From Conflict to Common Ground:

Establishing Religious Cultural Competence in Evolution Education (ReCCEE)

by

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ABSTRACT

Evolution is the foundation of biology, yet it remains controversial even among college biology students. Acceptance of evolution is important for students if we want them to incorporate evolution into their scientific thinking. However, students' religious beliefs are a consistent barrier to their acceptance of evolution due to a perceived conflict between religion and evolution. Using pre-post instructional surveys of students in introductory college biology, Study 1 establishes instructional strategies that can be effective for reducing students' perceived conflict between religion and evolution. Through interviews and qualitative analyses, Study 2 documents how instructors teaching evolution at public universities may be resistant towards implementing strategies that can reduce students' perceived conflict, perhaps because of their own lack of religious beliefs and lack of training and awareness about students' conflict with evolution. Interviews with religious students in Study 3 reveals that religious college biology students can perceive their instructors as unfriendly towards religion which can negatively impact these students' perceived conflict between religion and evolution. Study 4 explores how instructors at Christian universities, who share the same Christian backgrounds as their students, do not struggle with implementing strategies that reduce students' perceived conflict between religion and evolution. Cumulatively, these studies reveal a need for a new instructional framework for evolution education that takes into account the religious cultural difference between instructors who are teaching evolution and students who are learning evolution. As such, a new instructional framework is then described, Religious Cultural Competence in Evolution Education (ReCCEE), that can help instructors teach evolution in a way that can reduce students' perceived conflict between religion and

evolution, increase student acceptance of evolution, and create more inclusive college

biology classrooms for religious students.

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CHAPTER 1

INTRODUCTION

Evolution is important to biology, yet controversial in society. Evolution is widely

cited as the overarching theoretical framework of the entire discipline of the biological

sciences. Yet, public polls over the last thirty years show that around half of the public

rejects evolution, particularly the evolution of humans and the common ancestry of life

on Earth (Gallup, 2014). Further, this rejection of evolution is not limited to the lay

public, even in college biology courses for majors, students who reject evolution can

comprise a significant proportion of the classroom (Ingram & Nelson, 2006).

While a significant proportion of college biology students can reject evolution,

acceptance of evolution is an important educational outcome for these students. Studies

show that a student can learn the facts and processes of evolution and still choose not to

accept evolution as fact (Hermann, 2012). However, if a student understands but does not

accept evolution, then they are unlikely to use this knowledge in their scientific thinking

(Sinatra, 2013). Further, students who do not accept evolution will be unlikely to engage

with evolution beyond the necessities of their courses, which will further limit their

understanding of evolution overtime.

If understanding evolution does not necessarily lead to acceptance of evolution,

then how can biology instructors foster acceptance of evolution among their students?

Studies consistently show that students' religiosity, or the extent to which they are

committed to religious beliefs, are often the most predictive factor for whether a student

will choose to accept evolution (Barnes, Evans, Hazel, Brownell, & Nesse, 2017; Dunk,

Petto, Wiles, & Campbell, 2017; Glaze, Goldston, & Dantzler, 2014; Ha, Haury, &

Nehm, 2012; Rissler, Duncan, & Caruso, 2014). This is likely the result of complex historical and cultural narratives that have conceptualized evolution as necessarily in conflict with religious beliefs, particularly in the United States (Numbers, 2006). However, students may be able to conceptualize evolution and their religious beliefs as compatible, and this can help increase their acceptance of evolution (Gould, 1999; Settlage & Southerland, 2007; Southerland & Scharmann, 2013).

Since religiosity is the main factor in predicting whether a student will accept evolution and changing students' religious beliefs is unlikely and may be perceived as unethical by some instructors, many researchers have hypothesized that decreasing perceived conflict between religious beliefs and evolution may be the best way to increase student acceptance of evolution. Some researchers hypothesize that it is a person's *perception* that their specific religious beliefs conflict with evolution that is the main barrier to accepting evolution, and not religiosity itself (Kahan & Stanovich, 2016; Wiles & Alters, 2011). In fact, it is likely that this is the very reason we see high rates of rejection of evolution in some religious denominations but not others; if individuals within a religious denomination perceive a greater conflict between evolution and their religious beliefs, then their acceptance of evolution will be lower. If students conceptualize their religious beliefs in a way that does not necessarily conflict with evolution, it increases the probability of them accepting evolution. For instance, if a student concludes that evolution does not preclude the existence of a God/god(s), this may help these students become more accepting of evolution. Indeed, preliminary unpublished data from an upper level evolution course (n=319) at a secular university and an upper level genetics course at a Christian university (n=33) indicate that if students

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perceive conflict between religion and evolution, then they are more likely to have lower levels of acceptance of evolution (r=. -45 and -.57 respectively, p<.001). Therefore, instructors may be able to increase students' acceptance of evolution by helping to decrease perceived conflict between religion and evolution among their students.

Chapter 2 of this dissertation describes a study that was published in *The American Biology Teacher* that explores whether instructors may be able to help students reduce perceived conflict between religion and evolution (Barnes, Elser, & Brownell, 2017). In this study three instructional practices were explored that may reduce perceived conflict between religion and evolution among students. These practices included providing students with examples of scientists who are both religious and accept evolution, increasing student awareness of the variety of viewpoints on the relationship between religion and evolution, and teaching students the bounded nature of science. Using pre-post instructional surveys from students, we found that these instructional strategies were able to reduce the number of students who perceived a conflict between religion and evolution by fifty percent. However, the question remained whether instructors who were teaching evolution used these practices.

Chapter 3 describes a study that was published in *CBE Life Sciences Education* to answer the question of whether evolution instructors at public colleges were using practices to reduce student perceived conflict with evolution (Barnes & Brownell, 2016). Interviews with these instructors revealed that they struggled to implement practices shown to reduce students' conflict between religion and evolution. First, instructors often did not see increasing student acceptance of evolution as a goal when teaching, which made reducing perceived conflict between religion and evolution an unlikely goal as

well. Further, instructors cited their own lack of religious beliefs and lack of training in addressing issues related to religion and evolution as reasons for not implementing instruction that could help reduce students' perceived conflict. Instructors also revealed negative stereotypes about religion and religious individuals that could prevent them from implementing effective instruction for religious students. However, it was still unclear how religious students perceived their instruction from public college instructors who were not implementing practices that could reduce students' conflict between religion and evolution.

Chapter 4 describes a study that was published in *CBE Life Science Education* that illustrates the perspectives of religious students who are learning evolution at public colleges (Barnes, Truong, & Brownell, 2017). Through interviews, it was found that religious students perceive that their instructors have negative attitudes towards religion and that this is a barrier to their learning of evolution. Further, it was found that when these students experienced evolution instruction in which the instructor did not mention religion at all, students still assumed that the instructor had negative attitudes towards religion and that there was a conflict between religious beliefs and evolution. Students described learning evolution "just for the grade" and subsequently "forgetting" evolution.

These three studies illustrated that there were instructional practices that could help reduce students' perceived conflict between religion and evolution. However, it was also identified that public college instructors are not using these practices and that the instructors' own personal religious background, or lack thereof, may be influencing whether or not they are using these practices Further, it was identified that religious students are aware of religious differences between themselves and their instructors and

they cited instructors' negative attitudes towards religion as a barrier to their learning of evolution. These studies started to indicate that perhaps the difference between the religious cultures and backgrounds of evolution instructors and their students may be an important factor to consider when examining the current state of evolution education. To explore this possibility, it was thought that perhaps instructors who share similar religious cultural backgrounds and beliefs as their students may exhibit different patterns with regards to their use of practices that can reduce student perceived conflict between religion and evolution.

Chapter 5 describes a study that was published in *Science Education* in which the practices of evolution instructors at Christian universities were explored (Barnes & Brownell, 2017). This is a unique situation in evolution education because most instructors teaching evolution at Christian universities self-identify as Christian and so do their students. Therefore, we were able to explore evolution education in the unique context of when evolution instructors and students share similar Christian cultural and religious backgrounds and beliefs. Through interviews, it was identified that instructors teaching evolution at Christian universities were overwhelmingly using practices that can reduce students' perceived conflict between religion and evolution. These instructors did not exhibit the same struggles with implementing these practices as their public college instructor peers. When these instructors teaching evolution at Christian universities were asked why they were using practices to reduce students' perceived conflict with religion and evolution, they cited their own religious cultural backgrounds, including their experiences having to reconcile religion and evolution, as driving their instructional decisions.

Cumulatively, these studies began to indicate that instructors may need to take into account how their own personal religious backgrounds and beliefs may be influencing their evolution instruction. Specifically, it may be the case that non-religious instructors inadvertently create suboptimal learning environments for their religious students by not implementing instruction that can help reduce these students' perceived conflict between evolution and their religious beliefs. These findings led to the creation of a new instructional framework that encourages instructors to use cultural competence when teaching evolution.

Chapter 6 was published in *CBE Life Sciences Education* and describes this new instructional framework, called Religious Cultural Competence in Evolution Education or "ReCCEE" (Barnes & Brownell, 2017a). This framework includes a suite of evidence-based practices that instructors can use to help reduce students' perceived conflict between religion and evolution. Further, by framing evolution education as an area in need of cultural competence, instructors are encouraged to consider religious cultural differences between themselves and their students, and how these differences may contribute to instructors who do not take into account their students religious background when teaching evolution.

Chapter 7 concludes with suggestions for future research directions to establish ReCCEE as a robust framework for evolution education. From a literature review of over 300 articles that examine student acceptance of evolution, we find that more research needs to be conducted to determine which ReCCEE practices are most effective in which educational contexts. While current studies are promising for preliminary indications of the effectiveness of various ReCCEE practices, more robust studies using quasi-

experimental designs, standardized outcome measures, and diverse populations are

needed to establish ReCCEE as effective across different educational contexts.

CHAPTER 2

IMPACT OF A SHORT EVOLUTION MODULE ON STUDENTS' PERCEIVED

CONFLICT BETWEEN RELIGION AND EVOLUTION

M. Elizabeth Barnes, James Elser, and Sara Brownell

Abstract

Evolution has historically been a topic in biology that is fraught with controversy, and a conflict between religion and evolution is often assumed. If students perceive that evolution is in conflict with their religious beliefs, it can have negative ramifications for their learning of evolution and attitudes toward science. However, religion and evolution have been argued to be compatible. An instructor can incorporate a discussion of this compatibility into their teaching, but the impact of this on students' perceptions of compatibility is still unknown. In this study, we describe a two-week module on evolution with embedded discussion about compatibility between religion and evolution. We surveyed introductory biology students before and after this evolution module about whether they thought evolution and religion could be compatible. We found that the evolution module reduced the number of students who perceived a conflict between evolution and religion by 50 percent. Unexpectedly, perceived conflict between religion and evolution was reduced for both religious and nonreligious students. These results indicate that how instructors present a module on evolution can have an impact on student perceptions of compatibility between religion and evolution.

Introduction

Evolution is a core concept of biology (AAAS, 2011; Brownell et al., 2014) and should be a foundational component of any introductory biology class. However, there is variation in what components of evolution are taught in biology courses, how much of a course is dedicated to evolution, and whether the perceived conflict between evolution and religious beliefs is addressed (Smith, 1994; Southerland & Scharmann, 2013). Religion and evolution are thought to be incompatible by many people in the public eye, including some religious leaders (Ham, 2010), scientists (Coyne, 2015; Dawkins, 2009; Harris, 2005), and politicians (Satlin, 2012). However, despite the seemingly prevalent viewpoint that religion and evolution are incompatible, there are many examples of how evolution and religion can be reconciled.

Evolutionary biologist Stephen J. Gould and others articulated the Non-Overlapping Magesteria (NOMA) framework in which religion and science do not conflict because they operate within two nonoverlapping domains of knowledge (Barbour, 1990; Gould, 1999). In addition, religious biologists have written on how evolution and religion can be reconciled in the form of theistic evolution, in which evolution is the mechanism used by a God/god(s) (Collins, 2006; Miller, 2002). Even religious leaders have agreed that religion and evolution do not have to be in conflict, including Pope Francis, who in 2014 stated that "Evolution in nature is not inconsistent with the notion of creation" (Tharoor, 2014). In fact, many denominations of Christianity have official stances that are either neutral or supportive of evolution (The Clergy Letter Project, 2016). Whether an instructor in a biology class presents evolution and religion as compatible is potentially important because it could impact how some religious students

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feel in biology classes. If instructors highlight only the conflict between religion and evolution, this may make religious students feel as if their religious beliefs have to be incompatible with evolution and biology.

If a student has religious beliefs that are important to their identity, perceiving that evolution is in conflict with those beliefs may influence that student's sense of belonging in biology. A lower sense of belonging can influence student retention in biology (Good, Rattan, & Dweck, 2012). If instructors choose to completely avoid the topic of religion and evolution, they may inadvertently solidify students' conceptions that religion and evolution are in conflict (Smith, 1994). Prior research shows that when instructors do not address religion when teaching evolution, it makes religious students feel excluded (Hermann, 2012). However, we do not know how students in biology classes feel when instructors present evolution and religion as potentially compatible and if students' perceptions of the relationship between evolution and religion change in response to this instruction.

In this study, undergraduate biology majors were taught evolution in a two-week module that included portraying evolution and religion as potentially compatible for students. Student perceptions of the compatibility of religion and evolution were determined before and after the evolution module. We also explored whether students were uncomfortable with discussions of religion in the module or whether they appreciated this discussion in order to determine whether these discussions were appropriate.

We also measured student religiosity to determine if the module had differential effects on religious and non-religious students. Religiosity was defined as the extent to

which a student thinks that their religion is an important part of their identity coupled with how often they participate in religious activities. We did not disaggregate religious students by denomination because polls show that regardless of denomination, individuals in the United States often perceive a conflict with evolution. For instance, although the Catholic Church officially has a pro-evolution stance, 42% of the Catholic population still rejects evolution (Pew, 2009). Further, although the LDS church has a neutral stance on evolution, 72% of the LDS population rejects evolution (Pew, 2009). Therefore, asking students about their level of religiosity coupled with whether they perceived a conflict with evolution and their religious beliefs was more indicative of a student's religious identity and position about evolution than was their religious denomination.

Course characteristics

The study took place in an introductory majors' biology course at a large public university located in the southwest United States. The course was held three times per week. Twice per week the class met for 70 minutes and once per week the class met for 50 minutes. The course design was a "flipped class" where students were assigned readings and videos to introduce them to the material before coming to class (Jensen, Kummer, & Godoy, 2015). The normal weekly schedule of the class involved the following: (1) During the first class session of the week, students took a quiz covering the previous week's material, were given an overview of the coming week's materials, and then, as a class, met with a guest scientist (in person or via videoconference), (2) During the second and third class session of the week, students were given a mini-lecture that briefly reviewed the material students explored for homework, instruction on how to

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complete in-class learning activities, and then the majority of the time was spent on student-centered group activities that were also based on the concepts that they were assigned in their reading and video homework.

Student population. There were 95 students enrolled in the course during the two weeks in which the study was conducted. Of the 95 students enrolled, 60 (63%) completed pre and post module surveys. The majority of students in the course were first year students and they received extra credit for participating in the study, but were informed that their specific responses did not have any impact on their grade.

Characteristics of the Evolution Module

Learning objectives from the evolution module can be found in **Table I**.

Table I: Course learning objectives for a two-week module on evolution.

Science Concepts
• Students can describe and distinguish creationism, spontaneous generation, and evolution.
• Students can evaluate and summarize evidence including the fossil record, homologous traits, vestigial traits, biogeography, and experimental data to assess the validity of the three hypotheses stated in the learning objective above.
• Students can describe the theory of uniformitarianism and understand its contribution to the development of the theory of evolution.
Natural Selection
• Students can explain how evolution/diversification can account for hierarchy of shared characteristics (including homologous traits, vestigial traits)
• Students can describe Darwin's idea of how heritable variation and limits on reproductive success result in differential reproduction (natural selection) and thus evolution.
• Students can propose explanations for the rise of adaptations that are consistent with evolution by natural selection.
• Students can articulate the differences between Lamarck's theory of evolution by inheritance of acquired characteristics and Darwin's theory of evolution by natural selection.
Speciation
• Students can describe Darwin's idea of how processes of natural selection & isolation can lead to speciation.

• Students can define and differentiate between allopatric and sympatric speciation.
• Students can propose and analyze scenarios by which speciation might occur.
• Students can describe the biological species concept.
Process of science
• Students can distinguish between a theory and a fact in the context of evolution.
• Students can delineate how creationism violates the assumptions of science and identify and articulate the misconceptions/logical flaws of arguments from intelligent design.
Context of science
• Students can describe key elements of the historical context within which Darwin's ideas emerged and the events in his life leading to his theory.
• Students can distinguish between societal controversy about evolution and scientific status of evolution within biology.
• Students recognize relevance of constitutional limits regarding public school instruction about creationism.

Guest scientists. The students met with two guest scientists during the module. The first guest was a biologist who was a devout Roman Catholic and a public defender of evolution. In class, the students were shown a video of this biologist discussing the potential compatibility of religion and evolution. Then the biologist video-conferenced with the students in class and discussed his own journey of reconciling his Catholic faith with evolution. This biologist's visit was meant to provide students with a potential scientist role model who is both religious and an advocate for evolution, thus demonstrating that religion and evolution do not have to be in conflict. The second guest was an evolutionary biologist and ecologist. She video-conferenced with the class and discussed her research on microbial communities. The purpose of her visit was to provide students with a female scientist role model who studies evolution to showcase that current researchers are working on evolutionary problems.

