they will be recreating the status quo. According to these students, the context of their teaching experience will greatly determine whether or not they will teach evolution, regardless of their content knowledge on the subject, their understanding of the nature of science, or their familiarity with evolution instructional strategies and resources.

## Discussion

This purpose of this study was to examine the impact of a biology-focused science methods course on prospective teachers' anticipated plans for teaching evolution. Our first research question was concerned with the impact of the course on participants' views of the nature of science and acceptance of evolution. Data from the MATE indicate participants' experience in the course had little, if any, affect on their acceptance of evolution. Similarly, no changes in participants' views of NOS were apparent in the VNOS-C data and interviews. Given NOS was a primary focus of the first methods course, and less so in the third course which served as the context of the study, this result is not entirely surprising. However, that these participants still maintained inaccurate views of the function and relation of theories and laws is of concern. Samantha, for example, believed that there was evidence to both support *and* refute scientific theories, such as evolution. How such views affect her teaching of evolution was the focus of our second research question.

We examined the data to identify relationships between prospective teachers' NOS views and acceptance of evolution and their plans and intentions to teach evolution. Personal conflicts with evolution have been cited as a reason for avoiding teaching evolution (Meadows, Doster & Jackson, 2000; Moore, 2000). Given *all* of our participants accepted evolution prior to the course, the inferences we can draw in this regard are limited. In this case of Elizabeth, however, it stands to reason that had she *not* worked through her personal conflicts between evolution and her religious beliefs, she might not have been as receptive to learning to teach evolution during the methods course. Developing her understanding of the nature of science proved critical to this process, and provided her reassurance that both science *and* religion could be used as lenses through which the view the world, allowing her to maintain her faith. Of the five participants, she alone expressed the belief that teaching students about the nature of science might help them similarly resolve their personal conflicts. That none of the other participants made such a connection suggests a disconnect between the attention to NOS in the course and the attention to evolution teaching. Though these prospective teachers did not identify NOS as an approach to teaching and a tool for allaying students' concerns about evolution, NOS did contribute to their PCK for teaching evolution in two distinct ways. First, their views of NOS served as a means for deciding whether or not to teach alternative conceptions such as creationism or ID. Second, participants' understanding of the nature and role of theories in science guided decisions about whether to approach teaching evolution as a distinct unit, or as an underlying theme of their

curriculum. Understanding of NOS thus provided a guide for *how* they might teach evolution, but did not appear to be a critical factor in determining *whether* these prospective teachers plan to teach evolution in their future classrooms, which was the focus of our third research question.

Our third research question was concerned with identifying the impact of the course of participants' plans and intentions to teach evolution, i.e., their response to the question *Will I teach evolution?* Through our analysis of the data, we came to view this as a complex, multi-layered issue that also involves questions of whether the prospective teachers feel they *should* teach evolution, as well as whether they believe they *can* teach evolution. The secondary methods course that served as the context of the study addressed these questions to varying degrees for each of the prospective teachers. Although the course was not designed around these three questions, we find the post-analysis framework to be a useful tool.

**Should I teach evolution?**

As instructor of the course, the first author anticipated her students lacked a clear message about whether they should teach evolution or not. Drawing on recommendations from Moore (2004), she focused one class session on the legal history of evolution education and the evolution position statements of NSTA, AAAS, and NABT. In addition, the students reviewed the National Science Education Standards for Life Science for grades 9-12. In class, students synthesized this information to address the question, "Should I teach evolution?" Based on interview data and student journal entries, all of the participants indicated an affirmative response to this question. Yet, it is unclear how developed their rationales for teaching evolution may be, since writing a rationale was not a specific requirement of the methods course. For example, Samantha initially believed it was important for students to understand evolution "because it will come up in conversation and in college." A stronger rationale was provided by Gary, who used his understanding of the nature of science to exclude creationism and ID from the curriculum. Articulating a rationale in writing may assist prospective teachers in justifying their decision to teach evolution to future colleagues, administrators, and parents. In retrospect, the first author assumed biology teachers would teach evolution if they knew that they should. However, the decision to teach evolution proved to be more complex.

