J Sci Teacher Educ (2013) 24:597–616
DOI 10.1007/s10972-012-9328-6

High School Biology Teachers' Views on Teaching Evolution: Implications for Science Teacher Educators

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Published online: 23 November 2012

Abstract In the US, there may be few scientific concepts that students maintain preconceived ideas about as strongly and passionately as they do with regard to evolution. At the confluence of a multitude of social, religious, political, and scientific factors lies the biology teacher. This phenomenological study provides insight into the salient aspects of teaching evolution as viewed by public high school biology teachers. Transcribed interviews were coded, and data were sorted resulting in key themes regarding teachers' views of evolution education. These themes are presented against the backdrop of extant literature on the teaching and learning of evolution. Suggestions for science teacher educators are presented such that we can modify teacher preparation programs to better prepare science teachers to meet the challenges of teaching evolution.

Keywords Evolution · High school teachers · Qualitative · Phenomenological

Introduction

In the United States, there may be few scientific concepts that students maintain preconceived ideas about as strongly and passionately as they do with regard to evolution. Many biology teachers can share anecdotes of parents and students raising questions about the extent to which evolution will be covered in the course. Given the extreme variation in teachers' location, background, formal science training, political and religious views, one could expect great variation in the manner in which evolution is covered in the public high school science classroom. The purpose of this study is to better understand biology teachers' beliefs, attitudes, and perceptions of teaching evolution in public high school classrooms and their

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perceptions of student understanding and acceptance of evolution. Moreover, these insights have several implications for science teacher educators and the teacher preparation programs they support.

A recent study of 926 teachers indicated that 13 % of the participants were advocates for teaching creationism or intelligent design and 60 % avoid endorsing either evolution or alternatives to avoid controversy (Berkman and Plutzer 2011). However, evolution is a central concept that provides a framework for understanding many other concepts within the life sciences. Likewise, evolution provides an explanatory framework that supports, and is supported by, a diverse range of concepts within several scientific disciplines ranging from geology to physiology. Given the prevalence of scientific concepts that support, or are supported by, the modern theory of evolution, the scientific community almost unanimously accepts evolutionary theory to be the best explanation for the diversity and interrelatedness of species on earth. However, segments of the general public are not as accepting of evolution, especially within the United States where a low number of Americans accept evolution relative to European countries (Miller et al. 2006). Though it is not a scientific controversy in the United States, there is little doubt that evolution remains a socioscientific controversy. Evolution is a sociocontroversial issue because it aligns with four defining characteristics of controversial issues: (1) There are at least two opposing groups, (2) there is a heated disagreement between supporters on both sides of the issue, (3) the answer is not clear to all reasonable people, and (4) there is acknowledged uncertainty and disagreement about evolution from a societal perspective (Hermann 2008). While the teaching and learning of evolution in the United States is well documented as being a contentious subject, it is becoming increasingly common to hear of challenges to the teaching of evolution in schools around the world. Many countries have experienced anti-evolution challenges for several decades, while others are experiencing a resurgence of anti-evolution challenges.

Global Perspectives of Evolution

At the risk of minimizing the subtle intricacies that may exist across a country with respect to people's views of evolution, I rely on extant literature to provide an overview of evolution education in several countries to better contextualize the focus of this research which explored United States high school biology teachers' views of evolution. While there are likely countless differences that may exist between countries, one central aspect to understanding the populace's interaction with evolution is the religious demographics of the country and the prevalent views on the extent to which evolution is to be taught in the science classroom. Burton (2011) cautions that research on Middle Eastern creationism should emphasize the role of state educational systems and other factors involved in education policy in addition to religion. She takes these factors into consideration when stating that Iranian students receive positive exposure to evolutionary theory as compared to their Israeli counterparts because the Israeli Ministry of Education provides individual biology teachers significant power to decide how they address evolution in their classrooms (Burton 2011). BouJaoude et al. (2011) investigated distinctions

among different religious traditions of Lebanese and Egyptian Muslim high school students finding that although Lebanese Sunni and Shiite students and Egyptian Sunni students say they do not see a conflict between religion and evolution, many of them accept religious rather than scientific explanations for the diversity of life on Earth.

Researchers in many countries are documenting an increased effort to introduce intelligent design (ID) or creationism in the classroom. For example, McCrory and Murphy (2009) state that they have seen an increase in public efforts to place ID in science classrooms in Northern Ireland. Moreover, they sampled 112 pre-service science teachers after showing them a DVD promoting intelligent design and found that after viewing the video, 68 % of students thought a range of theories should be taught. Nine out of the ten participants thought the movie demonstrated legitimate scientific challenges to evolution. Murphy et al. (2010) report on the extent to which evolution is supported in Northern Ireland indicated that there is opposition to evolution in both the political and religious domains and that, in general, Catholic schoolchildren are less likely to oppose evolution than Protestant pupils. Francis and Greer (1999, 2001) conducted surveys of over 2000 Northern Ireland pupils 13–17 years of age and reported that support for creationism was higher among Protestants than Catholics with 48 % of students agreeing to the statement "God created the world as described in the Bible".