Readings and Videos. Students were required to read a chapter on natural selection and a chapter on speciation from their textbook Biological Science (Freeman, Quillin, & Allison, 2013). Students were also assigned to read a handbook from the

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National Academy of Sciences entitled *Science, Evolution, and Creationism* (NAS, 2008). A theme throughout the handbook is that evolution and religion can be compatible with one another. For instance, the handbook explains how science only explores natural causes in the natural world and is neutral to the existence of God. The handbook also includes statements from biologists and religious leaders explaining how religion and evolution can be compatible.

In addition to presenting biological content, the video lectures focused on comparing and contrasting different theories that attempt to explain the development and diversification of life. The instructor discussed various creation stories from different religions and cultures. The instructor also described different types of "creationism" including Young Earth Creationism, Theistic Evolution, and Intelligent Design and the extent to which claims from each of these ideologies are consistent or inconsistent with the theory of evolution. The instructor then compared and contrasted religious and scientific explanations. Similar to the *Science, Evolution, and Creationism* handbook, the course instructor highlighted that scientists study natural causes within the natural world while religious ideas address questions of morality, purpose, and the existence of a higher power. In accordance with the NOMA paradigm described in the introduction, the course instructor told students that if religion were only used to answer questions of purpose, ethics, and the existence of a God/gods, then it is not in conflict with evolution. In one of these videos, the instructor described the history of Charles Darwin's theory of natural selection. Additionally, the instructor explained the processes of natural selection and speciation. Finally, the videos addressed the misconception that evolution is random, the

misconception that evolution occurs in individuals rather than in populations, and the misconception that evolution is progressive or need-based.

In-class activities. For the first in-class activity, students constructed a timeline of the universe, beginning with the Big Bang and ending with modern day. The students had several strips of paper that represented major events in the history of the universe (i.e., the development of the solar system, the development of Earth, the development of humans). The students constructed a proportionally accurate timeline by taping these strips along a string. This exercise was intended to help students think about deep time and an old Earth, a concept that is crucial for evolution to be plausible. In the next in-class activities, students used simulation software, SimBio, to explore natural selection in a population of crabs and speciation in a population of finches. For the fourth activity, students participated in an argument building and evaluation exercise. Students were given arguments for and against evolution and the sources for those arguments. They were also given a handout that helped them evaluate the informational sources for each side of the argument. Students then read each source and evaluated the credibility of the source and the strength of the argument. At the end of the activity, a 10-minute in-class lecture was given, in which the instructor provided his own assessments of the arguments against evolution that the students evaluated.

Analyses

Student views on the relationship between religion and evolution. We determined students' perceptions of religion and evolution before and after the module by asking students to explain the relationship between evolution and religion in response to

the open-ended prompt "In a few sentences, briefly describe your views on the relationship between religion and evolutionary theory.".

To determine whether student perceptions changed pre to post evolution instruction, we performed content analysis by classifying student answers into predetermined categories (see Krippendorff, 2012 for a more thorough introduction to content analysis). We classified an answer as "Conflict" when the student's response indicated that evolution and religion were in conflict, "Compatible" when the student's response indicated that evolution and religion were compatible, or "Unclear" when the student's response did not provide enough information to determine whether their perception fit into one category or the other. We then recorded whether or not the student's response changed from pre to post evolution module and determined the frequency in which a change from one category to another occurred.

Student discomfort with discussions about religion and evolution. We assessed student comfort level with our discussions on evolution and religion by asking students at the end of the module whether any course materials about religion and evolution made them uncomfortable. If something did make them uncomfortable, we asked them to explain what made them uncomfortable. We used content analysis to classify the students' responses as either "uncomfortable" or "not uncomfortable" and determined the frequency of responses in each category.

Student appreciation of discussions about religion and evolution. We evaluated student appreciation of our discussions about religion and evolution by asking the students at the end of the evolution module if they appreciated anything said about

religion and evolution. If they did appreciate something that was said about religion and evolution, they were asked to explain what it was they appreciated.

We used content analysis by classifying student answers as "something appreciated" or "nothing particularly appreciated" and determined the frequency of students in each category. In order to determine what students appreciated about the module, we used grounded theory to further classify student responses that fell into the "something appreciated" category. Grounded theory is used instead of content analysis when themes emerge from the data that are not predetermined by the researchers (Glaser & Strauss, 2009).

In order to assess consistency and objectivity in the classification of student responses, an additional researcher independently analyzed a subset of student responses to each open-ended question. The two independent coders agreed 90% of the time.

Student Religiosity. Student religiosity was measured using a short, closed-ended survey. Student religiosity is defined here as the extent to which one perceives their religion as salient to their identity and the extent to which they participate in religious activities. The religiosity scale that the authors used was created by Cohen, Shariff, & Hill (2008) and has been previously validated with populations of college students. For items on the scale, see **Table 1**.

Results

Perceptions of the relationship between evolution and religion. Over 50% of students on the pre-module survey stated that they perceived that religion and evolution are in conflict with one another, whereas only 26% of students on the post-module survey

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stated that they perceived evolution and religion to be in conflict (**Figure I**). This indicates that the evolution module reduced the number of students who perceived a conflict between evolution and religion by half.
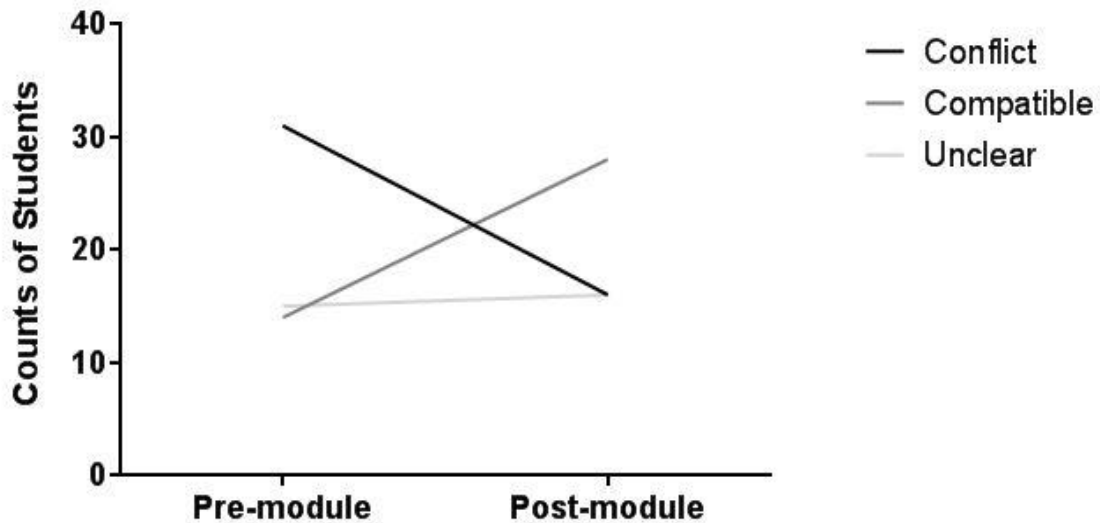
Fig. I: The number of students who had a perception of conflict or compatibility between religion and evolution pre to post evolution module. "Unclear" means the student's answer could not be unambiguously characterized as to whether s/he perceived religion and evolution to be in conflict or compatible.

Of the 32 students who had a stance that evolution and religion are in conflict on the pre-module survey, 11 (32%) of those students changed their stance and indicated that they thought religion and evolution could be compatible at the end of the module. Eight out of 15 (53%) students who provided unclear responses on the pre-module survey had responses on the post-module survey that indicated they thought that evolution and religion are compatible. Notably, no students started with the perception that evolution

and religion are compatible and ended with the perception that they are in conflict.

Further, no students started with an unclear perception and ended with a perception of

conflict between religion and evolution (**Table II**).

We further broke down changes in perceptions by level of student religiosity. We

created a dummy variable for religiosity in which students were categorized as 1, for

religious, if they scored in the upper half of the religiosity scale, and a 0 for non-religious

if they scored in the lower half of the religiosity scale (Green & Salkind, 2010). We then

looked at the composition of religious/non-religious students whose perceptions changed

over the semester. Although the majority of students whose perceptions changed from

conflict to compatibility were non-religious students, we also saw religious students'

perceptions change to compatibility (**Table II**).

Table II: Percent of individual changes from pre-evolution module to post-evolution

module of student perceptions of the relationship between evolution and religion.

Change in Perception of Religion and Evolution	Religious Students	Non-religious Students	All students
Perception Changed from Compatibility to Conflict	0%	0%	0%
Perception Changed from Unclear to Conflict	0%	0%	0%
Perception Changed from Conflict to Compatibility	8%	26%	18%
Perception Changed from Unclear to Compatibility	20%	9%	13%
Perception Changed from Conflict to Unclear	4%	11%	8%
Perception Changed from Compatibility to Unclear	8%	6%	7%
No Change in Perception of Religion and Evolution	**Religious Students**	**Non-religious Students**	**All students**
Conflict to Conflict	28%	26%	27%
Compatibility to Compatibility	16%	14%	15%
Unclear to Unclear	16%	9%	12%

The following are examples of students' pre and post module responses that show students' perceptions of religion and evolution changing from conflict to compatible. Pseudonyms are used to protect student identities.

Christina, religious student:

Pre-module: I think these two things contradict each other [evolution and religion].

Post module: Evolution isn't hating on religion. It says that God may have created Earth, but evolution is still taking place in the world today.

David, religious student:

Pre-module: "Religion says that all started from Adam and Eve, but based on the evolutionary theory, it disproves this. If the evolutionary theory is falsified, there could be some validity to Adam and Eve."

Post module: "Evolution coincides with religion and there is no reason why it can't."

Ashley, non-religious student:

Pre-module: "Religion according to the bible, tends to assume that humans haven't evolved much and have been in the same state since god. Evolutionary theory says that every living organism has evolved from species which contradicts what the bible says."

Post-module: "I believe god could have put evolutionary theory into place."

Samuel, non-religious student:

Pre module: "It's a can of worms. It's a fight that will keep being waged until the end of time."

Post-module: "They can agree."

Student comfort with content about religion and evolution. Of the 60 students who took our post-module survey, only 3 students (5%) reported that discussing religion in the context of evolution made them uncomfortable. The following quotes reflect those students' responses:

Olivia, religious student:

> "I did not like that the belief (or theory) of there being a higher being was completely thrown out."

Martin, religious student:

> "Only because I am not comfortable discussing religion with people outside of my family or church."

Lisa, non-religious student:

> "The only moment I felt uncomfortable was when I didn't know if I was speaking to someone who was firmly a believer in creationism, since my opinions on evolution are strongly for it."

Some students demonstrated an appreciation of content on religion and evolution. Of the 60 students who took our end of module survey, 40 (66%) of them expressed that they appreciated something about the discussions on religion and evolution. Most responses indicated that the student was "refreshed" or "fascinated" with the idea that religion and evolution could be compatible. Fifteen out of the 25 students (60%) who were classified as religious said that they were relieved to learn that they do not have to "pick a side" and that they can incorporate both evolution and their religion into their lives. Interestingly, both non-religious and religious students shared an appreciation of the content on religion and evolution. Twenty five out of 35 students (71%) who were classified as non-religious said that they appreciated the content on religion and evolution. They tended to say that they found it reassuring to know that one could hold religious beliefs and yet not let it affect their views on science. The following are example responses from students who said they appreciated the discussions of religion in the context of evolution in the evolution module:

William, religious student:

"It made me feel better about the fact that I'm religious and it shouldn't affect the fact that I believe in evolution."

Wes, non-religious student:

"I appreciated that scientists are able to be considered religious without it compromising their research."

Natalie, non-religious student:

"I appreciated that there are people who believe in evolution who are religiously affiliated because it showed me that they did not let their religion interfere with fact."

It is worth noting that some students specifically noted that our religious scientist role model visitor influenced their beliefs about religion and evolution. Twenty students (33%) said that this visitor influenced their perceptions of religion and evolution. Notably, only half of these students fell into the religious category, indicating again that discussions about religion and evolution not only impacted religious student perceptions of the relationship between religion and evolution but also the perceptions of non-religious students. The following are a subset of student responses in which students discussed how the religious scientist visitor influenced their perceptions of the relationship between religion and evolution:

Margaret, religious student:

"[The religious scientist visitor] helped me to see that it is possible to have religion and science both within your life. It helped me realize that I do not necessarily have to pick one over the other."

Vicki, non-religious student:

"He opened my eyes to others beliefs and views. I now know that many religions do accept evolution."

Jason, non-religious student:

"He made me realize that people can still believe in God while accepting the theory of evolution."

Religiosity. A paired samples t-test comparing student religiosity levels before the evolution module (M= 23.63, SD= 8.60) and after the evolution module (M=23.34, SD=8.80) indicated that there was no change in the level of students' religious beliefs (t=.584, p=.561, df=58). On average, our students began and completed the module with a moderate level of religiosity, indicating that the instruction did not affect the level of religiosity among students. The instructors did not aim to change student religiosity and this result confirms that, although student perceptions of the relationship between religion and evolution changed, their baseline religiosity did not.

Discussion

In this study, we showed the positive impact that evolution instruction that integrates potential compatibility of religion and evolution can have on student conceptions of the relationship between religion and evolution. The original intention of this instruction was to give religious students who perceive a conflict with evolution the opportunity to see how evolution and religion can be compatible. However, we were surprised to find that even non-religious students' perceptions shifted to a compatibility perception. Although this was an unexpected finding, we believe there are several possible advantages that stem from changing non-religious student views that can serve as a fruitful area for future research.

First, all of our students in biology classes, both religious and non-religious, are potential future communicators of science (Brownell, Price, & Steinman, 2013). When our students go on to teach their own biology classes, will they teach evolution as compatible or in conflict? How will this influence their own students' views on evolution? If an instructor is willing to present evolution and religion as compatible to

their students then, as we demonstrated in this study, it could change their students' perception about religion and evolution. Over time, this cycle could create a cumulative effect in which more students see evolution and religion as compatible, including both religious students and non-religious students.

Second, even if our non-religious students do not become teachers, they may have discussions about evolution and religion with others around them. By talking to their friends and family, some of whom may be religious, about how evolution and religion can be compatible, nonreligious students may positively impact the perceptions of friends and family about religion and evolution. The impact of the type of evolution instruction reported in this manuscript could have ramifications that extend beyond the students in the biology class. Future research should explore the longitudinal effects of evolution instruction that highlights compatibility between religion and evolution.

Last, there is a scarcity of religious individuals in biology and helping non-religious students see religion and evolution as compatible could possibly ameliorate this lack of diversity in science. While the majority of the general public reports identifying with a religion (Pew, 2015), only a minority of biologists report believing in God (Ecklund & Scheitle, 2007). Recent evidence suggests that the underrepresentation of minorities in evolutionary biology could be at least partially explained by the perception that evolutionary biology is incompatible with religious belief (Mead et al., 2015). Additionally, a recent study has shown that Christians are seen as less competent in science than non-religious individuals, which may cause Christian students to identify less with science (Rios et al., 2015). Non-religious students who accept this stereotype and believe that religion and evolution are incompatible may inadvertently make their

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religious peers feel like they do not belong in biology. However, if non-religious students know that there are successful religious biologists and that there are ways in which evolutionary science and religion can be reconciled, this may diminish their potential negative stereotypes about religious individuals in science and possibly reduce the discomfort religious students may feel in biology classes.

Advice for instructors. We believe that a key component of this module was providing students with a religious scientist role model who accepts evolution, because approximately one-third of students mentioned this visitor in their responses. However, due to various constraints, an instructor may find it difficult to have this kind of visitor join their class. We have several suggestions for alternatives. First, if instructors have their own experiences reconciling their religious beliefs with evolution, then they might consider sharing this journey with their students (Barnes & Brownell, in review) Second, an instructor may present other scientists who have published on their reconciliation strategies through online videos or books. For instance, Dr. Kenneth Miller is a well-known evolution proponent as well as a devote Catholic and he has written a book on the reconciliation of his religious beliefs and evolution called *Finding Darwin's God* (Miller, 2002). Further, Francis Collins, the director of The National Institute of Health, has also published a book, *The Language of God*, on his reconciliation of evangelical Christianity and evolution (Collins, 2006). Both of these individuals would be excellent examples of scientists who were able to reconcile their religious beliefs with evolution that instructors could introduce to students.

Limitations

First, we cannot be sure what specific factors caused the change in student perceptions about religion and evolution over the two week module. Although explicit discussions of religion and evolution seem to be the most likely aspect of instruction that would influence student perceptions of religion and evolution, it is possible that other aspects of the lesson influenced student perceptions. Disaggregating the effects of specific aspects of the curriculum on student perceptions of the compatibility of evolution and religion is a potential area of future research.

Second, these findings are limited to one class with one instructor. Future research should explore the effectiveness of this module among different populations of students and with different instructors.

Finally, we collected these data through a survey, which meant that some students provided answers that could not be categorized as either compatible or conflict (so we called them "unclear"). It would be interesting to follow this study with an interview study where we could explore student perceptions on a deeper level so that we would have fewer unclear responses.