**Can I teach evolution?**

As a methods course**,** this experience was designed to foster the development of prospective teachers' PCK for teaching evolution. Although we did not try to capture the development of the participants' PCK as part of this study, in the post-instructional interviews, 4 of the 5 participants stated that they felt more prepared to teach evolution as a result of the course. These participants referred to their increased awareness of curriculum materials (e.g., *Galapagos Finches* and *TB* software); instructional strategies (e.g., focusing on evidence; discussing different ways of knowing; NOS activities); and knowledge of common misconceptions related to natural selection.

Although 4 of the 5 participants felt more prepared to teach evolution, each still had lingering doubts as they considered the question, "Can I teach evolution?" Gary expressed the need to write an evolution unit with detailed lesson plans before he would feel completely prepared to teach evolution. In retrospect, this was a missed opportunity in the course. One of the major course requirements was to design a 5-E curriculum unit. To broaden the prospective teachers' backgrounds, the first author encouraged students to create curriculum units on topics not discussed in class. After analyzing the post-instructional interview data, we would change this

recommendation, and require the prospective teachers to design 5-E units for teaching evolution. The prospective teachers needed this critical planning opportunity to further synthesize the course material related to evolution teaching.

To increase their confidence and preparedness, the participants discussed the need for evolution teaching experiences in actual high school classrooms. Elizabeth & Sybil felt less prepared because they did not experience learning evolution as part of their high school education, missing an opportunity to observe their high school biology teachers teach evolution. The pre-college curriculum has been identified as an influential source of teachers' knowledge (Ball & McDiarmid, 1996). To further add to their concerns, Elizabeth and Sybil learned that they would not be allowed to teach evolution during their student teaching. Participants wanted mentored experiences teaching evolution in what they perceived as the safe environment of the mentor teacher's classroom. As novice teachers, they viewed their student teaching mentors as a potential source of support in learning to teach evolution. However, in Elizabeth and Sybil's cases, their future student teaching mentors only re-enforced the message that evolution was too controversial to teach.

The methods course could be re-designed to meet some of the lingering concerns expressed by the participants (e.g., designing an evolution unit). However, some of the participants' concerns, arguably, cannot be addressed within the existing context of the course itself. The third methods course with its one-hour field practicum is taught during the fall semester. In surrounding local school districts, evolution is typically taught in the spring semester; so prospective teachers don't have the opportunity to observe evolution teaching while enrolled in the methods course. Looking beyond the individual methods course, some of these concerns might be addressed on the program level by placing student teachers with mentor teachers who emphasize evolution. Logistically, this may not be possible when studies indicate that approximately 40% of high school biology teachers place little or no emphasis on evolution. Prospective teachers' need to observe high school teachers teaching evolution and their need to have mentored experiences teaching evolution were critical factors contributing to the third question we've posed.

**Will I teach evolution?**

We assumed that prospective teachers who responded, "yes" to the first two questions would plan to teach evolution. However, this was not the case. Participants were uncertain about their future plans and indicated that they could not answer this question with confidence. Although this finding is disappointing, it should not be surprising for the following reasons.