Creationist lobby groups in New Zealand date back to 1871 and creationism has found a place in school classrooms (Campbell and Otrel-Cass 2011). According to Numbers and Stenhouse (2000), the Auckland Department of Education issued a creationist textbook for senior biology classes in 1982 and such views continue to this day. Every New Zealand secondary science department head was mailed teaching materials promoting an alternative theory to evolution by a Christian lobby group as recently as 2008 (Campbell and Otrel-Cass 2011).

The results of a poll of 1520 German respondents age 14–94 indicated that 12.5 % were adherents of creationism and 25.2 % were adherents of Intelligent Design (ID), with the remainder largely supportive of naturalistic evolution (Kutschera 2008). Kutschera suggests that the large number of adherents to creationism and ID may be due to kindergarten and elementary school students' exposure to biblical portrayals of Adam and Eve, whereas science education begins much later and may not emphasize biological evolution. This is also a legitimate concern in the United States where children may be exposed to anti-evolution messages prior to formal evolution instruction (Lombrozo et al. 2008). Such concerns raise awareness of the need for a greater emphasis to be placed on the introduction of evolutionary concepts during elementary school science (Hermann 2011; Wagler 2010). Research reports from several countries indicate their awareness of the need for foundational evolutionary concepts to be taught at the elementary level. For example, Chanet and Lusignan (2009) provided details on the teaching of some aspects of evolution that are taught in France during the early elementary years such as, animal classification, interrelationship trees, and a comparison of natural selection to intelligent design. Reports such as this clearly indicate that, if taught correctly, elementary level students can understand aspects of evolution. However, among Canadian pre-service elementary teachers, even the

most basic concepts of evolution were not well understood and almost a third of the teachers planned to avoid or had reservations about teaching evolution despite recently completing a course in which evolution was addressed (Asghar et al. 2007).

In Brazil, creationist fundamentalism has become an influential political movement, though whether creationist views should be taught in science courses is not a central issue (El-Hani and Sepulveda 2010). However, El-Hani and Sepulveda did report that they have been gathering more teacher narratives indicating conflicts with protestant students related to teaching evolution. Furthermore, Pazza et al. (2010) interviewed 231 freshman university students in Brazil and found that although most students accept the notion of inheritance with changes, they do not understand how evolution occurs.

Allgaier (2010) reported on an incident in the United Kingdom where rooms at Emmanuel College in North England were rented to a creationist organization holding a conference. The news media accused the school of teaching creationism in science classes. While the intent of Allgaier's paper was to research the manner in which science experts are portrayed in the media, the incident indicates that though creationist organizations are present in the UK, they are rather unpopular. Furthermore, given the dearth of work on creationism in the UK, much of the referenced work focused on the creationism in the United States.

Due to the controversial nature of evolution, several scientific, religious, and educational organizations have felt the need to explicitly state their support for the teaching of evolution (Sager 2008). Despite the support offered for the teaching of evolution, enough resistance to evolution education exists in the United States that individual states experience pressure from a variety of stakeholders when new science standards or textbooks are adopted. As such, there remains a great deal of inconsistency with respect to the manner in which state standards address evolution (Cavanagh 2005; Lerner 2000; Skoog 2005). Lerner et al. (2012) assigned grades to each state in an effort to provide an evaluation of state standards. An undermining of evolution was highlighted as a major issue leading to poor state science standards in the United States and the inconsistency across states (Lerner et al. 2012). Jeffery and Roach (1994) reported on the considerable variation among published textbooks and Aleixandre (1994) suggested textbooks provide a superficial handling of key ideas. Just what, then, does occur in a public high school biology lesson on evolution? It appears the answer to this question may vary considerably from teacher to teacher, despite a concerted effort in the US to develop national standards for science education (AAAS 1993; NRC 1996, 2011).

At the confluence of a multitude of social, religious, political, and scientific factors lies the biology teacher. Faced with unparalleled external pressure to teach evolution in a manner that is consistent with their belief system, professional responsibility, scientific and pedagogical training, and the expectations of the larger community, it should come as no surprise that science teachers approach the teaching of evolution along a continuum running from omitting evolution from the curriculum all together to stringent supporters of evolutionary theory. Science teachers are active participants in the socioscientific discussion on the extent to which evolution ought to be taught. Moreover, they are uniquely positioned to demonstrate their active participation in the discussion through their instructional

approaches to teaching evolution. Compared to other science concepts, science teachers likely approach the teaching of evolution with the greatest range of instructional approaches and teaching philosophies. Science educators would be well served by better understanding the approaches biology teachers take to teach evolution. This study sought to understand biology teacher views on teaching evolution by presenting biology teachers the opportunity to have their voice shared with science educators and policy makers.