Conclusion

In this study we found that, after a two-week module on evolution that emphasized the potential compatibility between religion and evolution, both religious and non-religious students' perceptions of the relationship between evolution and religion changed to compatibility. Further, we found that no students changed to a perception of conflict between evolution and religion after instruction. Thus, this study indicates that compatibility of religion and evolution embedded in a short evolution module can have a positive impact on students that may extend beyond the classroom.

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CHAPTER 3

PRACTICES AND PERSPECTIVES OF COLLEGE INSTRUCTORS ON

ADDRESSING RELIGIOUS BELIEFS WHEN TEACHING EVOLUTION

M. Elizabeth Barnes and Sara Brownell

Abstract

Evolution is a core concept of biology and yet many college biology students do not accept evolution because of their religious beliefs. However, we do not currently know how instructors perceive their role in helping students accept evolution or how they address the perceived conflict between religion and evolution when they teach evolution. This study explores instructor practices and beliefs related to mitigating students' perceived conflict between religion and evolution. Interviews with 32 instructors revealed that many instructors do not believe it is their goal to help students accept evolution and that most instructors do not address the perceived conflict between religion and evolution. Instructors cited many barriers to discussing religion in the context of evolution in their classes, most notably the instructors' own personal beliefs that religion and evolution may be incompatible. These data are exploratory and are intended to stimulate a series of questions about how we as college biology instructors teach evolution.

"Scientists also must realize that the presentation of science, though necessary, is not sufficient in itself. For topics such as evolution or climate change, where there may be religiously-based opposition, "mere" science will not be persuasive on its own." Eugenie C. Scott, former Executive Director of The National Center for Science Education, 2013.

Introduction

Evolution has been defined as one of the core concepts of biology (AAAS, 2011; Brownell et al., 2014) and is often referenced as the grand unifying theory of biology (Dobzhansky, 1973; Gould, 2002; Heddy & Nadelson, 2012; Mayr, 1982). However, a significant portion of the population rejects evolutionary theory. According to a 2014 Gallup poll, 42% of Americans reported that they believed that humans arrived on Earth in their present form (Newport, 2014). Even among students in introductory biology classes, rejection rates of evolution can reach up to 50% (Rice, Olson, & Colbert, 2010).

Multiple agencies and evolution education researchers have indicated that students' acceptance of evolution is important. The National Academy of Sciences and the Association for the Advancement of Science have issued several documents that highlight the importance of a scientifically literate society that is equipped to make policy decisions of the future (AAAS, 2011; Singer et al., 2012). Applying evolutionary concepts to solve problems is one component of being a scientifically literature citizen (NAS, 1998, 2008), but this is unlikely to happen if a person rejects evolution. (Sinatra et al., 2008). More than 165 studies from evolution education researchers have focused on student acceptance of evolution and leaders in this field have proposed that student acceptance is an important aim of evolution education (Alters, 1997; Cobern, 1994; Nadelson & Southerland, 2012; Nehm, Kim, & Sheppard, 2009; Rutledge & Sadler, 2011; Sinatra, Brem, & Evans, 2008). If the consensus of the scientific community is to help students become scientifically literate and to incorporate evolution into their scientific thinking, policy making, and voting decisions (AAAS, 2011; NAS, 2008), then it may be important for instructors to help students accept evolution. However, we

currently do not know how college instructors perceive their role in helping students accept evolution.

In this manuscript, we define student acceptance of evolution as the extent to which a student accepts that evolution is the best scientific explanation for the diversity of life on earth, which is in accordance with definitions from national documents (NAS, 1998, 2008).We define understanding of evolution as the extent to which a student has an accurate conception of the tenants and processes of evolutionary theory. While we acknowledge that student understanding of evolution is important, we delineate this as a separate construct and it is not a focus of this manuscript.

Students who understand but do not accept evolution may not apply evolutionary thinking when making public decisions related to biology, such as wildlife and disease management, which can affect both biodiversity and global human health. A voter who does not incorporate deep time and the co-evolution of species into their thinking may not be able to fully appreciate the complex interconnectedness of all organisms on earth and thus the extent to which the extinction of one species, or the pollution of one environment, might affect global biodiversity. Also, accepting that humans have evolved from other animals highlights the shared cognitive processes and basic mental capacities of all animals, such as the capacity to feel pain and fear, which could affect voting decisions on animal welfare (Rachels, 1990; Singer et al., 2012). Finally, researchers in evolutionary medicine have suggested that physicians need to account for the evolutionary history of humans to adequately understand and treat diseases such as obesity, heart disease, and mental illnesses, some of the most prevalent ailments that affect humans today (Nesse, 1996; Nesse et al., 2010). If instructors only focus on student

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understanding of evolution and avoid addressing student acceptance, then the desired outcomes of science education may be diminished.

Factors influencing student acceptance of evolution. Researchers have identified several factors that influence student acceptance of evolution. Acceptance of evolution has been positively correlated with higher educational levels (Heddy & Nadelson, 2012; Rissler et al., 2014) except in cases of biblical literalists, who become less accepting of evolution with higher levels of education (Baker, 2013). Researchers have found that the level hypothetico-deductive reasoning of high school students is positively related to student acceptance of evolution (Lawson & Worsnop, 1992) and college students' level of intuitive reasoning is negatively related to their acceptance of evolution (Gervais, 2015). This is in line with work that has identified cognitive constraints that make the idea of evolution feel intuitively false to the human mind, just as the idea of a spherical Earth is initially unintuitive to most children (Evans, 2001; Sinatra et al., 2008). So if a student has more of an intuitive thinking style than an analytical reasoning style, it may be difficult for them to override their initial intuitions about the improbability of evolution. Other factors that positively impact an individual's acceptance of evolution include a higher socioeconomic status (Heddy & Nadelson, 2013) and trust in science and scientists (Nadelson & Hardy, 2015)

However, of the many factors that have been shown to influence acceptance of evolution, religious commitment is the strongest. Most researchers recognize that it is Judeo-Christian and Muslim belief systems that are most likely to conflict with evolution (Scott, 2005). If a person's commitment to religion is high, then his or her acceptance of evolution is predicted to be low regardless of other factors that have been shown to be

related to acceptance (Allmon, 2011; Alters & Nelson, 2002; Eve et al., 2010; Rice et al., 2015; Rissler et al., 2014; Sinclaire et al., 1997; Southerland & Scharmann, 2013). The vast majority of individuals in the United States report being religious (Pew, 2015) and more than half of students in U.S. biology classes report being religious (Ingram & Nelson, 2006; Cooper et al., unpublished), making religious belief[1] a prevalent potential barrier to student acceptance of evolution. Further, similar to the general public, it has been shown that students struggle with a perceived conflict between evolution and their religious beliefs and some students may resist learning about evolution (Sinatra et al, 2003).

Religiosity, the extent to which one is committed to and practices religion, has a minimal effect on one's understanding of evolution (Ingram & Nelson, 2006; Rissler et al., 2014) and this might lead instructors to conclude that they do not need to address religious concerns when teaching evolutionary theory. However, studies have shown that if a student has an accurate understanding of evolution, this does not necessarily mean they are more likely to accept evolution (Lloyd-Strovas & Bernal, 2012; Sinatra et al., 2003).

A potential solution: reducing students' perceived conflict between religion and evolution. To reduce student resistance to learning evolution, researchers have proposed that we need to diminish the perceived conflict between religion and evolution in biology classes. Smith has urged instructors to discuss with students how the nature of

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[1] The extent to which religious belief matters is how salient the religious belief is to a student and which religious belief the student has. There are some religions that have put forward statements that indicate that they endorse evolution, whereas others have officially taken an antagonist stance towards evolution. Throughout this study, we referred to student religious beliefs broadly, without disaggregating it into specific denominations/sects, because instructors are unlikely to know specific student religious beliefs.

science implies that evolution and religion do not have to be in conflict (Smith, 1994). In 2013, Southerland and Scharmann posited that teaching the bounded nature of science in relation to religion can help students be more open to subjects that generally conflict with religious ideas. They argue that engaging students' religious beliefs might be the most important factor to consider when teaching scientific subjects that relate to human origins (Southerland & Scharmann, 2013). These suggestions are supported by an emerging empirical literature.

Several studies support the assertion that discussions of religion in college science classrooms can help students be more open to evolution. In an interview study done in Lebanon, researchers found that Christian and Muslim college students reported an appreciation for discussions about the relationship between evolution and religion. The authors argued that the student experience learning evolutionary theory is more likely to be enhanced by discussions of the nature of science and students' values and beliefs in relation to scientific knowledge (Dagher & BouJaoude, 1997). An interview study in an astronomy class in the United States with non-major college students of different religious beliefs demonstrated that having open discussions about the relationship between religion and science increased students' positive views of science and evolution (Brickhouse et al., 2000).

Helping students construct bridges between their religious beliefs and evolution may also help students accept evolution. In a case study done in Canada with two high school physics students over a period of two years, researchers explored the interaction between students' personal religious beliefs and their learning of controversial topics in class. They found that the two students used both rational *and* social discourses to

evaluate scientific claims, yet still came to different conclusions about whether or not they believed them. Based on their examination of students' discourse, the authors concluded that educators may have to help students construct mediating concepts between their religious world-views and potentially controversial concepts in science in order for students to accept those concepts (Roth, 1997).

In fact, empirical studies are beginning to support Roth's conclusion. Manwaring et al., 2015 found that by showing LDS college students that their denomination had an official neutral stance on evolution, they were able to increase those students' acceptance of evolution. In a study done with college biology majors, the number of students who perceived conflict between evolution and religion was reduced by half after a two week module on evolution in which the instructors highlighted the compatibility between religion and evolution (Barnes, Elser, & Brownell, in review after revisions). Thus, this literature indicates that students can benefit from instruction in which their religious beliefs are acknowledged by instructors and in which instructors discuss how religion and evolution can be compatible.

Additionally, the availability of religious scientist role models has been shown to affect student acceptance of evolution. For instance, Winslow et al. found that a significant factor for Christian biology majors to accept evolution was these students' interactions with their religious biology professors who reassured them there need not be a conflict between religion and evolution (Winslow, Staver, & Scharmann, 2011). Thus, providing students with examples of biologists who have values similar to their own could facilitate greater acceptance of evolution among students.

Potential barriers to reducing students' perceived conflict between religion and evolution. Despite calls for acknowledging students' religious beliefs when teaching evolution (Smith, 1994; Southerland & Scharmann, 2013) and preliminary evidence that engaging with students' religious beliefs may be effective for helping students accept evolution (Barnes et al., under review; Roth, 1997; Wiles & Alters, 2011; Winslow et al., 2011), we know little about college biology instructors' practices related to addressing religious beliefs when teaching evolution (Dagher & BouJaoude, 1997). We suspect that biology instructors may perceive barriers to addressing religious beliefs in the classroom for the following reasons.

First, an educator's lack of experience in teaching the nature of science in relation to religion may cause them to feel unprepared to engage in these discussions about evolution and religion (Southerland & Scharmann, 2013). Second, biology educators may not want to discuss religion because their own belief systems may be different than their students' belief systems. Many biologists do not hold religious beliefs: twenty two percent of biologists report a belief in God in contrast to 77% of the public holding religious beliefs (Ecklund & Scheitle, 2007; Pew, 2015); evolutionary biologists are even less religious with only 4.6% reporting belief in any existence of the supernatural (Graffin & Provine, 2007). Third, there is a long history of attempts by certain religious groups to legislate the teaching of creationism as a valid alternative to the theory of evolution. Over the last 100 years, religious groups have repeatedly attempted to either prevent educators from teaching evolution or demand the teaching of creationism as an alternative theory (Numbers, 2006).While much of this legislation has centered on K-12 instruction, it may cause college level biology instructors to be wary of discussions of

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religion in the classrooms, even when these discussions are not about teaching religious doctrine, but acknowledging religion as a part of students' social identities. Also, there is potential disagreement about whether it should be an educator's goal to help students both understand and accept evolution (Alters, 1997; Nadelson & Southerland, 2010; Shtulman & Calabi, 2008; Sinatra et al., 2003; Smith, 2009). A biology educator might perceive his or her duty to help students to understand evolution, and that helping students accept evolution would be beyond their job as a science educator. Finally, a biology instructor may perceive that a lack of discussion about religion will help them avoid potential conflicts in their class. However, a recent study has shown that presenting evolution without making reference to religion can alienate religious students (Hermann, 2012). In this study done with high school students in AP sciences courses, students expressed dissatisfaction with instructors' neglect of the relationship between evolution and religion in class. If biology instructors present the science of evolution, but ignore the religious sociocultural context surrounding evolution, then prior literature indicates that student acceptance of evolution is unlikely to change (Scott, 2014).

The current study. Currently, we do not know the reasons why instructors decide to discuss or not discuss religion in relation to evolution and what barriers they perceive to discussing religion when teaching evolution. In this paper, we report the results of an exploratory interview study of 32 college biology instructors who teach about evolution in undergraduate biology classes in Arizona. While there are many studies in the literature that explore student acceptance of evolution (Dagher & BouJaoude, 1997; Hermann, 2012; Ingram & Nelson, 2006; Rissler et al., 2014b; Wiles & Alters, 2011), this study fills a void in the literature on instructor perspectives on their instructional

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practices related to student acceptance of evolution. We set out to investigate the following research questions:

1. Do college biology instructors who teach about evolution have a goal to promote student acceptance of evolution? Why or why not?

2. To what extent do college biology instructors who teach evolution discuss religion in the classroom? Why do they choose to discuss or not discuss religion?

3. Do college biology instructors who teach evolution utilize instructional practices that align with suggestions in the literature for increasing student acceptance of evolution? Why or why not?

4. What barriers hinder instructors from engaging with students' religious beliefs when teaching evolution?

Methods

Instructor Recruitment. We recruited a convenience sample of instructors who teach evolution at public institutions of higher education in Arizona. We recruited from 10 community colleges in Maricopa County, which is the largest community college network in Arizona, and three public R1 institutions in Arizona. Collectively, these institutions serve a diverse demographic of students as well as geographic locations. The Maricopa Community College network is composed of ~50% ethnic minority students and 40% non-traditional students (over the age of 22), while the universities in Arizona are composed of 35-40% minorities and span northern, central, and southern Arizona (Arizona State University, 2013; Forbes, 2014; Maricopa Community Colleges, 2012; University of Arizona, 2014) We chose to interview instructors from public institutions

because private institutions could have special interests that influence instructor practices, including how evolution is taught. We specifically chose to recruit from a subset of two year colleges because ~70% of students in public colleges in Arizona attend two year colleges (NCES, 2012). We limited our sampling to Arizona public institutions of higher education. We did this to limit the data collection to a realistic number of individuals as well as keep constant different political and religious contexts that may lead to different instructional practices in different states.

Instructors of college biology with full time positions at these institutions were identified through their online institutional profiles and sent individual emails. Instructors were then sent a reminder email approximately two weeks later if they had not responded. We limited our study population to instructors with full time positions because we thought that the controversial nature of discussing religion in a classroom might limit the openness of instructors who do not have secure positions. Because full time faculty have greater job security, we thought they would be more open about their beliefs and practices, so we included tenured and non-tenured full time faculty. Our recruitment email asked instructors if they would participate in a 30-60 minute interview exploring their perspectives on how students might experience conflict between their worldviews and evolution and how they, as instructors, might address this in their classroom. Out of the instructors who responded to the email, we only included interviews of instructors who taught an evolution lesson to undergraduates within the last seven years. This ensured that the instructors had been teaching evolution after the publication of national documents that outlined the potential compatibility between religion and evolution (NAS, 1998, 2008).

Data Collection. Thirty two semi-structured interviews were conducted by one researcher between spring 2014 and autumn 2015. The set of questions that guided the interview can be found in **Table I**. Interviews lasted from 15 to 75 minutes, averaged 35 minutes, and were audio recorded.

A survey was administered to all instructors immediately after the interview to record demographic information, academic credentials, experience teaching evolution to undergraduates, childhood and current religious affiliation, and their perceptions of whether there is a role for God/god(s)[2] in evolution. We asked instructors what role they believe God may have played in evolution and had three evolutionary biologists review the question for accuracy and interpretation. We asked instructors to choose what came closest to their personal beliefs: 1) Human beings have evolved over billions of years from older life forms and God guided this process, 2) Human beings have evolved over billions of years from older life forms and God started this process but did not intervene after. 3) Human beings have evolved over billions of years from older life forms and God was not involved in this process, 4) Human beings have evolved over billions of years from older life forms and I do not know whether or not God had anything to do with this process, and 5) God created human beings, more or less, in their present form. We decided to administer these questions via a survey after the interview, because we did not want the participants to feel as though the interview was about their personal religious beliefs rather than their instructional practices, which could make them uncomfortable.

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[2] We use the term God/god(s) to be as inclusive as possible since some religions prefer capitalization, and some recognize multiple deities. We acknowledge that some religions do not use the word God/god to describe a higher power, so we encourage readers to interpret this term broadly.

All research was approved by the Arizona State University's IRB, protocol # 00000631.

Table I: Question checklist that was used during interviews with instructors.

