

Biology Teachers' Professional Development Needs for Teaching Evolution

Abstract

The social controversy surrounding the teaching of evolution puts pressure on secondary biology teachers to de-emphasize or omit evolution from their curriculum. In this growing pressure, professional development can offer support to biology teachers. In this study, we surveyed secondary biology teachers in Missouri and report the data from teachers who are teaching evolution (N=276). Teachers were asked to self-report their content understanding of evolution topics, the nature of their evolution teaching practice, their level of familiarity with available evolution education resources, obstacles they perceived as barriers to their evolution instruction, and their self-reported professional development (PD) needs related to evolution education. Seventy-five percent of teachers reported having an adequate understanding of all the listed evolution topics. Sixty percent of teachers reported teaching evolution as a unifying theme as well as including a unit devoted to evolution. Natural selection and nature of science were the most commonly taught topics. Teachers identified the lack of good labs and supplemental materials as their two biggest obstacles to teaching evolution. Teachers were not familiar with available evolution education resources. Teachers expressed interest in many aspects of professional development with over 75% of teachers reporting that they wanted "some emphasis" or "great emphasis" placed on every topic listed. In particular, teachers reported they wanted PD that placed a great emphasis on current research in evolution, labs/investigations

using real data and/or live organisms, evolution simulations, contemporary evolution examples, and misconceptions. Implications for professional development are given.

Introduction

In the first six months of 2014, The National Center for Science Education documented anti-evolution legislative bills in South Carolina, Louisiana, Oklahoma, Missouri, Virginia, and South Dakota (<http://ncse.com>). This social controversy directly impacts biology teachers and their teaching practices. Past research has focused on determining which teachers are teaching evolution, factors contributing to the likelihood a teacher will teach evolution, the nature of teachers' evolution practice, as well as obstacles to teaching evolution (Sickel & Friedrichsen, 2013). But few researchers are examining the professional development (PD) needs of secondary biology teachers who are teaching evolution in the face of increasing anti-evolution efforts. By better understanding secondary biology teachers' professional development needs and addressing those needs, we can improve the quality of evolution education in our schools.

Literature Review

We focused our review of the literature on studies of practicing secondary biology teachers in the United States. Evolution teaching takes place within a community and state context, with state standards and community values differing across the country. To reflect this, we identify the state in which each study took place. In the first section, we review the literature on teachers' content understanding for teaching evolution, including understanding of the nature

of science. Next we review the nature of secondary biology teachers' practice as it relates to teaching evolution, including number of hours evolution is taught, approach to teaching evolution, and topics most likely to be taught. The section concludes with a review of perceived obstacles to teaching science and teachers' self-reported professional development needs.

Teachers' Content Understanding for Teaching Evolution

Studies in which researchers directly assess evolution content knowledge report secondary pre-service biology teachers often have the same misconceptions as secondary students (e.g., only the strongest survive, need-driven adaptation) (Abrie, 2010; Crawford, Zembal-Saul, Munford, & Friedrichsen, 2005; Zuzovsky, 1994). Other studies show that misconceptions persist among in-service biology teachers (Aleixandre, 1994; Nehm, Kim, & Shepard, 2009; Nehm & Schonfeld, 2008) and, consequently, some in-service teachers have difficulty identifying students' alternative conceptions (Aleixandre, 1994). For a comprehensive review of common misconceptions held by students, pre-service and in-service teachers, see Nehm & Schonfeld, 2008.

When biology teachers rate the adequacy of their teacher preparation in regard to teaching evolution, there is a great range in perceptions. On the high end, 99.2% of Ohio biology teachers (Borgerding, 2012) and 95% of Florida biology teachers (Fowler & Meisels, 2010) reported they understood evolution well enough to teach it. In the mid-range, 74% of Oklahoma biology teachers felt well prepared to teach evolution (Weld & McNew, 1999) and 62% of Louisiana biology teachers reported

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their academic training was adequate to teach evolution (Aguillard, 1999). In contrast, only 1/3 of Minnesota biology teachers felt they had proper undergraduate training to teach evolution (Moore & Kraemer, 2005).

Teachers with evolution coursework are more likely to teach evolution (Aguillard, 1999; Berkman & Plutzer, 2011) and teachers with more total hours of biology credits in their degree programs allocate more time to teaching evolution (Aguillard, 1999). However, Nehm, Kim and Shepard (2009) reported that in regard to advocating for creationism, there was no difference between teachers in a study who had taken an evolution course and those who had not.

A strong understanding of the nature of science (NOS) has been shown to be positively correlated ($r=.59$; $p<0.05$) to biology teachers' emphasis on teaching evolution (Trani, 2004). However, many studies report biology teachers have inadequate NOS understandings. A study of pre-service teachers revealed they misunderstood fact and theory (Jackson, Meadows, & Wood, 1995). In a larger study of practicing teachers enrolled in a certification program, the biology teachers ($n=109$) had low levels of NOS understanding related to evolution (Nehm et al., 2009). Indiana public school biology teachers had only moderate levels of NOS understanding (Rutledge & Warden, 2000). Oregon biology teachers showed a stronger understanding of NOS in a stratified sampling of teachers from different size schools, with teachers having moderate to high levels of NOS understanding, with an average score of 66.08 out of a possible 85 on NOS survey items (Trani, 2004). Although the level of NOS understanding varies among high school biology teachers, explicit NOS instruction can improve in-service teachers' NOS understandings (Scharmann, 1994). In summary, teachers with strong content knowledge and NOS understandings tend to emphasize evolution in their biology courses.