Purpose

The purpose of the present qualitative research is to provide insight into the salient aspects of teaching evolution as viewed by public high school biology teachers (hereafter referred to as "teachers") and address the implications of those aspects on the preparation of science teachers. This study provides teachers with a voice with which they can express their concerns and opinions regarding the teaching of evolution. As such, a phenomenological approach to the teaching of evolution was undertaken in which I attempt to understand the issues and events that surround the teaching of evolution in a public high school biology classroom. Therefore, the phenomenon under investigation is my viewpoint of what it is like to be a high school biology teacher teaching evolution. As such, the phenomenon is the combination of what the teachers said and the manner in which I filtered their thoughts and words through my background as a former biology teacher and current science teacher educator. Phenomenologists believe that there is a multitude of ways to interpret experiences and that reality is created by the meaning attached to those experiences (Bogdan and Biklen 2007). The ultimate aim of this study is to understand the teaching of evolution from the point of view of the teacher. To that end, several teachers were interviewed during the 2008–2009 school year. The questions that specifically guided this research were: (1) How do teachers view their students' ability to understand evolution? (2) What barriers do teachers perceive that may prevent their students from understanding evolution? (3) What types of pedagogical approaches to the teaching of evolution are employed by teachers? and (4) If provided unlimited time and resources, what types of pedagogical approaches to the teaching of evolution do teachers feel would be most effective in increasing understanding of evolution?

In the following sections, I provide the study methodology, findings resulting from the analyzed interview transcripts, discuss the implications of the teachers' views on the teaching and learning of evolution, and offer suggestions for science teacher educators and researchers of evolution education that stem from my reflections of the interviews conducted.

Methods

During the 2008–2009 academic school year, I sent a call for participants to several school systems and posted the call for participants on science education social networking websites. Six teachers (see Table 1) voluntarily participated in the study

Table 1 Overview of study participants' gender, number of years teaching, earned degrees, and interview length

Participant	Gender	Years teaching	Training	Interview length	Ethnicity	School setting
Alice	Female	5	BS in Biology	20:55	African American	Urban
Cathy	Female	3	BS in Biology	26:16	African American	Urban
Lauren	Female	14	BS in Biology; MA in Biology	24:57	Caucasian	Suburban
Maxine	Female	19	BS in Biological Sciences	28:07	Caucasian	Suburban
Reggie	Male	12	BS in Biology; MA in Ed. Admin.	32:41	African American	Urban
Susan	Female	8	BS in Biology; MA in Env. and Occupational Health	34:19	Caucasian	Suburban

which is within the appropriate sample size for phenomenological studies (Boyd 2001). Participants were given a pseudonym used during the transcription and within this paper. Each teacher met fairly broad selection criteria. First, they needed to be current biology teachers. Second, I sought to include teachers in both urban and suburban settings. Third, I sought to include both male and female teachers, though only one male teacher volunteered to participate. Finally, I sought to include teachers from a variety of ethnicities. The teachers taught a range of biology courses from lower level general biology to upper level Advanced Placement biology and their responses indicated a prototypical view of teaching evolution that accounted for the range of experiences they have had during their career.

Prior to the beginning of the study, I contacted and visited all participants for the purpose of building rapport and trust, removing any perceived status differences between the researcher and participant, and building a store of tacit knowledge about the setting. I had a professional relationship with two of the teachers interviewed and had previously engaged in several informal conversations regarding the teaching and learning of evolution with them. The remaining teachers were not previous acquaintances, so rapport was established via general discussions about teaching and my personal experiences teaching high school science. Once rapport and trust were established with a study participant, an interview was scheduled and conducted at a site that was most convenient for that participant. Upon meeting the teachers, I fully disclosed that I had taught science courses, including biology, in public high schools in Maryland for 11 years prior to assuming my role as science educator at the university. Participants were made aware of the confidentiality agreement and their anonymity in the study and signed consent forms. Each participant was requested to participate in a semi-structured interview on the topic of teaching evolution in a public high school biology class. The semi-structured interviews allowed me to explore the issues raised by the teachers, while still ensuring that all aspects of the inquiry were addressed. The twelve pre-planned questions on the interview guide were specifically formulated to incite participants to reflect on their own experiences. Several questions were developed based upon

research reports on the teaching of evolution that focused on teacher and student understanding and acceptance of evolution. Other questions stem from extant literature that described or measured the relationship between science and religion on learning evolution. The dearth of research specifically addressing how biology teachers teach evolution led to the development of a few questions as well. I also asked probing questions as needed to clarify participants' meanings and, where relevant, to ask participants for concrete examples to substantiate their espoused beliefs. Following is the semi-structured interview guide:

1. How many years have you been teaching biology?
2. What concepts do you think students have the most difficulty with?
3. What concepts do you think students are the most reluctant to learn?
4. To what extent do you think your students understand evolution? How do you know?
5. To what extent do you think your students accept evolution? How do you know?
6. To what extend do you think your students have issues with learning evolution due to a perceived conflict?
7. How do you attempt to determine who has issues?
8. How do you teach evolution?
9. If you had unlimited time would you teach evolution differently? How so?
10. What techniques do you use when teaching students who make anti-evolution statements?
11. What obstacles do you think prevent some students from understanding evolution?
12. What obstacles do you think prevent some students from accepting evolution?