Experience teaching evolution	How many years have you been teaching evolution to undergraduates?
	Are there specific strategies you use to teach evolution? What are they?
	Do you have any strategies related to religion when you teach evolution? What are they?
	Do you mention religion at all in your class? How?
	Have you ever been challenged by a student in class about evolution? If so, describe your experience.
Perception of student rejection rates	Would you be willing to guess what percent of students in your class reject evolution?
	Have you ever asked?
Goal when teaching evolution	As a biology educator do you think it is part of your job or goal to help students become more comfortable with and accept evolution? Or do you only aim for students to understand evolution? Why?
Use of specific strategies when discussing religion and evolution	Do you discuss the spectrum of viewpoints that exist about the relationship between religion and evolution? If no, why not? Would you?
	Do you discuss that evolution does not mean atheism/ evolution is compatible with religion? If no, why not? Would you?
	Do you provide students with religious scientist role models who accept evolution? If no, why not? Would you?
Perception of what it means to "accept evolution"	What is "acceptance of evolution"?
	If a student says they accept common ancestry and natural selection but they believe god started or planned evolution, does that student accept or reject evolution? Why or why not?
Personal experiences learning evolution	Did you experience any worldview conflict with evolution when you learned about it? Any other time? Why or why not?

Data Analysis. Interviews were initially transcribed and coded by the first author using a combination of content analysis and grounded theory. She used content analysis to identify pre-determined themes that the research team was interested in exploring prior to the data collection (Krippendorff, 2012) and she used grounded theory to identify additional themes from the interview transcripts that emerged after the data collection

(Glaser & Strauss, 2009). For instance, when exploring instructor practices, she used content analysis to explore the pre-determined theme "provides students with examples of religious scientist role models" but she also discovered new instructor practices via grounded theory, such as the theme "presents evolution in a way that seems incompatible with religion."

The analysis was an iterative process in that themes and categories were molded and transformed with each additional reading of the transcripts. Categories consist of different types of instructor perspectives and experiences and multiple categories usually fit under one theme. For instance, "instructors provide students with religious scientist role models" and "instructors discuss the spectrum of viewpoints about religion and evolution" would be categories within the theme "instructors address religion in class". Most themes and categories were specific to one interview question. For instance, the theme "goals of evolution instructors" and the category "instructor does not consider acceptance of evolution as part of their instructional goal" consisted mostly of quotes from responses to the interview question in which the first author asked instructors about their goals when teaching evolution. A theme was created from each interview question and then categories emerged from instructor responses to those questions. Constant comparison methods (Glesne & Peshkin, 1992) were used throughout the analysis. That is, quotes that were assigned to specific themes and categories were gathered together and compared to one another throughout the iterative process of qualitative analysis. This constant comparison of quotes was meant to ensure that the description of the theme and category adequately represented all quotes within the same group and that the quotes were not different enough from one another to deem a separate category or theme.

Results

      Inter-rater reliability. After the first author completed the analysis of the data, she created a coding rubric. The coding rubric consisted of detailed descriptions of each theme and category that was established in the analysis. The rubric also included instructions on how to code the transcripts, which was reflective of the first author's process when she did her final round of coding. In order to establish inter-rater reliability, a second researcher used the codebook without the help of the first author to blindly code ~10% of the statements originally coded by the first author. After the second researcher coded the statements, the first author labeled each statement based on whether the second researcher applied the same code to the statement as the first author.

      The independent codes from both researchers agreed 91% of the time. However, reporting percent agreement for inter-rater reliability may inflate agreement rates because percent agreement does not take into account agreement that would occur by chance alone (Hallgren, 2012). Therefore, in addition to percent agreement we also used a Kappa Statistic to measure the observed level of agreement among raters and control for agreement that would happen by chance. Cohen's Kappa was calculated in SPSS 21 for each coded statement and then averaged. Our average Cohen's Kappa was .83, which indicates very high agreement (Landis & Koch, 1977). Some researchers have questioned the utility of inter-rater reliability in qualitative studies using unstructured interviews, because this might compromise the richness and depth of the analysis and results (Morse, 1997). However, this is less of a concern with research designs such as ours, in which the interview questions remain the same for all interviews and are asked in the same order in each interview.

Response rates and demographics. Of the 229 instructors emailed for

recruitment, 32 completed interviews that were used in our analyses (R1

universities=19/149 (13%), community colleges=13/80 (16%)) for a total response rate of

14% (see the Limitations section for a discussion on low response rates). There were 21

male participants (66%) and 11 female participants (34%). Twenty nine out of 32 (90%)

of instructors were teaching a biology course in which evolution was one of many topics

and 5/32 (16%) of instructors were teaching a course in which evolution was the primary

topic (some instructors taught both types of courses, so the percentages do not add up to

100). Twenty of 32 (63%) participants identified as "atheist" or "agnostic", 6/32 (19%)

identified as a member of a denomination of Christianity, 5/32 (16%) identified as

Jewish, 1 participant identified as "questioning", 1 participant identified as "other", while

another participant did not answer the question pertaining to religion on the survey.

Participants were given pseudonyms to protect their identity.

Research Findings. Here we report our findings by discussing instructor

responses from the interviews and reporting the relative abundance of instructor

participant responses. Quotes are provided for instructor responses that are particularly

illustrative for the reader to gain a deeper understanding of an instructor's perspective.

Do instructor participants have a goal to help students accept evolution?

Instructor participants have different definitions of "acceptance of evolution". When

asked to provide a definition of what it means to "accept evolution," instructors gave a

wide variety of responses. The majority of instructors said acceptance of evolution had to

include acceptance that either natural selection is the main mechanism by which life has

diversified and/or acceptance that all of life on Earth shares a common ancestor. A minority of instructors said that acceptance of evolution includes acceptance that speciation occurs, acceptance that allele frequencies in a populations of organisms change over time, and acceptance that life changes over time.

Instructors were divided on whether a student had to accept that evolution occurred without God/god(s) starting, planning, or guiding evolution in order for that student to be considered an "acceptor". Some instructors thought that students could intertwine a belief in a God's/god's(s') influence on evolution. These instructors explained that whether or not a student accepts evolution is not dependent on the student's views of supernatural influences because the influence of God/god(s) is outside of the purview of science. For instance, Edward thought that what mattered for student acceptance of evolution was that students accept the natural phenomenon that biologists have studied and observed:

Edward:

> "I would say that if a person told me that they believe all life on earth shares a common ancestor and that natural selection has been a major mechanism for adaptation, then I would agree that they accept evolution. Questions of "what started it all" or "whether God has a hand" is out of the scope of science and biology, and that is partly why I think religion and science deal with different domains philosophically."

In contrast, other instructors explained that acceptance of evolution is not compatible with the view that God/god(s) had anything to do with evolution. These instructors, including Marie, felt that in order to accept evolution you have to accept that it could happen by only natural processes:

Marie:

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"I would be concerned that the student feels the need to impose a higher, directed order on natural forces. It implies that the student doesn't think that evolution could occur on its own, by purely natural forces."

A third category of instructors emerged who said that a student being an acceptor depended on what role the students thought God/god(s) played in evolution. These instructors thought a student would be considered an acceptor of evolution if the student believed God/god(s) started evolution. However, if a student thought God/god(s) planned or guided evolution than that would be inconsistent with the idea that evolution progresses in a non-determined direction, which is an important part of evolutionary theory:

Neil:

"God starting things out is probably consistent with believing in evolution. But since a key aspect of evolution is natural selection based on random mutation any guiding to me seems inconsistent with this key aspect of evolution"

A fourth category of instructors felt as though we should not have a dichotomy of "accept" or "reject" and that a student who believes God/god(s) had a role in evolution is somewhere in between a "rejecter" and "acceptor" of evolution:

Frank:

…I think for most purposes "reject" is too hard a judgment on that person. She accepts a hybrid interpretation under which both evolutionary and divine design processes act."

Most instructor participants do not know whether their students accept evolution and have not been challenged about evolution in class. Very few instructors reported that they had asked their students whether they accepted evolution and these instructors reported that approximately 20-34% of their students rejected evolution. Some instructors polled their students with multiple choice questions either through anonymous

clicker questions or surveys and others had students write essays about their views on evolution. The instructors who had student's write essays did not do so with the intention of polling their students, but to give them the chance to explore their conceptions and beliefs about evolution. Many of the instructors who had not polled their students said they thought it would alienate students if they were probed about their beliefs.

Although the vast majority of instructors had not polled their students, many of them were willing to guess what percent of their students reject evolution. These instructors who were willing to guess generally thought that very few (often less than 10%) of their students rejected evolution. Further, only a minority of instructors had ever been challenged by students about evolution, which may have led many instructors to perceive that students did not have a problem with learning about evolution.

The majority of instructor participants state that helping students accept evolution is not an instructional goal. We let instructors use their own definitions of acceptance of evolution to answer the question of whether it was their goal to help students accept evolution. While relying on instructor definitions adds noise to our data, we felt what was most important was instructors' own perception of what they think their role as an instructor is and this is dependent on their own definition of student acceptance of evolution.

When asked if they considered helping students to accept evolution as part of their goal when teaching evolution, the majority of instructor participants said that it is only their goal to help students understand evolution and not to help students accept evolution. According to these instructors, changing a student's mind about whether evolution is true is not a focus of their instruction. They indicated that they were teaching

students to be critical thinkers rather than persuading them to accept evolution.

Interestingly, these instructors perceived that trying to change student beliefs would make

them feel manipulative and authoritarian and even that it may be an inappropriate motive

for instruction.

Anthony:

"I give them the information and I'm pretty straight forward. This is it, evolution is a fact, deal with it. But I'm not out to twist their views."

Craig:

"I'm there to teach them and so as long as you can matriculate through my class and understand concepts and how natural selection operates and how genetic change in population occurs etc., you're fine. If you don't believe that that occurs then that's your own personal choice. But you just have to know the stuff and if you're a [biology] major, I hope you're not my doctor."

Rose:

"My goal is for them to understand it and then it's their job to decide whether to accept or reject it. I don't have an agenda."

However, a minority of instructors said they did think it was part of their goal to help

students accept evolution. Some considered acceptance of evolution essential for

learning:

Ernest:

"I think you can't separate one from the other [acceptance from understanding]. Really, I think if students are not open and they're not accepting the material than they can't learn."

Other instructors who said acceptance was their goal questioned whether a student could

practice biology if they did not accept evolution. Since evolution is the foundation of

biology, these instructors thought acceptance is necessary in order to practice biology:

Marie:

> "I don't understand how a student who wants to be a biologist, and I'm teaching mostly biology students, I don't understand how a biology student, somebody who wants to do that, can do anything in science and biology without believing that. That's the guiding principle, is nothing makes sense [in biology without evolution]."

Last, some of the instructors who said acceptance was their goal did not distinguish between acceptance of evolution and understanding of evolution. According to them, if a student understands evolution, that means they accept evolution:

John:

> "I don't see a difference between understand and accept. If you understand, you accept. The same way if I explain how the water moves from the soils to leaves, or I explain how species evolve. They need to understand water doesn't move from the soil to the leaves because the leaves need water, it moves because there is a gradient water potential. And species composition doesn't change [because it needs to], it changes because one species has characteristics that increases their fitness. That's what I explain and if they understand that, they accept it."

Do instructor participants address the potential conflict between religion and evolution in their classes?

Very few instructor participants have in-depth discussion of religion in the context of evolution. In addition to asking instructors about their goals when teaching, we also asked them to self-report on the extent to which they discuss religion when teaching about evolution and why they choose to discuss or not discuss religion. Notably, very few instructors said that they addressed religion and evolution in-depth (in-depth is defined as using a whole class period to discuss religion and evolution or mentioning it several times throughout the semester). The vast majority of the instructors did not ever discuss it or discussed it briefly. Some instructors addressed religion in a way that made it seem incompatible with religion. In this section, we present the quotes that illustrate the extent to which religion is discussed in our participants' classrooms. For instructors who

do not talk about religion, elaboration of their reasons for not discussing religion will be discussed in the "barriers to discussing religion" section below.

The following quote is an example from those instructors who do not discuss religion at all in relation to evolution in their courses. Many of them said they never bring up religion in their courses because it did not seem relevant to the scientific content of the course:

Anthony:

> "You might talk about it [religion] in a different class that has to do about contrasting evolution with creationism, or something like that, but this is not what I'm doing here. I'm not doing that here."

The following quotes are illustrative of about half of instructors, who said they mention religion only briefly when they teach evolution. When they do mention religion in their classes, they generally contrast religion with science, often explaining how religious ideas are untestable or outside the realm of science. However, this was usually presented as a quick disclaimer and was not emphasized to students:

Edward:

> "I have occasionally compared religion to science, but not routinely or ever in depth."

Chester:

> "I don't think I really directly talk about religion but I'll say that other ideas about the origins of life and species and so on that aren't based on natural explanation or natural phenomenon aren't testable and so they don't fall within the realm of science and so you don't see them presented in this textbook in that way. So that's usually how I'll sort of touch on it."

Very few instructor participants said they either talked about religion several times while teaching evolution or spent at least one class period seriously discussing religion in relation to evolution. All of these instructors reported that

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their goal in discussing religion was to show students that religion and evolution do not have to be in conflict. For instance, this instructor explained how he tells students that religion is one way of viewing the world and intentionally does not discount the importance of religion to certain students' lives. The instructor believes that being accepting of religion in class helps students to be more open to evolution:

Ronald:

> "Very early on the first day of the class- the first discussion of the class-sometimes very often my classes start off with discussions about the nature of science and about how science is the way of explaining and understanding the universe and in that it is one of many ways of explaining and understanding the universe. That it is probably the narrow-minded person who uses any single particular way of knowing to understand and perceive and enjoy life experiences. And it's probably a more mature thinker who draws on several different ways of knowing to enjoy that experience. I don't discount religion as a valid way of experiencing life. It is one set of paradigms that people use, sometimes they work sometimes they don't. Sometimes they bring great comfort, sometimes they don't - whatever they have their role for some people. In that first discussion I think I neutralize a lot of feelings that could later turn into aggression towards some of the more controversial scientific theories such as evolution."

One instructor noted how some scientists think that instructors should avoid talking about religion, but he disagreed with those other scientists. According to him, ignoring religion when teaching evolution becomes awkward because it is such a notable point of contention:

Greg:

> "Some scientists think you should just avoid the whole creationism thing itself and not even mention it. I don't agree with that approach. I think that if you do that then creationism is this 100-pound gorilla that's sitting in the corner of your classroom that you seem to be carefully ignoring. I mean, I prefer to bring the gorilla out and sit the gorilla down center stage and start talking about the gorilla"

Instructors also discuss how some religious views can be more compatible with evolution than others. The intent of this discussion was to show that contrary to some assumptions, many religions are compatible with evolution. For instance, Martin highlighted in his course how evolution is not in conflict with religion as a whole, although it is in conflict with some fundamentalist religious views:

Martin:

> "In terms of strategies it's a pretty straight forward one hour lecture with PowerPoints and I talked a little bit about the history and objections to evolution dating from Darwin's time and I note that the one that is still with us is that it runs counter to a literal interpretation of the Bible. I note that the conflict-- that there is no conflict between religion and evolution. There is a conflict between evolution and certain sects of Christianity and many denominations of Christianity have no trouble whatsoever with evolution. Most practitioners of Islam have no trouble with evolution. The fundamentalist Muslims do. Other religions have no problem with evolution. So I make the point that it is not a matter of evolution vs religion- it is a matter of certain denominations of religion being opposed to the idea of evolution, of an old earth, a distinct ancestry of humans and other forms of life and of evolution in general."

Notably, all three instructor participants who had in-depth discussions about religion and evolution in their classes said they did not consider helping students to accept evolution as part of their goal when teaching. Further, all three of these instructors reported growing up in a household with a religious affiliation. Two of the three instructors identified with a religious group and reported that they were unsure of what role God played in evolution. From the data that we collected, there was nothing else that distinguished these instructors from other instructors in our subject pool.

Among instructors who do discuss religion, some of them reported discussing religion in a way that seemed incompatible with religion. Often times this seemed unintentional, but instructors would imply that knowledge from religion is inferior to knowledge of science

because it is not based on testable observable phenomenon. Other instructors, such as

Samuel, were more explicit in making religion seem incompatible with evolution:

Samuel:

> "(I would say), 'there's a terrible wind blowing through America… that is trying to impose religion as science. It is out to destroy America, because it is not simply evolution. Evolution is built on genetics. It's built on chemistry. It's built on physics. It's built on astronomy, all of the sciences. If you believe in creationism, you can't believe in any of the foundations of science and that will destroy America. You will destroy America.' Pretty harsh. There is a deathly silence over the classroom."

Do instructor participants use instructional practices that align with suggestions in the

literature for increasing student acceptance of evolution?

Many instructor participants do not report using instructional practices that

align with suggestions in the literature for increasing student acceptance of evolution.

Although most instructor participants did not report spending significant time discussing

religion in the context evolution, they may still be utilizing instructional practices that

have been recommended to help mitigate conflict between religion and science (NAS,

1998, 2008; Smith, 1994; Southerland & Scharmann, 2013). In our interviews, we asked

instructors whether they had provided students with examples of religious scientist role

models who accept evolution (Winslow et al., 2011), whether they had discussed the

spectrum of viewpoints about religion and evolution (NAS, 1998), and whether they had

told students that religion and evolution could be compatible (Barnes et al., in review;

NAS, 2008; Smith, 1994; Southerland & Scharmann, 2013). Further, we asked the

instructors how and why they choose, or choose not to, implement these practices. Based

on a small, but growing research literature (Barnes et al., in review; Manwaring et al.,

2015; Roth, 1997; Wiles & Alters, 2011; Winslow et al., 2011), these strategies have the

potential to increase student acceptance of evolution and make religious students feel more comfortable in class.