Nature of Evolution Teaching Practices

One window into teachers' professional development needs is to examine

their current practice. In general, biology teachers do not spend large amounts of time teaching evolution; however, the number of hours devoted to evolution has increased in recent years, possibly due to increased emphasis in state standards (Borgerding, 2012). In Louisiana, a survey of high school biology teachers revealed 60% of teachers spent five or fewer class periods teaching evolution (Aguillard, 1999). In Indiana, 33% of biology teachers spent less than three days teaching evolution (Rutledge & Mitchell, 2002). Moore and Kraemer (2005), comparing results of a 1994 and 2003 survey of Minnesota biology teachers, reported teachers were spending more time on evolution with the percentage of teachers spending six or more hours increasing from 43% (1994) to 57% (2003). More recent studies support a trend toward increased time teaching evolution; nationally, high school biology teachers devote 13.7 hours to evolution (Berkman, Pacheco, & Plutzer, 2008). A study of Indiana biology teachers reported similar results with an average of 14.3 days teaching evolution (Donnelly & Boone, 2007). A recent survey reported Ohio biology teachers spent an average of 11.6 hours teaching evolution (Borgerding, 2012). To summarize, although there may be a trend toward spending more time teaching evolution, high school teachers typically spend less than 15 hours teaching the foundational theory of biology.

When biology teachers do teach evolution, the majority of teachers teach it as a stand-alone unit rather than as the unifying theme in the discipline. In Indiana, only 33% of Indiana biology teachers reported teaching evolution as a unifying theme, while 25% taught evolution as a unit, 36% only briefly mentioned evolution, and 7% avoided teaching evolution (Rutledge & Mitchell, 2002). In a national survey of high school biology teachers, only 23% agreed that evolution was a unifying theme in their biology courses (Berkman et al., 2008). Although biologists view the theory of evolution as a unifying framework for understanding all biology, few high school students are taught this view.

When evolution is taught, what topics are included? In Louisiana, biology

teachers spent the most time teaching Darwinian evolution, mechanics of evolution and evidence for evolution (Aguillard, 1999). In a study of Texas biology teachers, Darwinian evolution and mutations were the only topics that were given 30 minutes or more by at least half of the teachers; the majority of the teachers did not teach human evolution (Skankar & Skoog, 1993). In a survey of U.S. Lutheran high school biology teachers (Shulteis, 2010), the top three topics teachers reported spending more than one lesson teaching were diversity (59.2%), natural selection (51.3%), and speciation (36.8%). Few of the teachers spent more than one lesson teaching evidence for evolution (26.3%), pace and rate of evolution (22.3%), human evolution (18.4%), and descent with modification (14.4%); nearly 70% of these teachers gave little or no emphasis to human evolution. In a recent survey of Ohio biology teachers, Borgerding (2012) reported that 90% or more taught the following evolution topics: mechanisms of natural selection, adaptation, fossil record, information about Charles Darwin, anatomical evidence for evolution, and connections between genetics and evolution; the least taught topics were cladistics, endosymbiotic hypothesis, and Hardy-Weinberg equilibrium. It is important to understand teachers' current practices regarding teaching evolution in order to address their professional development needs.

Perceived Obstacles to Teaching Evolution

Teachers' personal acceptance of the theory of evolution has been reported as a major obstacle to teaching evolution (Aguillard, 1999, Berkman et al., 2008; Rutledge & Mitchell, 2002; Trani, 2004). In our study, we focused on the professional development needs of teachers who are teaching evolution. As few teachers in the study (2.5 %) reported personal acceptance as an obstacle, we focused on perceived obstacles beyond personal acceptance. High school biology teachers experience increased pressure to include non-scientific alternatives to evolution or to de-emphasize or omit evolution

from their curriculum. In 1995, only 9% of Minnesota biology teachers reported pressure to not teach evolution; in 2003, this number increased to 48%, with parents being the primary source of pressure (Moore & Kraemer, 2005). A survey of Florida teachers revealed that 32% of high school teachers reported being censured by parents or students for teaching evolution (Fowler & Meisels, 2010). In a national survey of biology teachers in Lutheran schools, 25% reported pressure from parents to omit evolution (Schulteis, 2010). In 2005, the National Science Teachers Association (NSTA) conducted an informal survey of its members regarding evolution teaching (N=1050). Thirty-one per cent of teachers reported that they felt pressured to include non-scientific alternatives to evolution in their classrooms. When asked if they felt pressure to de-emphasize or omit evolution, 30% agreed. Students and parents were the primary sources of pressure (NSTA, 2005). Over time, the trend has been toward increased pressure from students and parents to include non-scientific alternatives and/or omit evolution. As professional developers, we need to support teachers in addressing this increased pressure to de-emphasize evolution education.

Familiarity with Evolution Education Resources

To support K-12 teachers in teaching evolution, various professional organizations have created evolution education resources. The *Understanding Evolution* website is a collaborative project of the University of California Museum of Paleontology and the National Center for Science Education and includes the following sections: "Evolution 101," teaching materials, a resource library, and evolution updates (<http://evolution.berkeley.edu>). NSTA Press publishes many resources, including: *Evolution in perspective: The science teacher's compendium* (Bybee, 2004), *EVO teachers guide: Ten questions everyone should ask about evolution* (Bybee & Feldman, 2012), *NSTA Tool kit for teaching evolution* (Jensen, 2008), and *The creation controversy and the science classroom* (Skehan & Nelson, 2000). Although there

are many evolution resources available for little or no cost, we found no studies exploring teachers' familiarity or use of these resources.

Self-Reported Professional Development Needs

We found only a few studies that specifically asked biology teachers about their professional development needs in regard to teaching evolution, and these studies involved only small numbers of teachers. Griffith and Brem (2004), in a qualitative study of 15 biology teachers in Arizona, reported that teachers needed more up-to-date evolution and genomics information, a safe place to reflect with peers about the personal and social implications of teaching evolution, and evolution lesson plans which included implementation and reflection narratives. Schrein et al. (2009) reported 11 middle and secondary teachers checked the following reasons they attended an evolution workshop: to increase their knowledge of evolution, to learn about teaching resources, to learn more about the laws associated with the teaching of evolution, and to learn how to address the evolution/creationism controversy in their classrooms. In this study, we address this gap in the literature on professional development needs by surveying high school biology teachers, asking them to identify their professional development needs in regard to evolution teaching.