Moreover, terms used in the semi-structured interview guide were also defined and clarified for the study participants to ensure that they understood the context in which the questions and words were being used.

Interviews were audio-taped and transcribed verbatim by a research assistant and participants were provided with their interview transcription to review and to clarify any misunderstandings. Five of the teachers were interviewed at their respective schools and one teacher was interviewed via phone. Each interview lasted between 20 and 35 min, with some of the shorter interviews taking place at the school during the teacher's planning period.

Analysis of Data

I analyzed all interview transcripts to seek patterns in the data. This analytic process was based on immersion in the data and began with open coding. Corbin and Strauss (2008) described open coding as that which "fractures the data and allows one to identify some categories, their properties and dimensional locations" (p. 97). Through repeated sorting and immersion in the data, the coded data were compared repeatedly both within and across all transcripts. Open coding broke the transcribed data into pieces so that patterns could be identified and data could be recombined into themes. Codes were developed in vivo, using the participants own language,

when applicable. Throughout the interview process, a few topics began to emerge at various points in the interview. Statements that were significant to the focus of the study were extracted and became raw data for analysis. Codes were assigned to the data by reading, rereading, and reflecting upon significant statements in the context of the original transcriptions. The coded data were analyzed to establish themes. To validate the themes, each original transcription was read to reexamine the meaning of the code. In addition a colleague with experience analyzing qualitative data provided a second analysis of the data in order to validate the themes. Throughout the analysis, the input, reflections, and feedback of all study participants were sought to ensure the authenticity of the interpretation of the data.

Findings

The two states in which all the participants teach, Illinois and Maryland, contain standards that explicitly address the teaching of evolution. For example, Illinois standards require students to be able to examine explanations of evolution and Maryland standards require students to be able to explain the mechanism of evolutionary change. Both states expect biology students to learn about the relatedness of organisms and the underlying mechanisms by which evolutionary change occurs. As such, the interviews with biology teachers did not yield any discussion about not teaching evolution as each teacher was expected to teach evolutionary concepts. Thus, open coding and sorting of the interview data resulted in key themes regarding teachers' views of teaching evolution to public high school students.

View Student Understanding as Low

Each of the teachers expressed the fact that evolution was a difficult subject for their students. There was a general sense of low understanding of evolution among their students.

> …when I teach evolution it's clear when I come out of there, I'm disappointed, they did not get it. Every time I test it, they say species change or they will say one species will turn into another one. They don't understand the time span of evolution and they don't understand variation in a species rather than, causes evolution, rather than just variation in one individual. (Susan)

The teachers did not need any prompting to suggest reasons for low student understanding. Alice's comments suggest the teachers were quite cognizant of the fact that test scores were low and formative assessment indicators provided evidence that evolutionary concepts were challenging for their students.

> I think some of the problem is that it is this kind of big open theory that, um, where, because it also it happens over such long periods of time that I think students have a hard time grasping that a thousand years, even though they think that's really long is not really enough time, like they have a hard time understanding how slowly this actually happens and what it all means as its slowly, slowly changing.

The teachers readily speculated on the reasons for such a low understanding without any prompting to do so. Reggie explained, "I definitely see a low understanding of evolution"… "students don't know about evolution because nobody talks about it at home and at church it's taboo and most of their teachers either don't understand it, don't accept it, or just don't want to deal with the consequences." In fact, most of the teachers attributed low student understanding to religious barriers, but rarely cited specific instances where students or their parents raised concerns about the teaching of evolution for religious reasons.

Perception that Evolution is Controversial

The interviewed teachers perceived evolution as being a controversial subject. When asked about whether their students viewed evolution as controversial, most of the teachers spoke hypothetically about the controversy, seemingly lacking first-hand accounts. For example, Reggie stated, "I know that there have been, that there are stories about students getting up and walking out and parents being upset." However, he could not recall specific instances in his classroom where students or their parents had challenged the teaching of evolution saying "I do meet parents quite often…but no parent has ever raised any questions or issues with what their student was learning." Some of the interviewed teachers provided generalizations about evolution being viewed as controversial without citing specific instances. Susan stated, "I would guess 75 % of my class would not believe in evolution because a lot of kids at (school name removed) um, are religious, they go to school, go to school, go to church every Sunday…" Likewise, Maxine said, "I would say that there are probably about half of them that don't agree with it, but there's probably only about 15 % of them that are angry enough about it, that they want to make it known to me that they don't like me for teaching it and they don't want to learn about it". Alice anticipated an issue with the teaching of evolution, but had not had any instances to date.