Although most instructor participants had said it was not their goal to help students accept evolution, almost half of those instructors who said acceptance was not their goal said they had used at least one instructional strategy that has the potential to increase student acceptance of evolution. Thus, we looked at all instructor responses, regardless of whether they said that it was their goal to help students accept evolution. About half of all the instructor participants said they were using at least one of the three strategies at some point when they teach about evolution.

Instructor participants who provided students with religious scientist role models said they did so with the intent to show religious students that there are people who have religious beliefs and also accept evolution. The instructor participants wanted students to know they do not have to choose between their religious beliefs and evolution. A few instructors used themselves as religious scientist role models for their students:

Greg:

> "I point out that I'm a Catholic, and I'm an evolutionary biologist, and you go to [a Catholic university], where I went, and they have a whole evolutionary biology curriculum, there are evolutionary biologists on the faculty."

Ronald:

> "I don't discuss other people's belief systems at length because I don't feel I have the capacity or perhaps even the right to but I never hesitate in class to talk about my own perspective towards religion and God and morality and things like that and so because I'm open about those things with my students, I think students appreciate that. They see at least one role model, me perhaps, in that I am an evolutionary biologist and I have found a way very easily to also have religious beliefs and live a moral life and all of those

things. I'm not an atheist and yeah we talked about that in class. And I think students see that you don't have to have that forced dichotomy."

However, most instructors who provided students with religious scientist role models who accept evolution, did so using examples of other scientists.

Richard:

> "I have in the past shown a film about the human genome project. And the guy who runs the human genome project is Francis Collins and he's a deeply religious man and so yeah, I think it's worthwhile to say there's nothing incompatible with religion and science."

The instructor participants who said that they talk about various viewpoints on the relationship between religion and evolution said they did it to show students that several religious groups do accept evolution. These instructors wanted students to know that evolution and religion can be compatible. Some instructors, such as Craig, use national polling results that disaggregate acceptance of evolution by religious groups as a way to show students different religious viewpoints:

Craig:

> "The one thing I do is I show a Pew survey that was done, it was pretty dated now I think, in the early 2000's that showed the different religious faiths and their percentage of acceptance of a statement like "the best explanation for the origins of human beings is through evolution."

Other instructors describe ways in which religious individuals have reconciled their religion with evolution:

Ronald:

> "I treat the notion superficially, but I do treat it. In fact, one of the additional handouts I use in at least that introductory class where we spend a significant amount of time on evolution is an article that describes Pope John Paul's acceptance of evolutionary theory and I use that as a platform to have that discussion."

Many instructor participants explicitly told students that evolution and religion can be compatible. These instructors would incorporate the philosophy of science and describe to students that methods of science are neutral to the existence and influence of a God/god(s). They stress to their students that science does not rule out the existence of a higher power:

Richard:

> "And I say, oh if you accept evolution, because I think that's where they get into trouble, they think that, okay if I accept evolution then I can't be a good Mormon or a good Christian or a good whatever, and so my idea is you know that you can go to church and still believe in evolution, it's not incompatible."

Rachel:

> "In my introductory biology class it comes up very explicitly when I talk about the philosophy of science. So we have a unit on evolution and now we're talking about what science is. I contrast science and religion and I talked about how they ask different questions. Just because science has nothing to say about the deeper truth that doesn't mean that it's saying that there is nothing."

A minority of instructor participants used more than one of the strategies outlined above. Notably, most instructors who used more than one of these practices did not think it was their goal to help students accept evolution. Only a few instructor participants used all three strategies and all of those instructors were the instructors who also discussed religion and evolution in depth in their course.

What kinds of barriers do instructor participants perceive in addressing conflicts between religion and evolution in their classes?

Instructor participants perceive multiple barriers to discussing religion while teaching evolution. Because a significant number of instructor participants were not

discussing religion, we explored what barriers might exist for them doing so. The majority of instructor participants said that they perceived barriers to discussing religion in class, which made them hesitant about incorporating religion into classroom discussions. Of the instructors who perceived barriers to discussing religion in relation to evolution in their class, half of them reported that they still discussed religion in the context of teaching evolution. This indicates that for some instructors, these perceived barriers are not sufficient to stop them from incorporating discussions about religion into their evolution instruction.

Many instructor participants believed there were barriers to discussing religion when teaching evolution. Instructors cited classroom constraints, the appropriate domain of discussion in a science class, lack of training in issues involving religion and evolution, and personal beliefs about religion and evolution. These are discussed in more detail below.

Classroom constraints. Some instructor participants felt that the logistics of their classroom were a barrier to discussing religion. The instructors usually referenced large class sizes as well as limited time as barriers. The instructors thought that large classrooms were not amenable to such personal discussions and that time constrained them because they had too much content to present:

Charles:

> "And the other thing is, we're teaching a class of over 300 students. It's very different if I'm in a classroom of 30 students to have a discussion about this (…) there's only so many things that we can go into and if we spent you know three or four weeks discussing all these different aspects, we would really lose out and I think we would do a disservice to the students to do that."

Jonathan:

> "They've got about just enough time to handle what I give them and not anything else."

Appropriateness of the biology class. Also, some instructor participants said that their science class was not an appropriate forum for discussions of religion and evolution. These instructors often said that discussions about religion in the context of evolution are only appropriate for a philosophy class, but not a science class.

Anthony:

> "Probably one of the reasons [this would be challenging] is that what we are really talking about is the difference between science and philosophy, and because we're really talking about philosophy and this is a science class (…) it's not really on the table."

Jonathan:

> "That gets into an area where you're starting to bring religion into the science curriculum and so that would be the reason for not doing that."

Albert:

> "I guess what I would find challenging about that is that it just seems to me that implementing a strategy like that would be more consistent with offering a class on religion and evolution. And less consistent with a class that is specifically designed to discuss evolution. I don't think it's the right venue."

Lack of training. The lack of training in discussing religion related to evolution was another barrier that emerged. Some instructor participants said that they did not feel that they were knowledgeable enough about the topic of religion and evolution to talk about religion to their students. Because it is such a sensitive topic for many students, instructors indicated that they wanted to be sure they have the knowledge to properly handle potential challenges from students.

Victoria:

"I am very uncomfortable with that because I am not a religious expert and that is really outside my realm."

Personal beliefs about religion. Of all the barriers cited, personal beliefs about religion and evolution was mentioned most frequently. Many instructor participants said that their own beliefs about religion would be a barrier to productive discussions in class. Much of the time this was due to the instructor's belief that aspects of religion are incompatible with evolution:

Samuel:

"I'm not going to get into a major debate over science versus religion. Somebody's religion-- my religion is very personal to me. I don't believe everything that my religion says I should believe. I don't want to bring God into the equation. I really do not want to do that because I don't know what kind of God I believe in. I do not believe in the God of my Bible or the less threatening God of your Bible. I have my own fuzzy… [belief in what god is]."

Albert:

"There is a real fundamental problem with being an evangelical Christian if you believe that you are saved by grace. The problem with that is that if we evolved then there was no fall, and if there was no fall, then there is no need for atonement of Jesus dying on the cross. So there's a real fundamental conflict there if you say you are a Christian and you believe in Jesus and you believe in the notion of needing to be saved with the basic tenets of evolution that say we evolved. So even though these folks say they are evangelical Christians I mean that's fine and I am not someone who disregards the value of having a spiritual life. I think that that part is actually quite important but the notion that you need to be saved and that the way to be saved is to believe in Jesus Christ is really at odds with the idea of an evolved species."

These personal beliefs as a barrier to incorporating discussions about religion are particularly interesting because they relate to other findings about instructor personal beliefs from the interviews. Most instructors do not personally think that a God/god(s) had anything to do with evolution. In our survey, 69% of instructors reported that they believed God had nothing to do with evolution, 22% of instructors reported they did not

know whether God had anything to do with evolution, and only 3% reported that they thought evolution was God guided. No instructor thought that God started evolution or that God made humans in their present form. Six percent of instructors declined to answer the question.

Further, the overwhelming majority of instructors said that they had never experienced a conflict with evolution and their personal religious beliefs. These instructors fell into two categories: (1) those who did not have religious beliefs and did not grow up in a household that was religious, so there was never an opportunity for a conflict or (2) those who grew up in a religious household but were taught that religion and evolution were not in conflict.

The following are quotes from instructors who did not experience a world-view conflict with evolution:

Neil:

> "I was brought up Jewish, and there's some way, that even though Judaism has basically the same story of 6 days and the 7th day, God rested and all that, that there's some way that Judaism says that that all has to fit in with what we know about how life works. If we know that life works through evolution, we have to figure out how this fits into that, rather than the other way around. I don't remember having any sort of tribulations to my worldview when I thought about evolution, or any of the hard sciences, any of the sciences. To me, evolution comes down to a belief in science. And that science tells us of that. For me, I don't see any evidence for a supreme being in science, and somehow that's always seemed natural to me. I don't remember any sort of crisis growing up about that."

Craig:

> "I'd say no [I didn't experience a conflict]. I crave empirical understanding and always have and so it was easy. I wasn't raised religious so I didn't have any sorts of understandings prior to this point that I had to reconsider really. I was an open slate and so as I began to understand this, I was like 'This is incredibly cool'. You can understand how this stuff works now."

The minority of instructors who did experience a conflict were either religious at one

point, but "chose science over religion" or remain religious to this day, but had to find a

way to reconcile religion and evolution.

Jonathan:

> "It's certainly a struggle in the sense of not knowing where God took over evolution and initiated evolution. There's no way of knowing that sort of thing and of course you struggle with it."

Anne:

> "I went to a very conservative college and I remember I took a couple of religion classes where they just said what I thought were just completely ridiculous statements. So I guess at that point I was 18 or 19 I was kind of trying to, you know, my parents weren't overly religious but some of my other family was and I was kind of trying to piece it together and put it into perspective of being a biology major and what everybody believed and I had a couple these classes… I had one teacher I remember that was lecturing us on the book of Genesis and he told us that God put dinosaur bones into the earth to test our faith (laughs) and I was just like, 'I know I'm only 18 but that's the most ridiculous sounding thing I've ever heard.' So actually I was kind of being exposed to a couple of... it's just so ridiculous there's no way I can believe this. Things that really force me to, I have to go with what seems like logical and reasonable to me and I just can't accept that."

Discussion

In this study, we explored the perspectives of instructors who have taught about

evolution to undergraduates. Given the flexibility in what college biology instructors can

choose to teach, the instructional decisions of college instructors is important for

understanding the landscape of evolution education. While there is a rich literature on

college student understanding of evolution (Bishop & Anderson, 1990; Hermann, 2012;

Lawson & Worsnop, 1992; Nehm & Reilly, 2007) and *college student* acceptance of

evolution (Abraham et al., 2012; Rice et al., 2010; Wiles & Alters, 2011; Winslow et al.,

2011), we only know of two other studies that have looked into the perspectives of

college biology instructors regarding student acceptance of evolution (Rice et al., 2015; Wilbur & Withers, 2015). However, these studies did not explore the perceived goals of college instructors when teaching evolution, if and how they discuss religion when teaching about evolution, and what perceived barriers exist to discussing religion when teaching about evolution. Thus, the current literature in evolution education seems to be devoid of the perceptions of the people actually teaching college level evolution. This interview study of instructors teaching in public institutions of higher education in Arizona represents the first step in exploring these questions, which could be followed up with observational studies of instructor practices in the classroom and the impact of these practices on students.

Many instructors do not see student acceptance of evolution as part of their instructional goals. Despite the extensive literature on student acceptance of evolution (Abraham et al., 2012; Espinosa & Guillermo, 2009; Heddy & Nadelson, 2012; Ingram & Nelson, 2006; Miller, Scott, & Okamoto, 2006; Nadelson & Sinatra, 2010; Nadelson & Southerland, 2010; Nehm et al., 2009; Rissler et al., 2014; Rutledge & Sadler, 2011; Sinatra et al., 2003; Wiles & Alters, 2011), we found that the majority of instructor participants do not think increasing student acceptance of evolution was their instructional goal. This debate of whether student acceptance of evolution is important has been extensively discussed in evolution education literature and in line with our findings, a consensus about whether it should be the goal of evolution education to increase student acceptance has yet to emerge (Alters, 1997; Cobern, 2004; Cobern, 1994; Sinatra et al., 2003; Smith, 1994). Notably, this distinction between understanding and acceptance seems to be a unique characteristic of the topic of evolution and is not an

area of contention for other core concepts of biology (AAAS, 2011, Brownell et al.

2014). If instructors do not debate whether it is their goal for students to understand or

accept structure function, pathways and transformations of energy and matter,

information flow, or systems - should the core concept of evolution be any different and

if so, why?

In our study, we did not ask instructors what might change their minds to include

acceptance as an instructional goal. However, if college student acceptance of evolution

is to improve, then determining how to effectively communicate with college biology

instructors on the importance of acceptance in evolution education could be key. Future

studies could explore what types of evidence would be effective in convincing instructors

that acceptance is a worthy goal of evolution education.

A definitional problem of acceptance of evolution. One possible reason that

instructors may not think it is their goal to help students accept evolution is how they

personally define acceptance of evolution. As we found in this study, some instructors

define acceptance of evolution as necessarily excluding the potential role of a God/god(s)

in creating evolution. If an instructor thinks that a student cannot believe that a

God/god(s) created evolution in order to accept evolution, then instructors may not think

acceptance is their goal because in order to get students to accept evolution, they would

be asking some students to give up a belief in God/god(s). However, if an instructor

allows for the possibility of a God/god(s) in their definition of acceptance of evolution,

then it may seem less of an ethical dilemma. With a looser definition of acceptance of

evolution, which allows students to incorporate an optional role for a God/god(s), perhaps

more instructors would indicate that it is part of their goals for students to accept

evolution. Because religious beliefs tend to be salient to a student's identity and because the methods of science are limited to studying the natural world, we encourage instructors to allow for the possibility of a student maintaining a belief in a possible role of God/god(s).While our study offers an initial exploration into this topic, a thorough treatment of the definition of acceptance of evolution is beyond the scope of this paper. A future publication by the authors will treat this issue in more depth.

Potential barriers to instructors discussing religion in the context of evolution. Instructor participants perceive multiple barriers to discussing religion in the context of evolution in their class. Some instructor participants said they did not think a science class is the appropriate forum for discussing religion in relation to evolution. Many instructors thought that discussions about religion in relation to evolution should be reserved for a religion or philosophy class and not a science class. While studies have shown that discussing religion in the context of evolution can be a useful way to demonstrate the nature of science (Alters & Nelson, 2002; Clough, 1994; Smith, 1994), it may be that instructors are not aware of this or do not consider this to be a part of their evolution units. Using religion as an example, one can compare and contrast what is science (i.e., evolution) to what is not science (i.e., creationism). An instructor can demonstrate the types of knowledge that science accumulates (i.e., information about the natural world) in contrast to the type of knowledge that religion accumulates (i.e., existence of God, influence of gods/God, prescriptions of how to live one's life morally). In this sense, an instructor can not only teach about the nature of science, but also potentially diminish students' perceived conflict between religion and evolution by explaining that they are different domains of knowledge.

Additionally, instructors indicated that they did not have the experience or training to discuss religion in the context of evolution in their classes. Indeed, research shows that when an instructor feels they are not knowledgeable in a content area, they tend to spend less time presenting that content in class and experience anxiety when they do present the content (Griffith & Brem, 2004). Instructors may need to become more familiar with the evolution-religion realm in order to feel more comfortable implementing strategies that deal with this content. The National Academy of Sciences' handbook *Science, Evolution, and Creationism* (NAS, 2008) and the book *Evolution vs. creationism* (Scott, 2005) are both potential resource for instructors to refer to when thinking about conflicts students may face with evolution. Books such as Dr. Ken Miller's *Finding Darwin's God* (Miller, 2002) and Francis Collin's *The Language of God* (Collins, 2006) can help instructors become familiar with religious ideas about evolution. Further, the National Center for Science Education has a webpage on Science and Religion that offers a list of practical resources for those interested in learning more about the topic (http://ncse.com/religion).Venues where biologists can interact with philosophers of science or biology and society programs may give college-level biology instructors the opportunity to become more familiar with these ideas. Both of the authors are housed in a School of Life Sciences where there is frequent interaction among evolutionary biologists and philosophers; institutional structures such as this could be a way to encourage these conversations to break down barriers.