Study Purpose

Our overarching research question is: In regard to evolution, what are the professional development needs of secondary biology teachers who are currently teaching evolution? To explore this question, we developed the following sub-research questions:

- 1) What is the nature of teachers' self-reported understandings of specific evolution topics?
- 2) What is the nature of teachers' practice with regard to the amount of time spent on specific evolution topics?
- 3) What are biology teachers' perceived obstacles to evolution instruction?

- 4) How familiar are biology teachers with available evolution curricula and supplemental resources?
- 5) What are biology teachers' self-reported PD needs regarding teaching evolution?

Methodology

Context

State science standards can provide support for teaching evolution (Borgerding, 2012). Our survey data were collected from Missouri teachers in the fall of 2012. In 2005, Missouri's K-12 Science Standards earned a "C" in a report issued by the Thomas B. Fordham Institute (Gross et al., 2005). In comparison to other states, Missouri scored 3 out of 3 possible points on its emphasis on evolution across the K-12 state standards. However, the evolution emphasis at the high school level deserves closer scrutiny. Although evolution is included in the state's standards, it is not emphasized in the state high school biology assessment. (See Table 1.) Note that the majority of the evolution performance indicators are starred (*), indicating a local assessment item that is not included in the state assessment. For example, evidence for evolution is starred so it is not included in the state assessment. When the survey was given, the state had not adopted the *Next Generation Science Standards* (NGSS Lead States, 2013). In 2016, the state adopted a closely aligned version of NGSS.

Instrument

To assess biology teachers' professional development needs, we designed an online survey using Qualtrics. Two former high school biology teachers, three science education graduate students, one biology faculty member and one science education faculty member reviewed the survey questions; their feedback informed revisions that increased clarity. The 33 question survey asked teachers to report the following: 1) professional background including whether they had previously taken an evolution course; 2) their self-reported content understanding of a list of evolution

Table 1. Missouri High School Biology Standards, Strand 4: Changes in Ecosystems and Interactions of Organisms with their Environments

3. Genetic variation sorted by the natural selection process explains evidence of biological evolution.	
A.	Biology
Evidence for the nature and rates of evolution can be found in anatomical and molecular characteristic of organisms and in the fossil record.	<p>a. *Interpret fossil evidence to explain the relatedness of organisms using the principles of superposition and fossil correlation.</p> <p>b. *Evaluate the evidence that supports the theory of biological evolution (e.g., fossil records, similarities between DNA and proteins structures, similarities between developmental stages of organisms, homologous and vestigial structures)</p>
B. Reproduction is essential to the continuation of every species.	<p>a. *Define a species in terms of the ability to mate and produce fertile offspring.</p> <p>b. Explain the importance of reproduction to the survival of a species (i.e., the failure of a species to reproduce will lead to extinction of that species)</p>
C. Natural Selection is the process of sorting individuals based on their ability to survive and reproduce within their ecosystem.	<p>a. Identify examples of adaptations that may have resulted from variations favored by natural selection (e.g., long-necked giraffes, long-eared jack rabbits) and describe how that variation may have provided populations an advantage for survival.</p> <p>b. *Explain how genetic homogeneity may cause a population to be more susceptible to extinction (e.g., succumbing to a disease for which there is not natural resistance)</p> <p>c. Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection.</p> <p>d. *Given a scenario describing an environmental change, hypothesize why a given species was unable to survive.</p>

*Indicates a local assessment item.

Source: Missouri Department of Elementary and Secondary Education. *Science Course Level Expectations: Biology*, revised 11/24/08, p. 14.

topics; 3) the nature of their evolution teaching practice, including the amount of instructional time devoted to specific evolution topics, as well as their overall approach to evolution instruction (whether they taught evolution as a unifying concept throughout the year, as one stand-alone unit or both); 4) obstacles they perceived as barriers to their evolution instruction; 5) familiarity with a list of available evolution education resources; and 6) their self-reported PD needs for evolution instruction. The survey was composed of 33 Likert-type questions and took approximately 15 minutes to complete.

Data Collection

During fall 2012, survey invitations were sent via email to secondary science teachers in Missouri using email addresses obtained from our institution's Office of Social and Economic Data Analysis. (The database does not include the science discipline(s) taught by individual science teachers.) Four reminder emails (with the survey link embedded) were sent to non-respondents. Only surveys completed by respondents currently or recently teaching general biology and

who reported teaching evolution were considered in this analysis (N = 276).

Participants

The respondents' experience ranged from first year of teaching to 41 years of teaching experience, with an average of 11 years teaching experience. Ninety percent of the teachers were certified in biology or unified science with a biology emphasis, and 58% of the teachers had taken an evolution course. Eighty-one percent had a master's degree. Ninety-four teachers were NSTA members, 38 were members of the Science Teachers of Missouri, and 12 were members of the National Association of Biology Teachers. Fifty-nine percent of teachers were not members of any science teacher organization. Forty-four percent of teachers taught in suburban schools, 43% taught in rural schools, and 13% taught in urban schools.

Results

The results are reported in five sections: self-reported evolution content understanding, nature of evolution teaching practice, obstacles to teaching evolution, familiarity and use of supplementary resources, and self-reported professional development needs related to teaching evolution.

Self-Reported Evolution Content Understandings

Teachers were given a list of evolution topics and asked to rate their level of content understanding: no understanding, limited understanding, understanding adequate for teaching general biology, or in-depth understanding for advanced biology course. (See Figure 1 for the list of topics.) In general, approximately 80% of teachers self-reported having adequate or in-depth understanding of all the listed topics. The top three topics where teachers reported having no understanding or a limited understanding were cladograms/phylogenetic trees (19.6%), microevolution (15.9%), and contemporary examples of evolution in action (14.2%). All teachers reported having at least an adequate understanding of natural selection for teaching a general biology course, with 69.2% reporting an in-depth understanding for teaching an advanced biology course.

Nature of Evolution Teaching Practice

Teachers were asked if they taught evolution as a stand-alone unit, as a unifying theme, or as a unifying theme with a specific unit dedicated to evolution.