> Interviewer: Do you have many parents come into talk about evolution?
> Alice: I will, I haven't yet, but I probably will. I don't, um, there's usually like 2 or 3 kids in each class that have maybe some religious issues with learning it. But I don't see it as a majority type thing at all.

As indicated in several of the teachers' statements, a common view was that students' religious beliefs could be a barrier to their understanding of evolutionary theory.

Religious Barriers

When asked what possible barriers may prohibit students from fully understanding evolution, the responses inevitably turned to religion and often the discussions began with little need to prompt teachers to discuss their views on the issue. The teachers made statements such as, "I think religious conflicts are probably the biggest impediment" (Maxine) and "I think the biggest obstacle is whatever kind of religious belief they had before" (Susan). Though this may be the prevailing view among these teachers, there is a hint that some teachers feel that it is possible

to overcome religious beliefs and effectively teach evolution to students with strongly held religious beliefs. Alice explained, "maybe initially they're put off because of their religious beliefs but it doesn't stick, it kind of fades and they want to know what happens." Alice felt that religious students were as engaged in the topic as any other student stating, "So by the end of that unit they're [religiously oriented students] answering questions, they're just as engaged as the other students." Other teachers also viewed religious beliefs as a barrier that can be overcome through instruction. Lauren said, "…if you give people all of the information about both sides most people will error on the side of evolutionary theory." In addition, Maxine also felt that some students' views of evolution could be altered with instruction.

> Maxine: I don't think they have much understanding at all when they come to the 10th grade…to the high school level.
> Interviewer: Do you think that after being in your class that changes?
> Maxine: I think probably for about 80 % of them it does. I think for the rest of them it is something that, um, is so different from what they've been taught that they can't assimilate it. But, I think that the majority of 'em can, uhh, follow the logic of it.

Acceptance and Belief

The teachers were asked whether they felt students needed to accept evolution in order to understand it. In general, the teachers felt that students can learn evolution even if they do not accept/believe in evolution, and Lauren provided an example.

> I don't think they have to accept it to understand it. Because I think you can teach it in a way where you say, okay, here's this information, here's why people believe this, here's all the evidence for it, and you can even show them scientific publications, um, if you show it from the point of view of science, I don't think that they have to accept it to understand.

It seems natural that teachers may want to separate acceptance from understanding to suggest to students that they can understand evolution even if they feel their religious beliefs may run counter to the tenets of evolution. Reggie viewed his teaching along this line.

> I present evolution to them as not a belief system at all, but of course if they have a problem with it it's because of religious views and so that's something to believe in and it can't really be supported by facts and so evolution is not a belief system so I kind of, early on, try to show them that what they are about to learn is not in conflict with what they believe because they are two separate things.

Science education researchers may find this approach worthy of further investigation to explore the extent to which high school students are able to differentiate between knowing and believing.

Array of Teaching Approaches

The teachers took many different approaches to teaching evolution. Some teachers described approaches that include activities on variation of species and explanations of survival and fitness. Others described approaches to discussing similarities and differences between scientific and religious ways of knowing about the world. Lauren took advantage of a summer reading opportunity to provide her students with a greater understanding of some of the research that supports evolutionary theory.

> I had my students read a book this past summer called *The Beak and the Finch* and it's about a real research project that took place on the Galapagos Islands over the course of twenty years. And they came away, although they hated reading the book because they had to read it for summertime reading, they came away from this going, wow, this was real research, this was real time changes, species change due to environmental changes, and they're like, I see it and I think the more that we give them that kind of information, the more that they can say I see this now really happening.

Many of the teachers reflected on the extent to which they do or do not permit discussion of religion to enter into their teaching of evolution. Teachers like Alice shy away from religious discussions during her treatment of evolution.

> I usually just tell them, like, that's fine you believe that, but in this classroom we're not going to be discussing that, we're just discussing what scientists believe happen.

Lauren goes a step further and presents evolution as one way of knowing about the world and she believes her students respond well to this approach.

> Most of the time they're very much, very open to all avenues, because if I present it from the point of view that it's just information, just background information, and if I give them all of that information most of the time they're very willing to listen.

Other teachers such as Maxine and Reggie facilitate religious discussions in their class to better help their students understand the boundaries and limitations of different ways of knowing. Maxine explained, "…they get a chance to write about how they feel about their beliefs about creation origins and then how they feel about what they know about evolution." Likewise, Reggie said "we have people give their view on evolution based on what their religion says."