The most cited barrier to discussion of religion in the context of evolution was an instructor's personal beliefs about the relationship between religion and evolution. The prevalence of personal beliefs as a barrier to discussing religion in the context of

evolution prompted us to examine other aspects of participants' personal beliefs. These were not explicitly cited as barriers by the instructors, but could contribute to instructors not discussing religion in the context of evolution in biology classes. Many instructor participants did not believe there were many students in their classes that rejected evolution. The average reported guess of rejection rates by an instructor about their class was ~15%, with some instructors believing the rejection rate was as low as 5% in their classroom. However, only three instructors had polled their class to determine the percentage of students who rejected evolution. In addition, the overwhelming majority of instructors reported that they have never been challenged by a student about evolution in class, which could be why they believe that most of their students accept evolution. However, a student not explicitly challenging an instructor's instruction may be a poor indicator for student acceptance of evolution given that studies indicate that some students find STEM instructors intimidating and unapproachable (Seymour, 2000). Further, religious students may be unlikely to raise concerns in a secular environment if they feel that environment is unsupportive of religion. Past research has shown that 30-50% of students in biology classes reject aspects of evolution (Ingram & Nelson, 2006; Moore & Kraemer, 2005; Verhey, 2005) and up to 26% of students are undecided about evolution (Espinosa & Guillermo, 2009), so it is likely that instructors are underestimating rejection rates and uncertainty about evolution in their classes.

Last, instructors may struggle when trying to relate to their students' religious conflicts with evolution. Only a small fraction of instructors reported that they experienced their own worldview conflict with evolution at any time in their life, which may be due to the low levels of religious belief among this population. Further, the

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majority of instructor participants reported that they believed that God/god(s) had nothing to do with evolution, indicating that they take a primarily atheistic view of the diversification of life. While an atheistic view of evolution is sometimes seen as more compatible with a scientific view, there may be students who do accept evolution but also believe a God/god(s) planned, started, or guided the process. It might be difficult for a secular instructor to identify with the struggles and challenges that religious students may face when learning about evolution. However, if secular instructors want to help religious students become more comfortable with evolution, they likely will need to become more aware of student religiosity, rejection of evolution, and the challenges facing students who may be going through a worldview conflict with evolution. Although instructors who personally believe that there is an irreconcilable conflict between evolution and religion may feel it is dishonest to tell students that the two are reconcilable, they can still show students examples of other prominent scientists and religious leaders who have reconciled evolution and religion.

Implications for equity in undergraduate biology. Although this was not the focus of our study, a possible extension of our findings is how instructional practices are impacting how religious students feel in the classroom. While discussions of diversity in STEM have traditionally focused on individuals from diverse races/ethnicities, gender identities, sexual orientations, and abilities/disabilities, we envision a need to broaden our efforts to diversify STEM to include individuals from diverse religious backgrounds. A disconnect between instructor and student beliefs about religion could possibly filter out religious students from pursuing careers in biology, thereby contributing to a less religiously diverse scientific community. Instructors could be inadvertently selecting

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against students who are religious and this could impact how a religious undergraduate feels about how they belong in the biology community. If a religious student feels that their beliefs are not compatible with the dominant views of the biology community, this could lead to a student choosing a different career path in a field where they feel their personal beliefs are more compatible with the dominant views in the field. If instructors insist that students have to choose between their religious identity and their biology identity, then students are likely to choose the identity that is most salient to them; for introductory biology students who have not had much experience with science, religious beliefs will likely be more important to them.

Religious student comfort when learning evolution could impact ethnic diversity in evolutionary biology as well as religious diversity. In recent years, the NSF has released data that shows doctoral degrees in evolutionary biology are rarely awarded to African Americans. Indeed, in 2011 there were no doctoral degrees in evolutionary biology awarded to African Americans, while other areas of biology granted ~5% of their doctoral degrees to African Americans (NSF, NCSES, 2011). In a recent study, researchers linked this underrepresentation of African Americans in evolutionary biology at least partially to their high levels of religiosity (Mead et al., 2015). As we strive to diversify who gets to participate in science (Bangera & Brownell, 2014; Eddy et al., 2014; Eddy, Brownell et al. 2015, Tanner, 2013), it is important that instructors are conscious of the biases that may result in the exclusion of a cultural group from evolutionary biology.

Limitations. This study was conducted with instructors in public institutions of higher education in Arizona. Arizona is a relatively conservative state and in 2009,

Arizona was ranked as the 8th in the nation for percent registered republicans (Gallup, 2009) (CNN, 2005). Therefore these results could be unique to the context of this geographic area and political climate. While we are not aware of any state mandates on what Arizona college instructors are not allowed to teach and interview participants did not mention any statewide policies, instructors may still be indirectly affected by their perceptions of state governance or even state politics. It will be important to replicate this study in other geographic areas to determine if the findings are consistent or if there are unique geographical constraints that impact these instructor attitudes and instructional practices.

We obtained a response rate of approximately 14%, which is low compared to the response rates for interview studies with similar recruitment methods (Bush et al., 2015). We may have gotten a low response rate due to the controversial nature of the topic, which means that we may have a self-selection issue that may bias the results (Brownell et. al, 2013; Rosenthal & Rosnow, 1975). We acknowledge that it could be possible that the pool of interviewees who were willing to talk about their instructional practices are not necessarily reflective of the larger population of instructors, so our findings should be interpreted cautiously (Shortlidge, Bangera, & Brownell, 2016). For instance, 34% of our participants said that they identified with a religious group while previous data indicates the rate of religiosity among biology faculty to be around 25% (Ecklund & Scheitle, 2007), which could indicate a small response bias from religious instructors. However, while our results may represent a specific population's responses, the diversity of viewpoints exhibited during the interviews gives us confidence that we were able to elicit interviews from faculty with different opinions on the topic.

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These were self-reports of instructional practices and not observational data. Factors that influence the way individual's self-report, such as social desirability bias, could have influenced these results (Edwards, 1957) and some of the instructors' experiences and perceptions may not be accurately represented. However, this is a limitation of most interview studies, which are often seen as a first step in exploring a new research area in order to subsequently inform more systematic and observational research (Glesne & Peshkin, 1992).

We relied on the interviewees' own definitions of acceptance of evolution, understanding of evolution, and religious beliefs. While this was intentional because we were interested in instructor perspectives, which are dependent on their own definitions, we acknowledge that an important area of future research in evolution education is to come to consensus on these definitions. The published literature on student acceptance of evolution is conflated with multiple definitions and interpretations (Cobern, 1994; Sinatra et al., 2003; Smith, 2009; Smith, Siegel, & McInerney, 1995; Southerland, Sinatra, & Matthews, 2001), making this an area ripe for future investigation. We can also begin to explore differences among different religious traditions. Similar to how the term "underrepresented minority" (URM) refers to multiple groups of people with unique social identities and experiences, by referring to "religious beliefs" we are not taking into account the differences among those belief systems. Although this is not often done currently, it is important for evolution education researchers to begin to disaggregate students by their religious denominations and the saliency of their religious beliefs.

Finally, some of the instructors in our study were teaching whole semester-long evolution courses, while some were teaching evolution lessons as part of a biology

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course. This may mean that our interpretations could change if we interviewed only instructors who were teaching semester-long evolution courses. For instance, instructors may be less likely to include a discussion of religion in a one week lesson on evolution than during a whole semester on evolution. However, we did not see any patterns based on the type of course for our study.

Conclusion

To our knowledge, this is the first study to document the attitudes and self-reported instructional practices of college biology instructors about discussing religion in relation to evolution in biology classes. We found that the majority of instructors do not think it is their goal to help students in their classes accept evolution, that they largely avoid the topic of religion when teaching evolution, and that there is a wide range of barriers that hinder them discussing religion in relation to evolution with their students. These data reinforce the need for a consensus on whether a goal of evolution education should be student acceptance of evolution, which includes a more specific delineation of the definition of acceptance of evolution. Further, it also brings awareness to the potential barriers that instructors may perceive when making decisions about whether to engage with religious students about religion and evolution. We hope that this study will be useful as a reference for instructors as they make their own decisions about how to engage with religious students when teaching about evolution.

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CHAPTER 4

EXPERIENCES OF JUDEO-CHRISTIAN STUDENTS IN UNDERGRADUATE

BIOLOGY

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Abstract

A major research thrust in STEM education is focused on how to retain students as STEM majors. The accumulation of seemingly insignificant negative experiences in STEM classes can, overtime, lead STEM students to have a low sense of belonging in their discipline and this can lead to lower retention. In this manuscript, we explore how Judeo-Christian students in biology have experiences related to their religious identity that could impact their retention in biology. In 28 interviews with Judeo-Christian students taking undergraduate biology classes, students reported a religious identity that can conflict with the secular culture and content of biology. Some students felt that because they are religious, they are a minority in their classes and would not be seen as credible within the biology community. Students reported adverse experiences when instructors had negative dispositions towards religion and when instructors were rigid in their instructional practices when teaching evolution. These data suggest that this may be a population that is susceptible to experiences of cultural conflict between their religious identity and their STEM identity, which could have implications for retention. We argue that more research should explore how Judeo-Christian students' experiences in biology classes influence their sense of belonging and retention.

Introduction

In order to the meet societal needs of the 21st century, colleges and universities must increase the number of students graduating with science, technology, engineering and math (STEM) degrees (AAAS, 2011; Holdren et al., 2010). To increase the number of STEM students, there have been national calls for researchers to explore factors that influence students' persistence in STEM majors. One prominent factor that has been shown to influence students' persistence in a STEM major is their sense of belonging (Brown et al., 2016; Espinosa, 2011; Good et al., 2012; Strayhorn, 2011, 2012). Sense of belonging has been characterized as whether a student feels as if they "fit in" or "belong" in their academic community (Trujillo & Tanner, 2014) and is related to a student's social and academic integration into a discipline (Freeman et al., 2007; Good et al., 2012; Strayhorn, 2012; Tinto, 1993). When a student feels a high sense of belonging in a domain, they are more likely to feel as if they are a part of the discipline rather than on the fringe of the discipline (Good et al., 2012).

The concept of sense of belonging stems from work focused on understanding why students, particularly those from historically marginalized groups, decide to leave college or switch majors (Tinto, 1993; Trujillo & Tanner, 2014). More recently, researchers who were exploring students' sense of belonging in undergraduate STEM programs have found that a student's sense of belonging predicts both their intent to persist (Good et al., 2012) and their actual persistence as a STEM major (Espinosa, 2011).

A major factor that can affect a students' sense of belonging is whether they feel they are part of a group that is negatively stereotyped. When students think their peers

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and/or instructors hold a negative stereotype about their group (i.e., gender group, ethnic group, etc.) this can result in the student feeling a low sense of belonging within that discipline (Brown et al., 2016; Good et al., 2012). For instance, Brown and colleagues (2016) found that African American students in STEM who reported experiences of subtle or overt forms of racism in their discipline were more likely to report a low sense of belonging in that discipline. Similarly, another study found that when women in mathematics perceive there is a negative stereotype about their gender's ability, they tend to have a lower sense of belonging in math (Good *et al.,* 2012). Good and colleagues speculated that persistence in STEM will be affected by a low sense of belonging within *any group* who is repeatedly met with experiences that imply their group is stereotyped negatively within their discipline.

We suspect that Judeo-Christian students in biology may feel that religious individuals are negatively stereotyped in biology due to several factors that are characteristic of the culture of the biological sciences. First, there is a cultural perception in the United States that biology and religion are in conflict (Scott, 2005; Numbers, 2006). Core areas of biology, such as evolution (AAAS 2011, Brownell et al. 2014), are often presented as incompatible with religious beliefs by many individuals in the public, including scientists (Coyne, 2015; Dawkins, 2009; Harris, 2005) religious leaders (Ham, 2010) and politicians (Satlin, 2012). Additionally, past research shows that students' discourse with their friends and family outside of class on topics such as evolution can lead students to perceive a conflict between religion and evolution (Winslow et al., 2011). It could be that Judeo-Christian students come into the classroom with the preconception

that there is a tension between their religious identity and biology, which could make them feel negatively stereotyped in biology classes.

Second, previous research has shown that the biology classroom is not always a comfortable environment for religious students. In past research, religious students said they felt alienated when instructors taught evolution and did not address the potential controversy with religion (Hermann, 2012). Additionally, research shows that instructors are often unwilling to acknowledge religious student perspectives when teaching evolution and unwilling to present evolution and religion as potentially compatible (Barnes & Brownell, 2016). Thus, it may be common for Judeo-Christian students to feel as if their perspectives are not acknowledged or respected when instructors teach relevant content.

Third, research has shown that Christian students can experience negative stereotypes in science generally (Rios et al., 2015), which implies that Christian biology students may also feel negatively stereotyped (Good et al., 2012). Rios et al, 2015 showed that Christian individuals perceive that there are negative stereotypes about their ability in science. Additionally, among a population of undergraduate Christian non-biology major students, the researchers showed that students who are aware of the negative stereotype about Christians in science underperform on tasks they are told are indicative of science ability (Rios et al., 2015), a phenomenon called stereotype threat (Steele & Aronson, 1995). Further, these Christian students who experienced stereotype threat subsequently said they identify less with science than did their counterparts who did not face stereotype threat (Rios et al., 2015). However, the researchers did not explore the authentic experiences of Christian students actually taking biology classes. We

suspect that Judeo-Christian students in biology classes may also perceive there are

negative stereotypes about Judeo-Christians in biology, which subsequently could

compromise their sense of belonging in biology and retention as a biology major (Good

et al., 2012; Rios et al., 2015).

Fourth and finally, there is a disconnect between the percentage of religious[3]

individuals in the United States and the percentage of religious individuals who are

biologists in the United States; while 83% of the public believe in God and 75% identify

with a Christian religious denomination (Pew, 2009), only 32% of biologists believe in

God and 25% identify with a Christian religious denomination (Ecklund & Scheitle,

2007; Pew, 2009). Even though Judeo-Christian students make up approximately half of

introductory biology classes (Cooper et al. unpublished), they may perceive that few

biologists are religious, and this perception may be further exaggerated by outspoken

prominent atheist biologists (Coyne, 2015; Dawkins, 2009; Harris, 2005). Thus, similar

to how many African American students in STEM report negatives experiences in part

because so few of their instructors are African American (Brown et al., 2016), Judeo-

Christian students may report negative experiences in biology because so few of their

biology instructors appear to be religious. While we draw a parallel here, it is important

to consider that religious identity is often a covert identity and less visible than an

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[3] In this study, we focus on students of a Judeo-Christian religious background. While the majority of religious students in our classes are Judeo-Christian, we recognize that not all religious students are from a Judeo-Christian background. When discussing past literature, we are as specific about the religious denominations of students as possible. When studies provide information about specific denominational characteristics, we report that denomination. However, when the study does not report the specific denominations of their students we refer to these individuals as "religious".

identity such as race, which could make the identification of role models even more difficult for religious students.

In this study, we explored experiences of Judeo-Christian students in biology classes that could lead them to feel uncomfortable in biology classes and this is the first study to take this approach. Further, in an effort to understand how we may help Judeo-Christian students feel more comfortable in biology classes, we explored the positive experiences that Judeo-Christian students have in biology classes. This exploratory interview study represents a first step towards better understanding the experiences of religious students in college biology and we hope that it will lay the foundation for future research on Judeo-Christian students' sense of belonging and retention in the biology major. We set out to answer the following research questions:

1. What aspects of biology instruction are relevant to students' religious identity?

2. What interactions with peers/instructors make religious students feel comfortable or uncomfortable in biology classes?

3. What experiences do religious students have with biology peers and instructors that make them feel like they fit in and are valued, or not?

Methods

Recruitment. We recruited a sample of religious students taking high enrollment biology classes at a large, public, research-intensive university in the southwest of the United States. Recruitment took place during spring, summer, and fall semesters of 2015. Students were recruited using flyers that the research team distributed to students in majors and non-majors introductory biology courses and upper-level biology courses including genetics and evolution. The flyer indicated that researchers were interested in

talking to religious students about their experiences in biology classes and were offering compensation for a 30-45 minute interview. Students then used a link on the flyer to sign up for an interview time via a Doodle poll using their name and email address.

Data Collection. When students arrived to the interview location, they were given an overview of the purposes of the study. They were told that the research team was interested in exploring experiences that may contribute to religious students' decisions to either stay or leave the biology major. We then conducted semi-structured interviews. We asked students general questions about their negative and positive experiences in undergraduate biology classes that were relevant to their religious identity and generally how they felt as a religious student in biology classes. As with many qualitative interview studies, our interview questions changed slightly throughout the data collection period (Glaser & Strauss, 1967). However, a list of the general interview questions that were used can be found in **Table I**. At the end of the interview, the participants were given a short questionnaire to determine their gender, background in biology, religious saliency and religious activity, their personal perception of God's role in evolution and their perception of the scientific view of God's role in evolution. Participants were compensated with $15 in cash at the end of the interview for their time. All research was approved by the Arizona State University's IRB, protocol #00002555

Analysis. The research team transcribed half of the interviews and conducted preliminary analyses on these interviews. We used content analysis to identify pre-determined themes that the research team was interested in exploring prior to the data collection (Krippendorff, 2012). We also used grounded theory to identify additional

themes from the interview transcripts that emerged after the data collection (Glaser & Strauss, 1967). After we felt that we had established a set of preliminary themes from the interviews, the remaining interviews were transcribed and analyzed to confirm that we had identified all preliminary themes. Then, we established more specific categories within each theme. For instance, within the theme "students see advantages to being religious in biology" there were two main sub-categories created: "students think they can help other religious individuals understand biology" and "students think they bring a unique perspective to biology." Constant comparison methods (Glesne & Peshkin, 1992) were used throughout the analysis. That is, quotes that were assigned to specific themes and categories were gathered together and compared to one another throughout the analysis. This constant comparison of quotes was meant to ensure that the description of the theme and category adequately represented all quotes within the same group and that the quotes were not different enough from one another to deem a separate category or theme. Qualitative analysis software, NVivo, was used to organize the final coding of all interviews but we did not use the automatic coding feature. All codes were applied through the software by a researcher manually.