Thirty percent reported they taught evolution as a stand-alone unit. Ten percent reported teaching evolution throughout the year, but indicated they do not dedicate a unit to evolution instruction. Sixty percent reported teaching evolution as a unifying theme with one unit also dedicated to evolution.

Teachers were also asked to identify the amount of time they spent teaching each topic in a list of evolution topics. The options were: not taught, less than 50 minutes, 50-150 minutes, and more than 150 minutes. Figure 2 shows the breakdown of the time teachers spend on selected evolution topics. The top five least taught evolution topics were: human evolution (26.8%), cladograms/phylogenetic trees (23.6%), origin of life (21.7%), microevolution (18.8%), and geological timelines (17.4%).

Natural selection and nature of science were the most taught topics. The largest percentage of teachers devoted a whole class period or more to natural selection (93.5%) and nature of science (67%). All teachers (100%) taught natural selection. Interestingly, a larger percentage of teachers report devoting more time (50-150+ minutes) on macroevolution/speciation (50%) over microevolution (38.4%). Over all, more than 75% teachers report teaching all topics except human evolution, which 26.8% reported not addressing.

Obstacles to Teaching Evolution

The majority of teachers (91.4%) rated the listed potential obstacles as either not an obstacle or an obstacle they could easily overcome on their own. (See Figure 3.) Specifically, teachers identified the

following topics as either not an obstacle or an obstacle they could overcome on their own: poor textbooks (81.2%), fear of controversy (84.1%), negative student responses (84.1%), lack of support from parents/community (85.6%), evolution not being emphasized on the state tests (86.2%), lack of content understanding (91%), and lack of support from administration (93.2%). Only 4.3% of teachers reported a conflict with their personal acceptance of evolution as a great obstacle that hinders their instruction or a constant obstacle they struggle with, and only 12.5% reported lack of support from their departments and peers as either a great obstacle that hinders their instruction or an obstacle with which they constantly struggle.

Teachers identified the lack of good labs and supplemental materials as their two biggest obstacles to teaching evolution. Specifically, 38.8% of teachers rated lack of good labs as either a great obstacle that hinders their instruction or a constant obstacle they struggle with, and 34.1% rated lack of supplemental materials as a great obstacle or a constant obstacle to their evolution teaching.

Familiarity and Use of Supplemental Resources

In general, teachers were not familiar with supplemental materials. In the survey we listed commonly available supplemental evolution education materials, including print materials and websites. (See Figure 4.) To help teachers complete this section of the survey, we listed both the title and an image of the resource (i.e., screen capture of website or front cover of print material). Over 60% of teachers reported they were not familiar with 8 of the 9 resources listed in Figure 4.

If we go beyond familiarity to actual use of resources, combining the two categories of “not familiar” and “somewhat familiar, but have not used,” the percentages are: *The Creation Controversy and the Classroom* (95.6%); *Science, Evolution, and Creationism* (92.8%); *NSTA Toolkit for Teaching Evolution* (94.9%); *Teaching about Evolution and the Nature of Science* (89.1%); *NSTA’s*

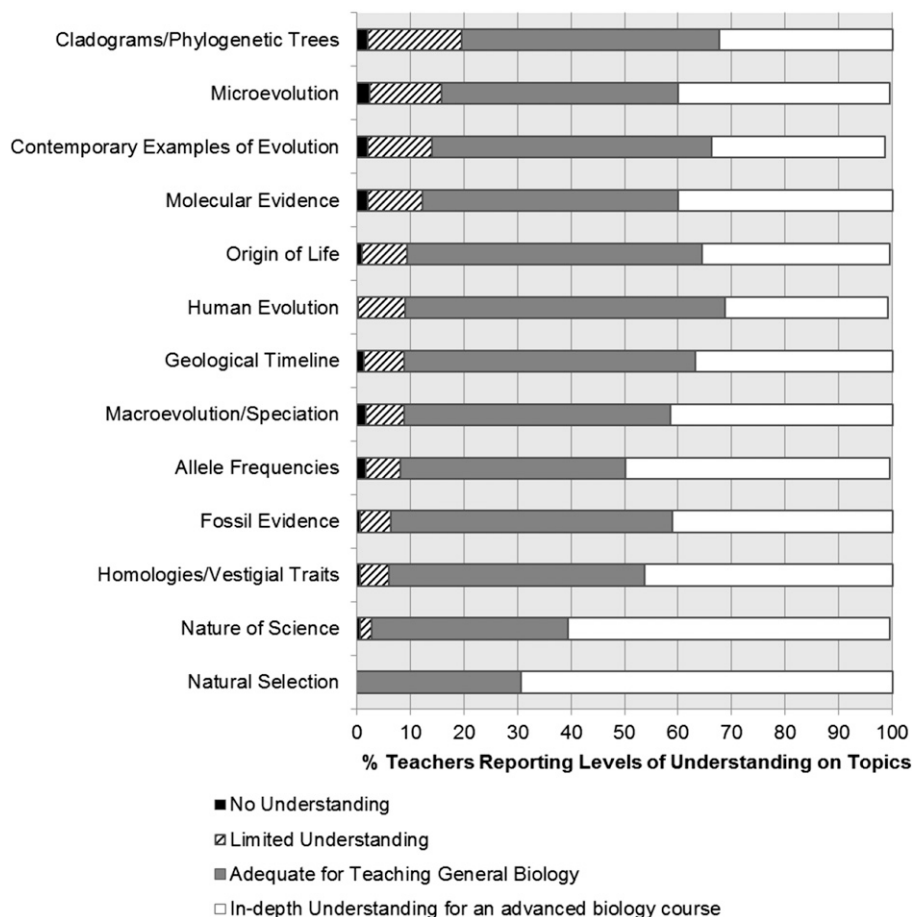


Figure 1. Self-reported evolution content understandings. Bars may not reach 100% due to missing responses for a particular item