Unlimited Time and Resources

Near the end of the interview, the teachers were asked what they would change if they had unlimited time and resources to teach evolution. Examples of their responses include, "I would probably go through and make sure I had all the skulls of all the primates and be able to show the nuances in skull structures that shows various changes, in, in not only in the skulls but in the skeletons by looking at

homologous structures" (Lauren). Susan stated a more pragmatic approach that she wanted to include the following school year.

> I'm going to spend two full days, three hours, on different variations, looking at different variations in various species and having them measure variation in any kind of, you know, lima bean, a leaf or whatever to really drive that into their brains before we ever start talking about how they will change over time.

Maxine thought about including some excerpts from a book she was reading and thought of including additional activities.

> There are probably some other good activities that I would do with maybe comparisons, maybe looking at fossil bones, or things like that, I would like to do that, but I just don't have time.

Reggie had been part of a grant opportunity that resulted in 24 teachers visiting the Galapagos Islands for 2 weeks.

> Ever since then I've been trying to get together a grant or some type of opportunity to take my students there to see what I saw so they can draw their own conclusions.

Discussion

Student Understanding

The teachers indicated their students generally possess a low understanding of evolution which is congruent with much of the research on student understanding of evolution (e.g.,, Demastes et al. 1995; Deniz et al. 2008; Peker et al. 2010; Sinclair and Pendarvis 1997). Many teachers also felt that after instruction, student understanding increased, though potentially not for all students. The teachers felt that evolution was a controversial topic despite most of them being unable to recall a significant event where a student or a student's parents challenged the teaching of evolution in their classroom.

Barriers to Understanding

Although Alice had not seen any direct evidence of parents having issues with the teaching of evolution, she expects that it will happen in the future. This is an interesting statement in light of the fact that Alice had been teaching for 14 years at the time of the interview without a remarkable interaction with parents concerned about the teaching of evolution. The fact that she expects such a discussion to occur in the future may serve as an indication of the extent to which the teachers perceived the teaching of evolution to be controversial. Scenarios such as these illustrate that there are a few ways to view the controversial nature of evolution. First, it may be that evolution is not as controversial as teachers initially believe, at least not for the specific school and community which they serve. The perception that evolution is

controversial may be much greater than the actual nature of the controversy, perhaps due to media coverage of anti-evolution challenges around the world that influences the manner in which teachers view the issue within their specific school and community. Second, it may also be that teachers are not adequately determining how controversial evolution is among their students. Students perceiving a conflict with their own beliefs are often not vocal and internalize the conflict which can result in disdain or complete withdraw (Scharmann 1994). It is possible that teachers are not asking students, or their parents, about their views on evolution, and the default thinking is that some students view evolution as being controversial. As a science teacher educator, I am left wondering about the extent to which we prepare teachers to elicit student views on socioscientific issues like evolution. Only by asking students in a meaningful manner such as, an anonymous survey or one-on-one conversation, are teachers likely to have a tangible sense of the extent to which evolution is considered controversial among their students. If teachers are unaware of the extent to which evolution is viewed as controversial among their students (and their parents), the default mode of thinking may be that evolution is controversial, and therefore, the teachers may treat the teaching of evolution differently than other concepts. As science teacher educators, it is quite possible that we could be doing a better job of exposing science teachers to (a) research findings on the extent to which evolution is viewed as controversial among high school students and (b) methods for discussing students' views of evolution in a non-threatening manner within the confines of legal parameters for the discussing religion in a public high school.

Pedagogical Approaches

There are a variety of approaches by which teachers can engage students in learning about evolution (Hermann 2008) including avoiding the topic altogether, advocating for evolution, and procedural neutrality wherein teachers permit students to present ways that different religions view evolution. The teachers varied in their approach to teaching evolution. Alice approaches evolution from an advocacy standpoint and does not permit students to discuss the extent to which their religious beliefs may impact their understanding of evolution. On the other hand, Maxine approaches evolution from more of a procedural neutrality standpoint permitting students to discuss their religious beliefs and how they influence their willingness to understand evolution. While there has been much written on the interaction between science and religion, Reiss (2009) recently suggested that "Teaching about aspects of religion in science classes could potentially help students better understand the strengths and limitations of the ways in which science is undertaken, the nature of truth claims in science, and the importance of social contexts for science" (p. 793). He went on to state that "…avoiding science/religion issues, when they are of relevance to students, may not only lead to a poorer understanding of the nature of science, it may increase the chance that science remains irrelevant for some students, unconnected to their worldview" (Reiss 2009, p. 793). I fully recognize that some teachers are uncomfortable discussing religion in their science classroom. The teachers I interviewed were at different places on a continuum running from

avoiding discussions of religion to facilitating such discussions. Science teacher educators should help teachers realize the benefits of discussing the merits and limitations of both science and religion as they relate to the ultimate goal of increasing students understanding of science broadly and evolution specifically.