Table I: List of questions used throughout interviews.

Identity questions	What religious faith do you most closely identify with, if any? How did you come to that faith?
	What is your major and why did you choose that major? What do you want to do when you finish school?
Experiences with instructors	Can you describe a time when an instructor in your biology class talked about religion in a positive way? In a negative way? How did those experiences make you feel as a person of faith?
	As a person of faith, can you describe an experience where your instructors in biology classes made you feel like they valued religion/religious beliefs? Did not value

	religion/religious beliefs? How did those experiences make you feel as a person of faith?
	Have any of your instructors ever talked about how religion and science are different from one another? How did those experiences make you feel as a person of faith?
Experiences with peers	Have your peers in biology classes ever done anything that made you feel like they valued religion/religious beliefs? Did not value religion/religious beliefs? How did those experiences make you feel as a person of faith?
Sense of belonging	As a person of faith do you feel like you "fit in" in biology classes? Why or why not?
	As a person of faith, do you feel like you "fit in" with the broader community of biologists? Why or why not?
	As a person of faith, do you feel like you can make friends with other students in your biology classes? Why or why not?
Perceptions of shared values with the biology community	Do you think a person can be religious and a biologist? What percent of biologists do you think are religious?
	If an instructor is religious would it matter for you to know that they were religious? Why or why not?
	If an instructor were religious would it make you more likely to talk to them outside of class or raise your hand in class? Why or why not?
Advantages/disadvantages to being religious in biology	Can you describe any reason that being religious would be an advantage to you as a biologist? A disadvantage?
	Can you describe any way in which you think your religious beliefs conflict with the science of biology?
Personal beliefs about religion and biology	Describe how you view the relationship between religion and biology. Have any of these views been influenced by your biology instructors?
Concluding remarks	Do you have anything else you would like to add about your experiences as a person of faith and a person in a biology class?

Results

Interrater reliability. During and after the analysis of the data, we created a coding rubric. The coding rubric consisted of detailed descriptions of each theme and category that were established during the interview analysis. The rubric also included instructions on how to code the interviews, which was reflective of our process during the final round of coding. In order to establish that the coding scheme was reliable and could be used to replicate the results by other researchers, the second author independently

coded 10% of the statements coded by the first author in her final round of coding and the two results were compared. The two researchers coding agreed 87% of the time. However, reporting percent agreement for inter-rater reliability may inflate agreement rates because percent agreement does not take into account agreement that would occur by chance alone (Hallgren, 2012). Therefore, in addition to percent agreement we also used a Kappa Statistic to measure the observed level of agreement among raters and control for agreement that would happen by chance. Cohen's Kappa was calculated in SPSS 21 for each coded statement and then averaged. Cohen's Kappa was greater than 0.70 for all codes reported in this manuscript and the average Cohen's Kappa for all codes reported in the manuscript was .81, which indicates very high agreement (Landis & Koch, 1977). Codes from the more expert author's analysis were assigned to excerpts in which there was disagreement about the coding of an excerpt.

Demographics. Our interview population consisted of 13 males and 15 females. There were 6 first years, 10 sophomores, 10 juniors, and 2 seniors. Almost all of the students were biology majors (25/28), but a few were non-majors taking biology as an elective course (3/28). Many of the participants indicated that they planned to earn higher than a bachelor's degree in a biology related field (20/28) and fourteen of these students said they planned to pursue a health/medicine related degree. Only 4/28 of our participants planned to earn a bachelor's degree as their highest degree in biology and 3/28 participants planned to obtain degrees in an unrelated field, as these were the non-biology major students. One student was unsure of the highest degree she expected to obtain.

Religiosity. As intended, all participants indicated in the survey that their religious beliefs were important to them and all participants indicated they participated in religious activities. Participants reported relatively high rates of religious saliency and/or religious activity. In the interviews, all participants said they identified with a Judeo-Christian religious faith. However, it is worth noting that we did not specify in our recruitment that we wanted to interview students from a Judeo-Christian religious background. Our flyer stated that we were interested in the experiences of religious students in biology classes. However, only students from Judeo-Christian backgrounds responded to the flyer. The large majority of participants (25/28) identified with a self-identified denomination of Christianity (10 non-denominational, 7 Catholic, 2 Presbyterian, 1 Anglican, 1 Baptist, 1 LDS, 1 Lutheran, 1 Orthodox, 1 Protestant) and 3 participants identified with Judaism.

Research Findings. While the majority of the students said that they felt accepted and respected in biology classrooms, the interviews also elicited responses from students that indicated that they may experience unique struggles in the context of undergraduate biology classrooms. Most participants said in their interviews that their overall experience in the biology community has been positive, but many students recalled negative experiences and/or negative perceptions in the biology community that related to their religious identity. While these instances were often subtle and infrequent and it is difficult to ascertain the specific impacts of these experiences, the research literature on microaggresions and stereotype threat suggests that small, seemingly insignificant events can have a substantial impact on an individual's larger sense of belonging and identity (Murphy et al., 2007; Steele et al, 2002; Sue et al., 2007; Sue et al, 2009). Below, we

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outline both the positive and negative experiences that religious students reported having in biology. We have organized these findings into three main categories: experiences students have navigating a religious identity in biology classes, students' perceptions of the advantages and disadvantages to being religious in biology, and students' perceptions of biology instruction as it relates to their religious identity.

Navigating a Religious Identity in Biology. The majority of students, but not all, reported that their religious identity can conflict with biology. However, many students also described unique ways in which they reconcile their religious identity with their biology identity. Students discussed how they have a general cultural perception that religion and biology conflict and this presents a challenge to them before even coming to college. Further, many students cited evolution as a potential source of conflict with their religious identity and our survey results show that students' beliefs about evolution are often different from what they perceive is the most accurate view according to current science. Mainly, while students believed in an influence of God on evolution, they also believed their view is not compatible with the scientific view of evolution. However, despite potential conflicts, students demonstrated instances of reconciling their religious identity and biology identity using several strategies. These findings are further illustrated with student quotes below.

Religious students reported that they came into college with the perception that religion and biology are in conflict. Throughout our interviews, many of the participants reported that their general experience is that most people believe that biology and religion are in conflict.

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Christopher, (non-denominational Christian):

"A lot of people think science and religion are completely separate from each other and it's like one or the other."

Some religious students said they already had this perception prior to enrolling in college biology classes. They expected that they would struggle in college as a student of faith and a biology major because of the perceived conflict between religion and biology:

Alexis (non-denominational Christian):

"I feel like anyone from a religious background who goes to a public college, they expect their professors when they are going to biology… there's going to be some sort of conflict in there […] I knew it would happen."

Further, the students expressed a general feeling that the biology community is not sympathetic to religion:

Brittany (Catholic):

"Even in high school, it was a total battle fighting if [biology] is really right for me because I love science, but it's just the whole community is super insensitive about religion."

These findings indicate that Judeo-Christian biology students may have a perception that their religious identity may conflict with their aspirations in biology before they even enter a college biology course. This potentially pervasive conception illustrates how the perception of religion and biology as in conflict can come from outside sources separate from students' experience in biology classes.

Students' personal beliefs about God's role in evolution can be in conflict with their perceived belief about how scientists view the involvement of God in evolution. Eighteen participants indicated on our survey that they personally believe God either started or guided human evolution, a view often referred to as "theistic evolution"

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(Miller, Scott, & Okamoto, 2006). Nine participants indicated that they believe humans were created in their present form by God, a view that is often labeled as "special creationism" (Scott, 2005). Four participants indicated they did not know whether God was involved in human evolution, but believed evolution occurred, a view that can be labeled "agnostic evolution" (Yasri & Mancy, 2016), and no participants said they believed God could not be involved in evolution, a view that is called "atheistic evolution" (Yasri & Mancy, 2016).

When asked what they thought was the most accurate *scientific view* of God's role in human evolution, 14 participants indicated that they thought the most accurate view, according to science, is atheistic evolution. Eight participants indicated they thought the most accurate scientific view is agnosticism of God's role in evolution. Four participants said that special creation is the most accurate scientific view, and four participants said that theistic evolution is the most accurate scientific view.

Notably, most students held beliefs about evolution that could be compatible with the scientific view of evolution (theistic evolution or agnostic evolution), but some of these students indicated that the most accurate scientific view of evolution was atheistic evolution, which would be incompatible with theistic evolution. Ten of our participants who said they personally believed theistic evolution also believed the most accurate scientific view was atheistic evolution.

Religious students use several strategies to accommodate biology to be compatible with their religious identity. Although some students felt as though their peers and instructors see a conflict between biology and religion, students showed evidence of managing their religious identity with their aspirations to pursue a career in the field of

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biology. Students reported using several strategies to reconcile their religious identity

with biology. The majority of students reported adapting their religious beliefs to

accommodate biology knowledge. For instance, William talks about how he used to

believe in special creationism, but after learning evolution, he changed his beliefs:

> William (Baptist):
>
> "I was taught creationism and that's it. I didn't question it, that's just how things were. The flood came and two animals reproduced with each other and that's how we have all the animals today. That's basically what I used to believe. Now that I've been learning evolution […] and things of that nature, it's definitely made me look back and reassess certain perspectives that I have."

Another strategy many students used to reconcile their religious identity with biology was

to seek out and utilize role models who are religious scientists. Religious scientist role

models have been shown in previous research to positively influence students' views on

the relationship between religion and evolution (Barnes, Elser, & Brownell, 2017;

Winslow, Staver, & Scharmann, 2011):

> Brittany (Catholic):
>
> "I found a bunch of people I can look up to that have talked about both [religion and science]. There is a professor here […] he teaches physics and he's a member of my church, the Catholic Church, so he's a great person to go talk to like 'Hey, I'm struggling with these two things that seem contradictory. Can you help me find a way to put them together?' and he's been amazing."

Some students chose to restrict their biology identity to areas outside of evolution in

which they perceived no conflict with their religious beliefs. Even though evolution has

been outlined as a core concept of biology (AAAS, 2011; Brownell et al., 2014), these

students are tried to segment biology into areas of less perceived conflict. For instance,

Alexis reported that she would not see her religious beliefs as a barrier to her specific

field of interest, but that she could have a problem if she were pursuing areas of biology that involve evolution:

>Alexis (non-denominational Christian):
>
>"I don't think that it's going to be a big problem in the medical field but I think any time you work with animals or plants in a way that brings up evolutionary history or that normally brings up evolutionary history, I think that that really draws more attention when you don't agree with everyone else."

Students also restricted their interest in biology to specific courses that did not conflict with their beliefs. When students who subscribed to special creationism had to take courses that included content like evolution that they saw as conflicting, they said they would take the class just to get a good grade and get their degree, but they did not believe the material in the same way that they believe the material presented in other classes. For instance, Martin, a special creationist, said he learned the "correct" information about evolution so he can get a good grade, but he was not generally interested in it:

>Martin (Orthodox Christian):
>
>"I agree with the professor [about evolution] for the sake of the grade, for the sake of my GPA. But other than that, I don't even want to be interested in taking it."

And Tonya, also a special creationist, says she just learned the material for the test but chose not to believe it:

>Tonya (Anglican):
>
>"In general certain things they teach us about evolution, I just feel a certain kind of way, I just don't feel like it's right or it's true. I mean, I just learn it and memorize it for exam purposes but I don't necessarily believe it."

Students also expressed that they compartmentalize their religious identity in order to accommodate biology. They restricted their religious identity to their lives outside of

their biology classes and that is how they navigated being a religious student in biology. Craig exemplifies this:

> Craig (Jewish):
>
> "I don't think of myself as a person of faith when I'm in a biology class, when I'm in recitation with my groups or I'm doing a group project with other students. So I have my friends in my classes and I don't really consider myself a person of faith. I consider myself more a biology student. So, I feel like I fit in because I kind of compartmentalize it. I can be a biology student now and on Friday night I can go to Shabbat or something."

Finally, religious students who were able to reconcile their religious beliefs with biology saw themselves as different from other religious students who see a conflict. They said they were able to fit in in the biology community because they were more open-minded and less conservative about their beliefs than other religious individuals. For instance, several students, including Beth said that they were different because they choose not to interpret religious documents literally:

> Beth (Jewish):
>
> "I can reconcile my own beliefs with what I've already learned because I believe that religious documents aren't meant to be taken as orthodoxly as some people do, where if it says 7 days it was exactly 7 days, no more, no less. I feel like it's just interpretation"

These quotes illustrate that although students see a conflict between their religious identity and their pursuits in biology, they were actively trying to reconcile the two using a diverse number of strategies.

The perceptions of religious students about the advantages and disadvantages of being religious in biology. Participants reported both advantages and disadvantages to being religious in biology. Some students said they thought it was advantageous to be

religious in biology because they could bring a diverse viewpoint to research and help other religious people appreciate or understand biology. However, students also said that there were some potential disadvantages to being religious in biology including that they see the potential for a low sense of belonging in biology and that their biology colleagues may undervalue their contributions. These findings are explored in detail below.

Religious students see their unique experiences as an advantage in biology. Students reported that they saw their religious identity as potentially valuable to the scientific community and other religious individuals. Many students thought that being religious in biology is valuable because it brings a diversity to science that can help create new ideas, which aligns with current literature that outlines the benefits of diversity in science (Intemann, 2009). For instance, Christopher talked about how thinking differently can lead to a broader outlook on solving problems in biology:

> Christopher (non-denominational Christian):
>
> "I mean I feel like I have a broader idea […] somebody that is not my faith is learning the same thing that I am. I just have a different outlook on a lot of things [in biology]."

Other students saw their religiosity as an opportunity to help other religious people become more comfortable with science. Students often said they thought they could communicate more effectively with the religious community about science than non-religious biologists, because since they are religious, they understand the perspectives of religious individuals better. For instance, Beth discussed the possibility that she could help educate religious individuals about biology:

> Beth (Jewish):

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"A large percentage of the United States is religious and I could help in making my research more accessible […] it would definitely help with understanding where people are coming from because I feel like that's important regardless of what you're in but especially for biology since there are some people who might just flinch at evolution. I grew up where there were a lot of people who were offended by the idea of evolution."

Further, Donna discussed how she is already trying to educate the younger religious children in her family about science:

Donna (non-denominational Christian):

"I think it's important for religious people to take up the field of biology to educate fellow religious people. So many people I try to educate […] like my brother and sister, who are younger than me, my sister wants to be a wildlife scientist. I know that she's going to be probably an animal physiology major. I've always reinforced ideas, like what I learn in science. Obviously my little brother and sister are super Christian because that's what they've grown up with, but I always tell them things that are inconsistent with the church. Now they're more open minded."

Religious students see disadvantages to being religious in biology. Although the religious students we interviewed often saw advantages to being religious, they more frequently cited disadvantages to being religious in biology. The majority of students said that they perceived a potential disadvantage to being religious in biology and many of the students cited multiple disadvantages. Approximately half of the students we interviewed reported that they felt as though they are the minority in their classes. Some students, like Amelia, described feeling like it was hard to find others like themselves:

Amelia (non-denominational Christian):

"I've only met a handful of people that are bio majors who go to my church. And that's really weird especially, like, girls, it's really hard to find females who are a biology major and religious. That's really, really difficult.

Further, Brittany went as far as to say that she wanted to feel a sense of community, but did not feel that way because she had a hard time connecting with others like herself in biology:

> Brittany (Catholic):
>
> "I've always wanted a class about religion and biology, I would take that in a heartbeat, just for a sense of community because you feel like you're the only one."

Some students reported that they had experienced discomfort due to their peers in biology classes who would mock religion and religious people. For instance, Carrie reported that she was uncomfortable when she overheard her peers making fun of religious people who do not accept evolution:

> Carrie (non-denominational Christian):
>
> "There were a couple kids sitting behind me during the evolution lecture that were kind of just spouting like, 'people who don't believe in evolution are so stupid' and I personally believe in it [evolution] but I see how a lot of religious people could be offended by that and they were like 'Oh what, God made us?' they were like 'no it has to be some sort of process.' I was like, 'What you're saying right now could offend a lot of people' but I feel like they thought they were in a safe place because they were in the biology community. They were like 'oh we can just say this because everyone in here believes in evolution,' which may be the case but it was still kind of inappropriate in my opinion."

Sometimes students felt like they are in the minority when peers laugh at jokes that instructors make at the expense of religious individuals, or agree with instructor comments that are anti-religious. For instance, Craig told a story about an instructor who was disproving the story of Noah's Ark with a negative disposition. All of his peers laughed at the professor's presentation and made Craig feel as though he was the only religious person in the class who disagreed with the professor:

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Craig (Jewish):

"The [students'] laughter at the presentation during the Noah's Ark disapproval kind of thing. I think that kind of shows that everyone was with the professor on it"

Students also reported that peers in class often assume that biology and religion have to be mutually exclusive. These students highlighted that their peers were surprised that they can both be biology majors and be religious. Sometimes this led to the religious student perceiving that their peers think that religious people are not intelligent. For instance, Amy talks about these negative encounters that she has had with other biology students:

Amy (non-denominational Christian):

"I've had other students ask me before, 'Well, how can you believe in God if you're a Biology major?' And they'll almost pull this whole intelligence thing like 'How can you be intelligent and an analytical student and believe in God?' So that's probably the most difficult situation. And so people essentially are like, 'Well, how can you believe in God which is stupid and then you know, be a Biology major?' So that for me was the only thing that's been difficult. It's really the students."