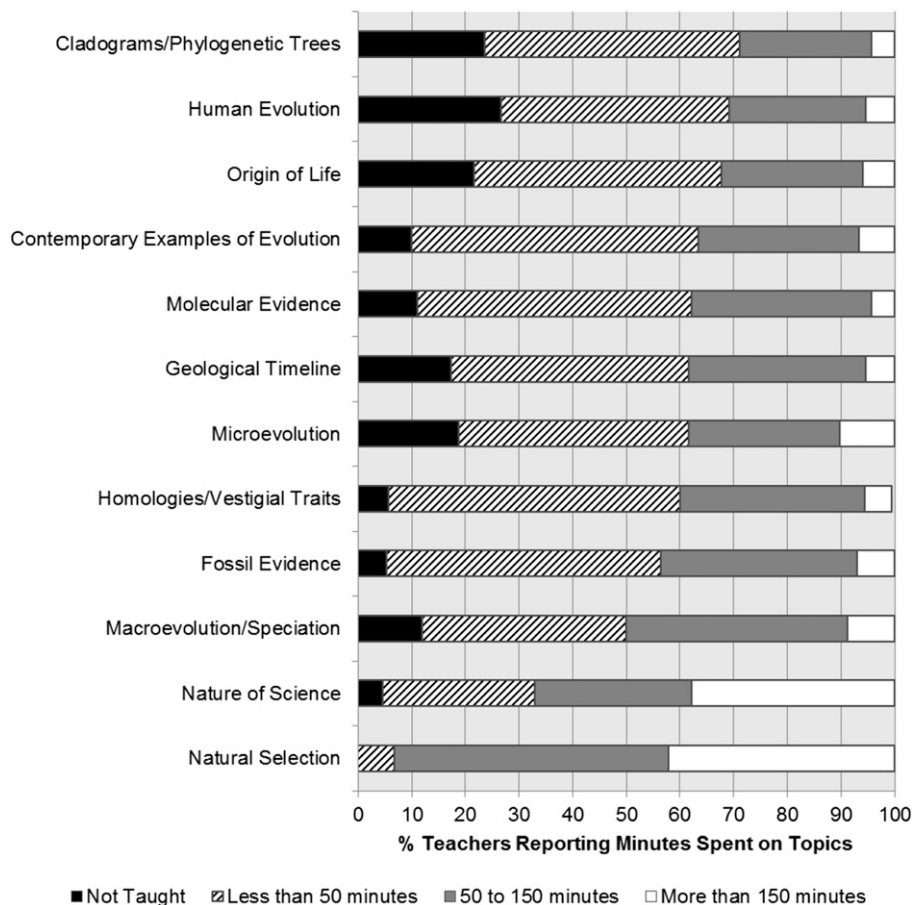


Figure 2. Nature of teacher practice represented in minutes spent per topic

An Inquiry into Biological Evolution (88.4%); *Institute of Human Origins* website (84.5%); *How Science Works* website (83.4%); *Understanding Evolution* website (76.1%). The exception to this trend was the PBS Nova *Evolution* website, only 47.4% of the teachers reported being unfamiliar or never using it despite being familiar. Although teachers were most familiar with the PBS Nova *Evolution* website, it was used regularly by only 28.3% of teachers.

Self-Reported PD Needs

Teachers were given a list of potential topics for a professional development workshop. (See Figure 5). Teachers were asked to rate the degree of emphasis they preferred be placed on each topic: great, some or no emphasis. Over 80% of teachers asked for some or great emphasis being placed on each of the listed topics. Over 66.3% of teachers asked for

great emphasis to be placed on both current research in evolution and labs/investigations that used real data and/or live organisms. Teachers also wanted great emphasis placed on evolution simulations related to evolution (57.2%). All teachers (100%) requested emphasis on contemporary evolution examples. Teachers showed almost equal interest in evolution on the Missouri biology standards (34.4%) and evolution in the Frameworks and NGSS (37%). Teachers were least interested in writing evolution assessment items, with 17.4% of teachers asking for no emphasis.

Discussion

Self-Reported Evolution Content Understandings

Over 80% of teachers reported either an adequate or in-depth understanding

of all the listed evolution topics. There are several possible explanations for this finding. Teachers who complete an evolution course are more likely to teach evolution (Aguillard, 1999; Berkman & Plutzer, 2011). In our sample, 58% of teachers had taken an evolution course. This may partially explain the high level of self-reported evolution content understanding. The nature of the sample, secondary biology teachers who were teaching evolution, may also be part of the explanation. From teaching experience, the teachers were familiar with the listed evolution topics. A closer look at their teaching practice may offer additional insights. A majority of teachers are spending less than a class period (<50 minutes) on an individual evolution topic. For example, 69.2% of the teachers did not teach human evolution or spent less than one 50-minute class period. Perhaps this explains why 90.2% of teachers self-reported they had either adequate understanding of human evolution for teaching general biology or in-depth understanding for teaching an advanced biology course. Teachers may be self-reporting their content understanding as adequate for the limited amount of time they spend on an individual topic.

We were interested in teachers' understanding of the nature of science, as understanding of the nature of science has been positively correlated with willingness to teach evolution (Trani, 2004). In this study, 36.6% reported having an adequate understanding of nature of science, while 60.1% reported an in-depth understanding. Many previous studies report secondary biology teachers have misconceptions about the nature of science (e.g., Jackson et al., 1995; Nehm et al., 2009). We caution professional developers in interpreting the teachers' self-reported high levels of understanding of the nature of science and evolution topics for the reasons stated above, as well as the self-reported nature of the data. Previous studies, in which teachers' content understanding is directly assessed, report secondary biology teachers have misconceptions about evolution (e.g., Alexandre, 1994; Nehm et al., 2009; Nehm & Schonfeld, 2008) and