Changes to Pedagogy

While the teachers explained that religious beliefs were the most significant barrier they perceived influencing students' understanding of evolution, not one of the teachers stated that they would incorporate or refine lessons to reduce this barrier. Many biology teachers may be uncomfortable introducing religious discussions in their science classrooms for various reasons including: a feeling of not being qualified to discuss religion, an unwillingness to discuss religion, a lack of understanding of the extent to which religion can be discussed in public high school science classrooms and an unwillingness to have to approach evolution differently than any other science concepts or theories. Some of the teachers are already incorporating students' views of evolution into their instruction so they may not see a need to modify this area of instruction. Overall, it is somewhat surprising that the teachers for the most part agreed that the major barrier to understanding evolution was the religious beliefs of their students, but this aspect of instruction was not targeted for improvement or modification by the teachers. Again this may be due to the teachers' unfamiliarity with the legal parameters for introducing religious discussions in the classroom. Our students may benefit greatly from texts that discuss the extent to which religion can be discussed in the public school setting. For example, Lofaso's (2009) text is designed to help educators, principals, superintendents, school board members, parents, and students understand what public schools can and cannot do when it comes to religion. Minimally, I recommend exposing preservice and inservice science teachers to texts that present information about teaching evolution in a manner that is not combative toward students with religious beliefs such as, the 2009 text *The missing link: An inquiry approach for teaching all students about evolution* by Lee Meadows. I realize it can be difficult to alter attitudes and beliefs. However, preservice and inservice teachers that possess combative dispositions toward evolution education, which may alienate their students, are unlikely to improve conditions. Science teacher educators must facilitate growth in this area by exposing our students to tools and techniques to teaching evolution to all students through explicit instruction on how to do so. Meadows (2009) provides an approach to teaching evolution to all students regardless of religious beliefs and specific tools and resources for doing so. Based on my interactions with the participants of this study, I recommend science teacher educators share this resource and similar resources with teachers and provide instruction on how to effectively use these resources to reduce the perceived conflict between science and religion.

Limitations

The six participants interviewed were from two geographical areas that do not have a history of challenging the teaching of evolution as prominent as those of other

areas of the United States. As such, the views of the teachers may not adequately represent those across the nation and that is not the intent of this study. Rather, I sought to draw upon the first-hand knowledge of these teachers to provide insight into the views they maintain about teaching evolution and how those views permeate their instructional approaches, perceptions of students understanding, and beliefs/acceptance of evolution. Future research extending this study to additional regions may be fruitful in determining the extent to which these views are held by other teachers and differences that may exist from region to region. Although all the teachers interviewed had similar views of evolution, teachers' views of evolution vary with respect to their perceptions, interests, and beliefs in evolution (Nadelson and Nadelson 2010). Likewise, Nehm and Schonfeld (2007) indicating that teachers may demonstrate knowledge of evolution while harboring antievolution world-views, though there is little evidence of antievolution views among the teachers interviewed. Additional light may be shed on what, specifically occurs within the high school biology classroom when evolution is taught. This study relied on the sole use of single interviews and would be greatly enhanced by the inclusion of data obtained during observations of the teachers as they teach evolution. Unfortunately, the time needed to gather such data was not possible for the author to commit to at the time of the study. This research provides a small window into what biology teachers are doing in their classrooms when teaching evolution, but there remains a need for more detailed investigations into the interactions between teacher, student and evolution content in the public high school classroom.

Implications

As a result of interviewing the six biology teachers, I have reflected upon my own practices as a science teacher educator. This process has served as a call to action for me to reconsider my practices, and I believe my reflections may also serve as a call to action for other science teacher educators. It has become clear to me that these teachers were not prepared in a vacuum. What teachers know and do in the classroom is, in part, due to our interactions with them during their teacher preparation programs at the undergraduate and graduate level, in addition to the role we can, and do, play in professional development of inservice science teachers.

Based on this sample of six public high school biology teachers, several themes that emerged from the data have significant implications for science teacher educators. The teachers readily admit that their students maintain a poor understanding of evolution which raises the question about what teachers can and do realistically know about the extent to which their students understand evolution. I am left wondering about the manner in which teachers assess their students understanding of evolution. I have begun introducing the preservice teachers I work with to a few instruments that have been widely used in evolution education literature. For example, the Conceptual Inventory of Natural Selection (Akerson et al. 2002), a survey developed by Rutledge and Mitchell (2002), Assessing Contextual Reasoning about Natural Selection (Nehm et al. 2012) and/or Knowledge of Evolution Exam (Moore and Cotner 2009) and the Measure of Understanding of Macroevolution (Nadelson and Southerland 2010). In

doing so, I hope to empower teachers to refine their lessons to bolster those areas where students are challenged with the aim of increasing students' overall understanding of evolution. At the same time, teachers can minimize instruction on topics that students typically understand well and more accurately assess what students understand.