First, if we view knowledge from a situated perspective, learning that occurs in one context is not automatically transferred to another (Putnam & Borko, 2000). Elizabeth alludes to this in her post-instructional interview. She talked to high school biology teachers to find out how they taught evolution because she was unsure of the practicality of the teaching strategies advocated by the methods instructor. Second, knowledge of context is one of the four domains of Grossman's (1990) teacher knowledge model. In this model of teacher knowledge, context knowledge, subject matter knowledge and general pedagogical knowledge interact and influence pedagogical content knowledge. Carlsen (1999), although critical of this structural view of teacher knowledge, proposed a revision of the model that embeds the domains of general pedagogical knowledge, subject matter knowledge and pedagogical content knowledge with the larger domain of knowledge of the specific context. The findings of this study support Carlsen's proposed revision. For the participants, a lack of knowledge about their future teaching context

was not merely influential in their decision to teach evolution, it was THE over-riding factor. Until the participants understand the context of their future schools, they cannot confidently answer the question, "Will I teach evolution?" Further support for this finding can be found in the beginning teacher literature. Beginning teachers' desire to "fit in" often overrides their knowledge and beliefs about reform-oriented practices, causing them to conform to traditional teaching practices (Abell & Roth, 1992; Black, 2004; Loughran, 1994).

The methods course was specifically designed to support prospective teachers' learning to teach evolution, with the goal of developing confidence and PCK for teaching evolution so that they would teach evolution. The course helped prospective biology teachers answer the question, "Should I teach evolution?" Introduction to curriculum and instructional strategies helped the participants begin to develop PCK for teaching evolution, giving them increased confidence in their answer to the question, "Can I teach evolution?" However, the overriding question, "Will I teach evolution?" remained unanswered due to their lack of knowledge about their future teaching context.

## Limitation

One limitation of the study should be noted. Only 5 of the 8 students in the course agreed to participate in the study. The data collection strategies were designed to minimize out-of-class research study participation (2 one-hour interviews), with the majority of the data collected from in-class activities and course assignments. One of the students who declined to participate stated that she had religious conflicts with teaching evolution. We do not know why the other two students declined to participate, nor do we know the impact of the course on these students. The five students who did agree to participate in the study entered the methods course with no internal conflicts with evolution teaching. (Elizabeth resolved her personal conflicts earlier in her program, while she was enrolled in the evolution course.) So in this regard, the five participants could be viewed as representing "best case" scenarios for prospective biology teachers in that they were receptive to evolution teaching.

## Implications

### Teacher education

The cases we present highlight prospective teachers' need for models of effective evolution teaching. Most were not provided with models as high school students, and even though several had enrolled in an evolution course at the university, they failed to view the instruction of that course as a viable model for their own instruction at the high school level. We propose that provision of effective models could be achieved in teacher education through field experiences and student teaching in classrooms where evolution is taught video case studies of exemplary high school evolution teaching. The difficulty in securing field sites in which evolution teaching occurs has been previously stated. Where field experiences do not afford the opportunity to observe evolution teaching, video-cases may provide a viable alternative. However, we are currently unaware of any existing video-cases of evolution teaching that might be put to use for this purpose. Development of video-cases might thus fill a need for teacher education programs. Even experienced biology teachers have expressed the need for examples of powerful evolution lessons with an accompanying teacher narrative (Griffith & Brem, 2004).

Beyond simply providing such models, teacher education programs need to afford prospective teachers opportunities to plan for and enact instruction on evolution. Efficacy for teaching

evolution can be built when prospective teachers are provided with meaningful feedback and the opportunity to reflect on their practice. However, this should not be limited to student teaching. In particular, our cases highlight the importance of contextual factors, such as whether colleagues teach evolution, in prospective teachers' decisions whether they will teach evolution. We argue that in order to avoid re-creating the status-quo of evolution teaching in our nation, prospective teachers also need support systems in their inductive years, which is a crucial time when most teachers refine their teaching and create routines to be used throughout the remainder of their career (Veenman, 1984). This emphasizes even further the importance of support when establishing their teaching practice, ensuring that evolution is included in their curriculum.

Furthermore, these five cases draw attention to the way in which prospective teachers' understanding of NOS is key to their understanding of evolution as a scientific theory and as a major unifying theme of biology. Their views of NOS can provide a rationale for whether or not to teach alternatives to evolution, and also a guide for how they will teach evolution. This highlights a need for NOS to be addressed in science teacher education, particularly in content courses where students have an opportunity to engage in discourse about the theory and evidence to support it. We echo previous work (e.g., Brickhouse, Dagher, Letts, and Shipman 2000) in this regard. Additionally, we support the recommendations by Anderson (2005) that teachers develop an approach to teaching evolution through the nature of science.