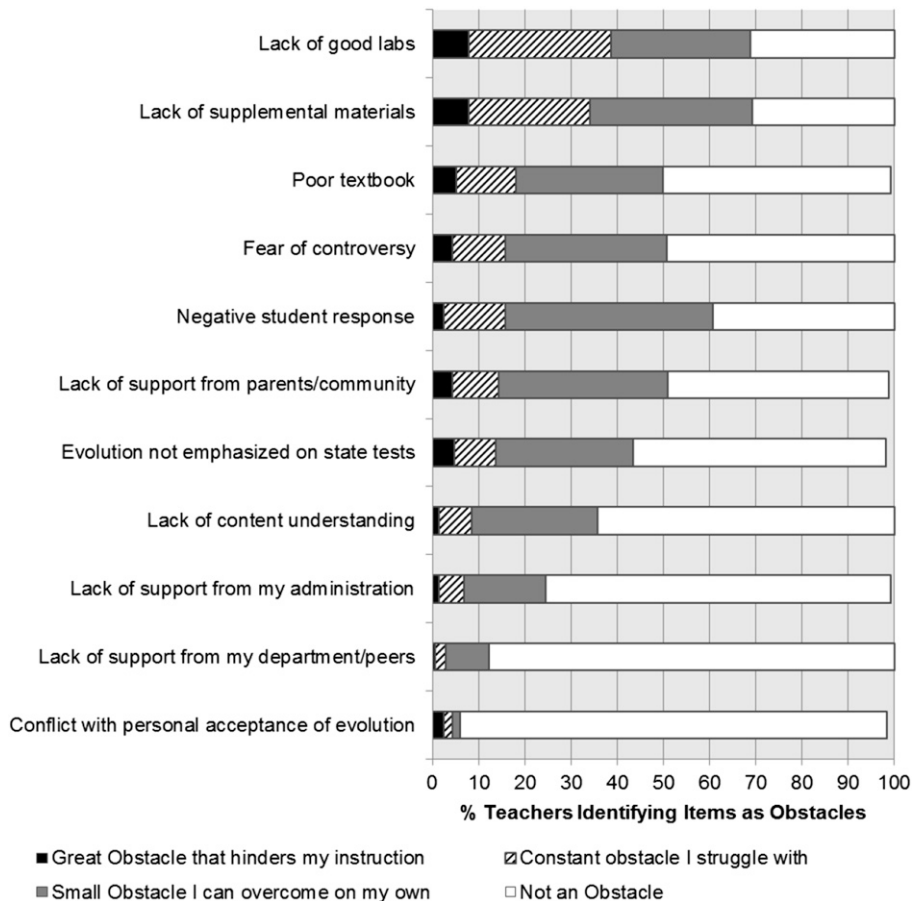


Figure 3. Perceived obstacles to teaching evolution. Bars may not reach 100% due to missing responses for a particular item

the nature of science (e.g. Jackson et al., 1995; Nehm et al., 2009). Teachers may not be aware of their own misconceptions or they may be self-reporting their understanding as being adequate based on the limited amount of time they devote to individual evolution topics.

Nature of Evolution Teaching Practice

The *Next Generation Science Education Standards* (NGSS Lead States, 2013) identifies evolution as a disciplinary core idea. Understanding evolution is critical to developing biological literacy. To represent this foundational theory in biology, the National Association of Biology Teachers' Position Statement on Teaching Evolution recommends teachers use a thematic approach in teaching evolution across the biology curriculum (<http://www.nabt.org/websites/institution/?p=92>). In our study, 30% of the teachers did not use a thematic approach and reported teaching evolution as a separate, stand-alone unit. When evolution is taught as one of many curricular units, students may not recognize evolutionary theory as the organizer of the discipline. The findings of this study point to a need for PD to help teachers develop a thematic approach to teaching evolution across the biology curriculum.

On a positive note, 60% of the teachers in this study reported teaching evolution as a theme in their biology course, as well as teaching an evolution unit. Nationally, only 23% of teachers agreed that evolution is represented as a theme in their courses (Berkman et al., 2008). The higher percentages reporting a theme-based approach to teaching evolution may be due to our sample of biology

teachers who teach evolution. However, if we look closer at teachers' reported practices, one begins to question the thematic nature of their practice. We asked teachers to report the approximate amount of time they spent teaching specific evolution concepts. All teachers reported teaching natural selection and the majority of them (93.5%) spent 50 minutes or more teaching this mechanism. The focus on the mechanism of natural selection aligns with past surveys of teachers' practice (Aguillard, 1999; Borgerding, 2012; Schulteis, 2010). With the exceptions of natural selection and the nature of science, 50% or more of teachers spent less than 50 minutes teaching macroevolution/speciation, fossil evidence, homologies/vestigial traits, microevolution, geological timeline, molecular evidence, contemporary examples of evolution, origin of life, cladograms/phylogenetic trees and human evolution. For human evolution, 26.8% of teachers did not teach this topic; this finding is in agreement with other studies reporting human evolution is given little or no time in high school biology classrooms (Berkman et al., 2008; Borgerding, 2012; Schulteis, 2010; Shankar & Skoog, 1993). Although the mechanism of natural selection drives evolution, the lack of attention to other evolution topics calls into question the thematic evolution approach claimed by 60% of the teachers in the study.

After human evolution, cladograms/phylogenetic trees was the least taught topic. In modern biology, the use of phylogenetic trees is widespread across the sub-disciplines and tree-reading skills are considered essential for understanding evolution (Baum & Offner, 2008; Gregory, 2008). However, 23.6% of the teachers in this study did not teach this topic and 47.5% spent less than 50 minutes teaching phylogenetic trees. Among Ohio teachers, Borgerding (2012) reported cladistics is one of the least taught topics. Teaching students how to interpret these powerful representational tools is critical to developing biological literacy (Halverson & Friedrichsen, 2013). Although 80.4% of the teachers reported adequate or in-depth understanding of