Similarly, teachers interested in knowing the extent to which students in the classroom are accepting of evolution can ask students to complete a survey, such as the Measure of Acceptance of the Theory of Evolution (Rutledge and Warden 1999). The results of this instrument can help teachers better identify students willing to learn about evolutionary theory and students who may be resistant to learning about evolutionary theory and plan instruction accordingly.

Several researchers (Brem et al. 2003; Brickhouse et al. 2000; Ingram and Nelson 2006; Jackson et al. 1995; Meadows et al. 2000; Sinclair and Pendarvis 1997; Woods and Scharmann 2001) have suggested that students should be provided with the opportunity to discuss their views of the interaction between science and religion. It appears some biology teachers are doing this, yet there is little empirical research on the effects of this type of pedagogical approach. On the one hand, the teachers identified students' religious beliefs as being a major barrier to them learning about evolution, but on the other hand when given carte blanche to teach evolution little emphasis would be given to addressing students' religious barriers. Glennan (2009) suggested that it is difficult to separate science from religion in the classroom when students hold religious beliefs that are inconsistent with scientific evidence and teachers must be prepared to tell students when their faith-based claims about the natural world are most likely wrong even though such statements contradict students' religious beliefs. As science teacher educators we can provide teachers with a tangible way to teach evolution to all students. A procedural neutrality approach becomes less of an assault on students' religious beliefs and more of an instruction on the differences between scientific and faith-based claims and which type of claims are appropriate within a science classroom, but teachers need our support to adopt and inspire this type of classroom dynamic. Hermann (2012) indicated that it is possible for students who do not believe in evolution to understand evolution. Science teacher educators should not only endorse the notion that all students should come to understand evolution, but we must provide instruction on the manner in which science teachers can achieve this goal. If we do not, it is unreasonable to think that K-12 science teachers will do so on their own.

The teachers interviewed largely viewed religion as a major barrier to students learning evolution. Religion is often viewed as a singular entity though it is important to keep in mind the varied religions that exist throughout the world and across the United States. Martin (2010) explored publicly available statements of the major US Christian denominations and reported that the majority, not the minority, view among US Christians is that evolution is compatible with their religion. This is an important point for science educators to present to science teachers and explore during pre-service and inservice instruction. Likewise, in-service teachers may gain much ground in their classrooms by tasking students with obtaining the position statements of their religious denomination to ascertain the compatibility of their own religion with evolution. It may be that some students

believe a conflict between evolution and religion exists, where their religious leaders believe there is not a conflict. Students who understand the views of their religious leaders may be more likely to remove some barriers to learning evolutionary theory.

In reflecting upon the teachers' experiences in teaching evolution along with my past personal experiences teaching high school biology and current experience as a science teacher educator resulted in the realization that science teacher preparation programs may vary greatly from institution to institution, instructor to instructor, and among program requirements and curricula. Further, while science teacher educators strive to develop programs leading to teacher certification that provide rigorous content knowledge, pedagogical knowledge and pedagogical content knowledge, it is possible that we may each overemphasize certain areas related to our research agendas. Indeed, I have done so here in encouraging a reevaluation of the effectiveness of teacher preparation programs with respect to evolution education. So how do we fit all of the important aspects of science teaching across all scientific disciplines, student demographics, learning styles, cultural and gender considerations, etc., within our science teacher preparation programs? The question clearly warrants further discussion among science teacher educators and personal reflection by science teacher educators.

My personal call to action is to increase the evolution content knowledge and pedagogical content knowledge specific to evolution education within the teacher preparation program of the students I serve and I encourage other science educators to do the same. I certainly was not well prepared to address student or parental concerns about my teaching of evolution as a high school teacher and it may be that many of the teachers we work with are ill prepared as well. Rather than researching the extent to which this is the case, we should turn our efforts to reevaluating our programs to ensure that we prepare teachers to not only teach the content of evolution, but to explore and develop pedagogical approaches to teaching evolution that do not alienate certain students and address the socioscientific issues surrounding evolution and evolution education.

I have also come to realize that a broader call to action is also needed. I realize that science teacher educators interested in evolution education are likely to nod in agreement to the recommendations herein, but those with other teaching and research interests may be wondering why they should focus on evolution education or how they can make a case for improving teacher preparation programs in other areas of science education related to their areas of interest. Admittedly, although I attempt to include a diverse and extensive array of ideas about science teaching in my methods class, I may deemphasize or omit some ideas in favor of others like evolution and the nature of science. I suspect I am not alone in this regard. So the broader call to action is to reexamine and modify my teaching and curriculum so that I can continue emphasizing the importance of evolution education while also seeking to identify ways of emphasizing other ideas, especially those that are currently lacking. Perhaps as other science teacher educators ponder this idea, they will find a place in their program for a detailed treatment of evolution education and find connections between evolution education and other areas of science education that reinforce and enrich one another.

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