**Research**

The nature of prospective teachers' concerns about evolution shifted over the course of the semester, such that each identified personal needs with regard to their preparedness to teach evolution. How will they meet their identified needs during induction? Because future career context appears to be such an important factor to these students in terms of whether they anticipate they will teach evolution, further research should explore contextual factors during the induction years that may contribute to their instructional decision making in regard to teach evolution. In particular, longitudinal studies are needed to characterize the trajectory of prospective teachers' PCK for teaching evolution in light of such personal and contextual factors.

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**Table 1. Course Activities Related to Evolution and NOS**

| Student Learning Experiences | Purposes/Intent |
|---|---|
| Reading and responding to articles on NOS and evolution through individual student journals and whole-class discussions | Help students differentiate between theories and laws; understand differences between creationism, ID, and evolution, and why ID is not considered a scientific theory |
| | Increase students' familiarity with the current situation across the U.S. in regard to evolution teaching, including significant court decisions, standards and position statements, and issues facing biology teachers |
| Weekly reading and student-led discussions of *The Beak of the Finch* | Enhance students' understanding of evolution and NOS through contextualized examples |
| | Provide opportunities for students to experience and implement a range of strategies for leading discussions |
| Attendance of Science Teachers of Missouri Conference | Encourage students to participate in a professional organization and identify resources to support their teaching |
| | Attend keynote address on evolution teaching by Craig Nelson |
| Exploration of web-based resources for teaching evolution | Assist students in developing an awareness of available resources to support their teaching and building a beginning repertoire of strategies and curriculum materials for teaching evolution |
| Completion of Variation Lab, measuring and graphing variation within different populations (e.g., seed pod length) | Model laboratory-based strategies for teaching evolution |
| | Help students understand the role of variation in natural selection |
| Engagement in a 5E Mini-unit on Natural Selection utilizing *Galapagos Finches* software (Tabak, et al., 200) | Model inquiry-oriented, technology enhanced lessons for teaching natural selection |
| | Assist students in constructing evidence-based explanations |
| | Help students understand the role of peer review in science |

**Table 2. List of Selected Course Readings on Evolution Teaching**

Alvarez, W. (1998). *T. rex and the crater of doom.* Princeton, N.J.: Princeton University Press.

Block, T.D. (1992). Problems facing evolution education. In R.G. Good, J. E. Trowbridge, S.S. Demastes, J.H. Wandersee, M.S. Hafner, & C.L. Cummins (Eds.). *Proceedings of the 1992 Evolution Education Research Conference* (pp. 85-86). Louisiana State University.

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McComas, W. (1996) Ten myths of science: Reexamining what we think we know. *School Science and Mathematics(96),* pp. 10 – 16.

Moore, R. (2004). Standing up for our profession: A talk with Ken Hubert. *The American Biology Teacher, 66*(5), 325-327.

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Scharmann, L.C. (1992). Problems & questions: Evolution education. In R.G. Good, J. E. Trowbridge, S.S. Demastes, J.H. Wandersee, M.S. Hafner, & C.L. Cummins (Eds.). *Proceedings of the 1992 Evolution Education Research Conference* (pp. 170-171). Louisiana State University.

Scott, E. C. (1997). Antievolution and creationism in the United States. *Annual Review of Anthropology,26,* pp. 263-289.

Staver, J. R. (2003). Evolution and intelligent design. In R. Bybee (Ed.), *Evolution in perspective: A science teacher's compendium* (pp. 43-48). Arlington, VA: NSTA Press.

Weiner, J. (1994). *Beak of the Finch.* New York: Vintage Books.