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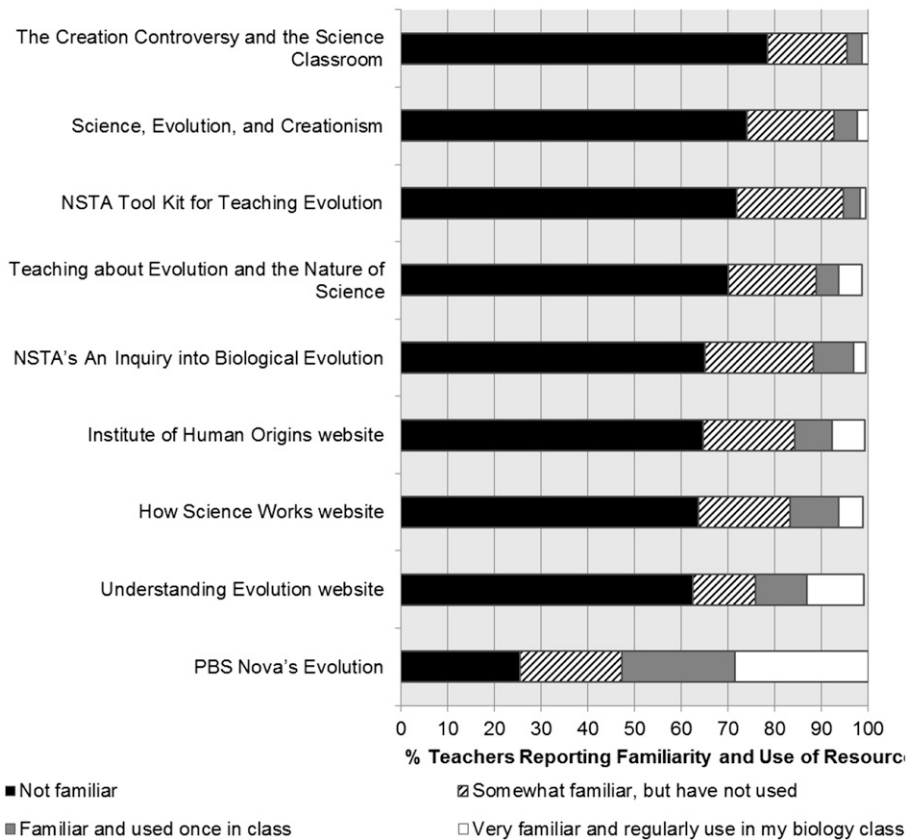


Figure 4. Familiarity with evolution education resources. Bars may not reach 100% due to missing responses for a particular item

cladograms/phylogenetic trees, they are not placing an emphasis on developing tree-thinking skills. There are several possible explanations: (a) teachers' undergraduate coursework may not have emphasized phylogenetics; (b) their current high school biology textbooks might not emphasize tree-reading; and (c) the state biology standards do not include phylogenetics. The results of the study indicate a need for professional development related to teaching tree-thinking skills.

Related to phylogenetics, teachers are spending little time teaching macroevolution/speciation. Fifty percent of teachers in this study reported either not teaching the topic or spent less than 50 minutes on it. The term "macroevolution" refers to two phenomena: evolutionary processes above the species level and large-scale evolutionary change (e.g., fish-tetrapod transition), while the

term "microevolution" refers to changes in gene frequency within a populations and species (Herron & Freeman, 2014). Knowledge of macroevolution has been correlated to college students' acceptance of evolution, both for biology majors (Nadelson & Southerland, 2010) and non-science majors (Walter, 2013). To understand evolution, one must have an understanding of both microevolution and macroevolution. Catley (2006) called for a paradigm shift in evolution education, giving equal weight to teaching microevolution and macroevolution. Although over 90% of the surveyed teachers reported having either an adequate or an in-depth understanding of macroevolution, only 8.7% spent more than 150 minutes teaching macroevolution. Professional development should emphasize the need to teach macroevolution and help teachers explore instructional resources for teaching this topic.

Obstacles to Teaching Evolution

Many obstacles to teaching evolution have been reported in the literature, including lack of personal acceptance (e.g., Berkman et al., 2008), as well as student and parental pressure to omit evolution (NSTA, 2005). The results of this study differ in that the respondents were teaching evolution and had overcome those obstacles. Only 4.3% of teachers reported personal acceptance as either a great obstacle that hindered their instruction or an obstacle they struggled with constantly. Additionally, small numbers of teachers perceived lack of parental/community support (14.4%) and negative student response (15.9%) to be either a great obstacle that hindered their instruction or an obstacle with which they struggled constantly. This study contributes to the literature by focusing on the teachers who are teaching evolution and reporting the specific obstacles they would like help overcoming. The greatest obstacles identified by teachers were lack of good labs and supplemental materials. The findings from this study point to the need to assess teachers' current evolution teaching practices in regard to their professional development needs. Based on this study, experienced biology teachers teaching evolution perceived lack of good labs and supplemental materials as their greatest obstacles. The next section examines teachers' familiarity with available evolution education print materials and websites.

Familiarity with Resources

Overall, few of the teachers were familiar with available evolution education resources. Many excellent evolution education materials have been created to help teachers teach evolution; two examples are the *Tool Kit for Teaching Evolution* (Jensen, 2008) and the website, *Understanding Evolution* (www.evolution.berkeley.edu). We found no other studies that examined biology teachers' familiarity with evolution education resources. This study contributes to the literature by its finding that few secondary biology teachers are familiar with and use available evolution education materials. Results from this study

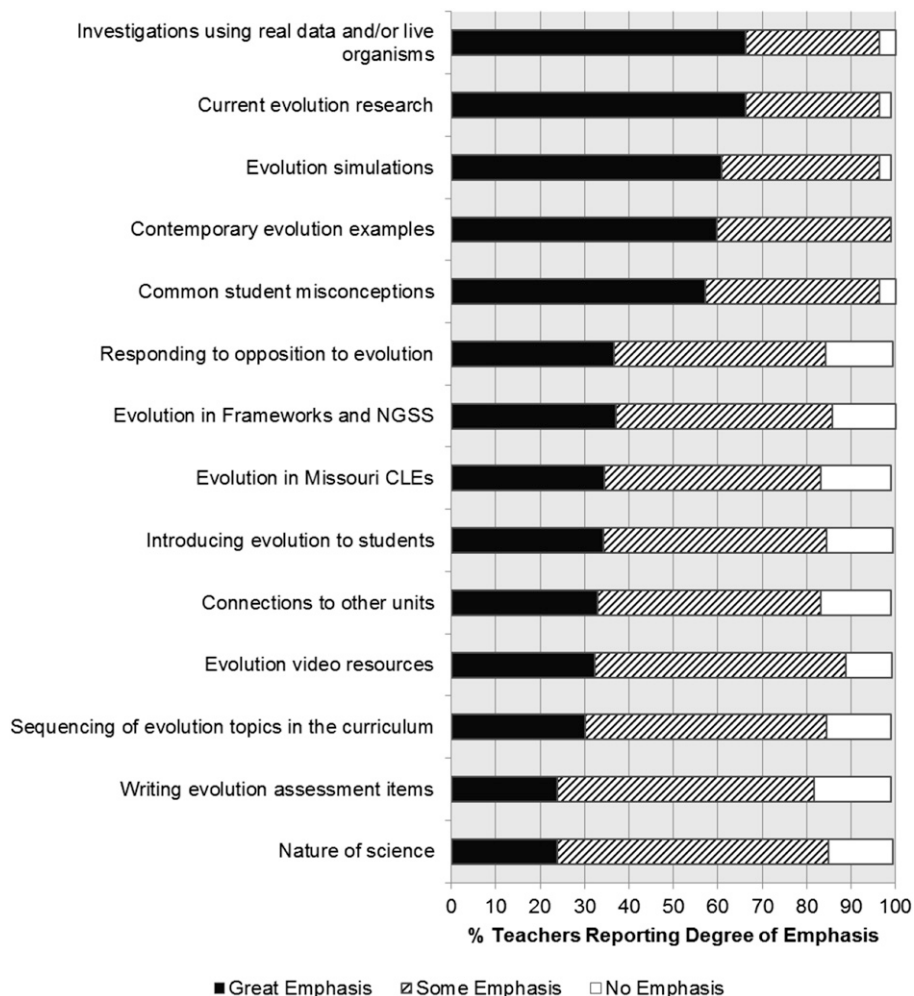


Figure 5. Self-reported evolution professional development (PD) needs. Bars may not reach 100% due to missing responses for a particular item

indicate that professional development should familiarize teachers with the excellent evolution education resources that are readily available.

Self-Reported PD Needs

We elicited teachers' self-reported PD needs by asking them to indicate the degree of emphasis they would prefer be placed on individual evolution topics in a PD workshop. Only a few studies have elicited biology teachers' self-reported evolution PD needs (Griffith & Brem, 2004; Schrein et al., 2009) and these studies involved small numbers of teachers, N=15 and N=11 respectively. This study contributes to the literature by using a statewide sample (N= 276) to elicit secondary biology

teachers' PD needs. Overall, 82% or more of teachers wanted "some emphasis" or "great emphasis" placed on every listed topic. We interpret this finding as indicative of secondary biology teachers' interest in evolution education PD.

The five most highly ranked topics were: investigations using real data and/or live organisms, current evolution research, contemporary evolution examples, evolution simulations, and common student misconceptions related to evolution. For each of these topics, over 80% of the teachers wanted great or some emphasis placed on these topics. "Evolution in Frameworks & NGSS" was the sixth highest ranked item even though Missouri had not adopted NGSS at the time.

These findings offer guidance to professional developers in designing PD for biology teachers who are teaching evolution.

Although the majority of teachers reported that negative responses from parent/community and students were not great obstacles, 36.6% preferred great emphasis and 47.5% preferred some emphasis be placed on responding to opposition to evolution. One possible explanation is that teachers are interested in learning how others handle opposition to evolution education. Although 96.7% of teachers reported being knowledgeable in teaching the nature of science, 84.8% indicated they would like some or great emphasis placed on this topic in a PD workshop. One possible explanation for the discrepancies seen between teachers' self-reported knowledge and their self-reported PD needs is that many secondary teachers view themselves as content experts (Beijaard, Verloop, & Vermunt, 2000) and might consequently, self-report high levels of knowledge in teaching most topics in the biology curriculum. However, when asked anonymously to report their preference for specific topics for PD, they indicate an interest in PD related to the nature of science and addressing opposition to evolution.

Conclusion and Implications

We need to focus on the professional development needs of biology teachers who are teaching evolution and provide support in light of increasing anti-evolution pressure. This study contributes to the literature in several ways. First, it identifies a lack of good labs and supplemental materials as the greatest obstacles faced by teachers teaching evolution. Second, secondary biology teachers are unfamiliar with the wealth of available evolution education resources. Third, the teachers in the survey reported being interested in many different aspects of PD, with the top five most highly ranked topics being investigations using real data and/or live organisms, current evolution research, contemporary evolution examples, evolution simulations, and common student misconceptions related to evolution. Based on the findings of this study,

we offer the following recommendations for PD for secondary biology teachers:

1. Assess biology teachers' current evolution teaching practices and their PD needs. Based on their current practice, teachers may have differing PD needs.
2. Use content assessment items to assess teachers' content knowledge and uncover their misconceptions, including nature of science misconceptions.
3. Emphasis phylogenetics and developing students' tree-thinking skills.
4. Emphasis the need to teach macroevolution and explore instructional materials for teaching macroevolution.
5. Help teachers develop a rationale for teaching evolution as a theme in their biology courses and explore what this means. Working in small groups, teacher could brainstorm evolution connections across the curriculum and develop short evolution connection materials to share with each other. As a starting point, the *Understanding Evolution* website (<http://evolution.berkeley.edu/>) includes a section on curricular connections. The materials include short sets of slides illustrating evolution connections to a variety of other topics, including DNA replication, mitochondria, photosynthesis, organic compounds, and protein synthesis
6. Provide teachers with supplemental materials, labs and resources for teaching evolution, and allow time to explore these materials. Consider forming study groups in which teachers explore various evolution education materials. Promote the exploration and classroom use of excellent web-based evolution education resources, such as the *Understanding Evolution* website.
7. In developing PD workshops for biology teachers teaching evolution, place a greater emphasis on investigations using real data and/

or live organisms, current evolution research, contemporary evolution examples, evolution simulations, and common student misconceptions related to evolution.

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