Some students also reported that they felt as though they would not fit in with the biology community as a whole, even beyond the biology class. For instance, Maria talked about how she worried that she might not fit in at academic scientific meetings:

Maria (non-denominational Christian):

"When I first entered [college], my plan was to stick with academia and become a PhD. So then I imagined myself meeting at conventions with other PhD's and I thought religion is going to come up at some point especially because I wanted to study Animal Behavior and a little bit of evolution, things like that. So, the people are always going to assume, my peers I assume most of them would not be religious because that seems to be the theme, that if you're going to be an evolutionary or some kind of biologist you can't also be religious. So I always imagined at some point that would be a debate."

In addition to feeling as though they may not fit in with the community of biology, they also felt as though they may be at a disadvantage because their peers would not like them or be offended by their beliefs. Maria expressed this fear when she continued to express her perceptions of what it may be like as a religious biologist in academia:

> Maria:
>
> "I know part of living in academia is getting yourself published, getting in with the right people and I can foresee [my religion] having been a problem had I stuck with that because if I offended somebody who I really needed, some professor with a lot of interest, who really I needed his support and if he decided to take offense at the fact that I was religious, that's a conceivable thing for him to take offense at, then that could be hard on my career."

She and other students expressed a concern that other biologists, particularly elite biologists, would not take their work seriously. Although Maria's quotes best illustrate this theme, four other students expressed similar concerns about feeling like they would be negatively stereotyped as a religious biologist. Maria continued in her interview to talk about how she was willing to face that challenge, but felt as though her work may be discriminated against because she is religious:

> Maria:
>
> "I think it would be a challenge. It was one I was originally willing to face and I didn't think it would completely hold me back. Maybe I'm optimistic but I thought my science would be good enough and that not everybody's going to discriminate but especially with the older crowd and the people who are already well-known in Biology, it could be hard for me to be a biologist and then have people say, 'Well, I'm not going to listen to you. You also believe in God. Why would your science be worth anything? You're obviously not a scientist.' There's always that derogatory attitude that could come from people who are atheists and also biologists."

In summary, students saw several disadvantages to being a Judeo-Christian student in biology: they perceived that they are in the minority among their peers in class, that peers

mocked religion in biology class which made them uncomfortable, that their peers assumed religion and biology are mutually exclusive, that they would not fit in with the biology community if they pursued biology as a career, and that their biology colleagues might think that their scientific work is not of value.

Biology Instruction where Religious Identity is Relevant. Participants reported a wide variety of experiences in biology classes that were relevant to their religious identity. In line with past research, learning evolution was cited by many participants as the most relevant experience related to their religious identity in biology classrooms (Dagher & BouJaoude, 1997; Goldston & Kyzer, 2009; Griffith & Brem, 2004; Winslow et al., 2011). Participants also reported that instruction that involved bioethics was relevant to their religious identity, particularly when discussing biology content surrounding reproduction. Below, we further outline how participants characterized their experiences of biology instruction as it relates to their religious identity.

Religious students saw instruction on evolution as relevant to their religious identity. The overwhelming majority of students we interviewed said that evolution instruction was relevant to their religious identity. When the interviewer asked students what experiences in biology classes were most relevant to their religious identity, students often talked about their experiences learning evolution:

Andrew (Protestant):
"I think the most direct, to faith and biology, would be the aspect of learning evolution."

Approximately 1/3 of students said that they rejected evolution. However, the aspects of evolution these students rejected varied, which is in line with previous research showing

that students differentially accept macroevolution (Nadelson & Southerland, 2012) and

human evolution (Dagher & BouJaoude, 1997; Nadelson & Southerland, 2012). For

instance, Andrew continued on to say he accepted microevolution but doubted

macroevolution:

> Andrew:
>
> "I mean, obviously, microevolution is impossible to think against. It's
> very obvious that that's a thing. But macroevolution is definitely a place of
> controversy. I, for one, would not absolutely believe it as a whole."

And some students, like Donna, accepted all of evolution except for human
evolution:

> Donna (non-denominational Christian):
>
> "Christians do believe evolution, you can see it in sedimentary rocks in the
> Grand Canyon. You can see that things have evolved. We do not believe
> in human evolution because we believe that God created Adam and Eve.
> God did not create Adam and Eve in the form of a primate, He created
> them in the form of Him, which is what we look like […] That is the only
> inconsistency."

Most students, approximately 2/3, accepted a view of evolution that is potentially

compatible with the scientific view. However, they often also struggled with reconciling

evolution and their religious beliefs at one time or another in their life and they also saw

evolution instruction as relevant to their religious identity:

> Maria (non-denominational Christian):
>
> "I'm taking an Evolution course right now and I personally don't see it
> conflicting with my own faith so much but I know it's always there. It was
> the first day of our Evolution class actually, the professor spent most of
> the first lecture talking about the differences between Science and
> Religion and how he feels that evolution is not the same thing as religious
> beliefs."

Religious students saw bioethics as relevant to their religious identity. Around 1/3

of our participants mentioned that discussions of topics related to ethics in biology were

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also particularly relevant to their religious identity. This mirrors the heated public debates in which there is religious based opposition to biology related issues such as stem cell research, birth control, and abortion (Charo, 2015; Liptak, 2016; NY Times, 2016). The students we interviewed were most frequently concerned about topics in biology classes related to reproduction and reproductive rights. The topic of abortion in classes was by far the most cited experience related to bioethics that students remembered. They often perceived that they were in the minority in their opinions in class, so they were afraid to contribute to discussions. For instance, Amelia said she was uncomfortable expressing her viewpoint in class:

>Amelia (non-denominational Christian):
>
>"Sometimes we'd talk about some controversial topics, like I know abortion came up a couple of times […] Sometimes it would make me feel a little uncomfortable if the professor was saying her viewpoint and why pro-life was a bad thing […] we would talk about religion and sometimes she'd ask for volunteers, she'd be like 'does anyone have anything to say about this?' I never felt comfortable enough to be able to speak up."

Religious students had positive experiences when instructors acknowledge and respect their religious views and had negative experiences when instructors ignore or belittle their views

Positive experiences. Many students reported that they had previous positive experiences with their instructors that were related to their religious identity. These experiences spanned two categories: instructors who acknowledge religious students or their beliefs and instructors who present evolution and religion as compatible.

Instructors who acknowledge religious students and their beliefs

Students often cited experiencing a higher level of comfort and belonging in classes

where instructors simply acknowledged religious students in their classes. For instance,

Alexis talked about her professor who acknowledged that there were students of different

faiths in the room and how it made her for more comfortable in class:

> Alexis (non-denominational Christian):
>
> "At the beginning of the semester the professor said 'I know some experiences that you might have probably had being religious in classes and I'm going to teach what science accepts as correct nowadays but I'm going to teach you in a way that is respectful to everyone regardless of faith and things like that […] It made me feel pretty welcome in the class."

Many students who were recruited from the same class mentioned a shared positive

experience in which their professor acknowledged the religious beliefs of the students

before she began her lesson on evolution. The instructor further discussed how several

scientists have been able to reconcile evolution with their religious beliefs. All of the

following quotes seem to stem from the same experience in a single class:

> Brittany (Catholic):
>
> "She was just talking about how throughout the years there's been a lot of scientists who have backgrounds in faith and have been able to cope with justifying both sides; that they don't have to sacrifice one for the other. She said for us we don't have to worry about having to pick one because there are ways to cope […] Even though it was one time, it was all I needed, just someone to bring it up and realize that there are religious people in the classroom."
>
> Interviewer: How does that make you feel?
>
> Brittany: "Good because I've never really had any science teachers that have brought up the discussion of faith ever. It's kind of like a thing I've had to deal with by myself."
>
> Carrie (non-denominational Christian):
>
> "My current bio professor briefly mentioned during the evolution section that she hopes none of our religious views will deter us from learning the concepts and understanding the facts that we see before us, how they're

interpreted and she seems really open to if we want to talk to her about it because we are uncomfortable with some aspect of how she's teaching it […] I was glad that she addressed it because I think it's a bit of a taboo topic sometimes, science and religion don't really tend to mix, so it was nice that she didn't gloss over it like it's not there."

Instructors who present evolution and religion as compatible

Students usually described experiences in biology classes as positive when instructors highlighted the potential compatibility between religion and evolution. This aligns with past research that showed biology students say they appreciated when instructors discuss the compatibility between religion and evolution (Barnes et al., 2017). For instance, Carrie went on to say later in her interview that she was surprised to hear the professor say that evolution and religion can be compatible and this made her feel like the instructor cared about her sense of belonging in biology:

> Carrie (non-denominational Christian):
>
> "[The professor] did mention in her very short brief speech that a lot of people have found a way to hold both their religious belief and also believe in the science of evolution and that sort of thing […] I don't think I have ever seen them mentioned as coming together at all. It is generally, a lot of the times, you're either creationist or evolutionist […] I think simply by bringing that up she was showing that she does care about our feelings, she doesn't want to see you left out or anything because of that belief, and she does care that we are part of the biology community"

Around 1/3 of our participants reported similar experiences with other biology instructors, in which they felt more comfortable because the instructor in a biology course acknowledged the religious beliefs of students in the classroom or discussed the two as being compatible with one another.

Negative experiences. In addition to positive experiences, students also reported negative experiences they had in their biology classes that were related to their religious

identity. Parallel but opposite to their positive experiences, students had negative experiences when instructors do not acknowledge religion when teaching relevant content and when instructors highlight conflict between religion and biology. Additionally, students also had negative experiences when they felt as though instructors are authoritarian in their teaching of evolution, when they felt as though instructors have a negative disposition towards religion, and when religious biologist role models are generally unavailable to them in the biology community.

Instructors who do not acknowledge religion or religious viewpoints

In our interviews we found evidence that avoiding religion when teaching relevant material can make religious students feel excluded, a finding that parallels that of another study that showed students felt alienated when instructors avoided religion when teaching evolution (Hermann, 2012). Our interviewees said they felt "invisible" or "excluded" when instructors did not acknowledge religious students or their beliefs during relevant instruction. For example, Bethany talked about how she felt as if she is in the minority when in reality there are probably a lot of religious students in her evolution class:

> Brittany (Catholic):
>
> "It's more just professors not addressing [religion] because especially in biology classes I always feel like I am the only one so it's not worth bringing it up, but in reality there's probably a lot of other students that are religious. So, it just makes the majority feel like the minority."

Instructors who highlight the conflict between religion and biology

Students also said they felt uncomfortable when instructors highlighted only conflict between religion and biology. Often times, students felt as though biology instructors caricaturized religion and presented it as inferior to science. For instance, Maria

described how her evolution instructor compared religion to magic when teaching evolution:

> Maria (non-denominational Christian):
>
> "I think they do [professors] present it [evolution and religion] in a way that is conflictual. I mean in the first lecture of evolution class we went through – he kind of lumped religious faith in with magic. He's like, 'They believed in magic and obviously that's wrong. Then they believed in creationism' He's like, 'obviously no one believes in magic, right? They tried making gold and the eternal life, those things didn't work. Then they believed in religion.'"

Instructors who try to force beliefs on students

Some students described negative experiences in which they felt as though instructors were trying to force certain beliefs on them. This often occurred in the context of learning evolution. When instructors said things like "You have to accept evolution" or tried to disprove religious ideas, students interpreted this as a negative experience. For instance, Alexis described a negative beginning to her evolution class in which she thought the professor was trying to force her to believe evolution:

> Alexis (non-denominational Christian):
>
> "In one of my general biology classes when they were teaching about the theory of evolution they said 'if you don't believe this of course you're wrong because it's proven this is right and you know you have to believe it this way' and then in the evolution class, it's a required class, at the beginning of the class the professor handed everyone sheets of paper and said 'I want everyone to write down reasons that they can prove that evolution is incorrect' and he read them out to everyone and he said 'so this is why these are all really bad reasons and this is why you can't believe anything different and you should believe this.' It kind of made a bad start to the class."

Instructors who have a negative disposition towards religion

The most cited negative experience among our participants was a general negative

disposition towards religion among their biology instructors. This included instructors

who were generally dismissive of religious ideas, made jokes at the expense of religion,

seemed angry when talking about religion, or seemed condescending to students who

brought up religious ideas. For instance Donna talked about how she became frustrated

when an instructor blatantly dismissed the notion of the soul:

> Donna (non-denominational Christian):
>
> "One of my professors said literally, in his mind or what he thinks, is that we are just brainwaves. I remember I asked, I raised my hand, I was like 'How do you explain the soul?' He's like 'Ask your religious leader. That doesn't exist.' […] That one made me mad."

Additionally, James discussed how an instructor seemed to question the intelligence of a

religious student because the student believed there may be a higher power behind the

Big Bang:

> James (Lutheran):
>
> "A student [in class] brought up some topic about how he's baffled that people can't recognize that the Big Bang might have something else behind it like a higher hand, you know? And the instructor just kind of shut him down. He said 'you're stupid if you believe that.' It was very blatant he was like 'I'm the only one who can say this and this is my class.' […] it's kind of bizarre to see how some of these professors will preach this openness in the classroom and discussions, but when it comes down to it, when someone brings up something that goes against what they're trying to portray, it's obvious you know they're truly not."

Maria discussed how she felt as if biology instructors, particularly evolution instructors,

seem angry when they talk about religion in relation to biology and this made her feel as

if there is tension between religion and biology:

> Maria (non-denominational Christian):

"I see this with a lot of professors when they start talking about evolution, people who are high up and studying evolution or genetics, they get angry when they talk about it [religion]. They're like 'Today we're going to explain why this is capital, bold point letters, **RELIGION AND NOT SCIENCE**.' Then in that whole lecture, there's like an angry attitude to it. So you can always feel it, even if you didn't know at that point that there's tension between evolutionary biologists and religious people."

Not having religious scientist role models

Many students commented on the lack of religious individuals in the community of biology. Students expressed that it was disheartening that there were so few religious scientist role models available to them in the biology community:

Brittany (Catholic):

"I feel like every teacher that I've ever had in any science class has not been a person of faith and it's hard to look at someone as your role model in science but not as your role model in your own faith."

In summary, we found that instruction in evolution and bioethics topics were most relevant to our participants' religious identity. Further, we found that these students felt more comfortable in class when they are acknowledged and respected, but felt less comfortable in class when instructors belittle, make jokes, or become angry about religion. Additionally, we found that students felt a lower sense of belonging when they did not perceive that there biologists that are religious.

Discussion

Our study is the first to our knowledge to characterize the positive and negative experiences of religious students in biology that affect their comfort in biology classes. We found that our participants were often able to reconcile their religious identity with

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biology, but most of them experienced struggles along the way. Students reported that sometimes they feel as though they have the minority opinion in their classes and subsequently feel uncomfortable sharing their thoughts and ideas about relevant topics. They also sometimes feel as though instructors can be insensitive or aloof when teaching subjects that are relevant to students' religious identity. Further, some students perceive that being religious in biology can be a disadvantage, because colleagues may not value their scientific work and they may not fit in with the biology community. Finally, we found that biology instruction in specific content areas such as evolution and ethics may present challenging situations for religious students and that instructional practices can impact how religious students feel. However, students also reported experiences that can increase their sense of belonging in biology. For instance, students said they felt more included when instructors acknowledged the beliefs of religious students when teaching evolution and they felt more like they belonged in biology when they saw religious biology instructors as role models. Below we outline the implications of our research for biology instruction, the limitations of the current study, and recommendations for future areas of research.

Teaching evolution. Our data reveal that instructors interested in helping religious students gain a sense of belonging in biology classes could consider how inclusive their instructional practices are when teaching evolution. Almost all of our participants cited learning evolution as an experience that was relevant to their religious identity and often these experiences were negative, even when the religious student personally had positive attitudes towards evolution. Instructor humor about religion and caricaturizing religion as something akin to believing in magic or belief for which there is

no evidence was overwhelmingly seen as alienating by our participants. Although instructors may find that humor about religion can amuse the secular portion of the class, we encourage instructors to think about the potential message that unnecessarily negative remarks and humor about religion might send to religious students in their class.

Beyond a general condescension towards religion being problematic, our interviews indicate that Judeo-Christian student perceptions of evolution instruction are complicated and may depend on individual student beliefs. If instructors only discuss the conflict between evolution and religion, a religious student who thinks evolution and religion are compatible may feel like their beliefs have been characterized by the instructor incorrectly. However, if an instructor only discusses how evolution and religion are compatible, this may present challenges for a student who thinks evolution and religion are in conflict and he/she may feel as if this instructor is advocating for a particular religious interpretation that they do not agree with. Further, there are some students who do not know that it is possible to reconcile some religious beliefs with evolution, so if instructors do not discuss this, the student may self-propagate their own conception that their beliefs and evolution must be in conflict. This leads us to believe that acknowledging that there are a diversity of perceptions about the relationship between evolution and religion could be helpful for increasing Judeo-Christian students' sense of belonging in biology.

Discussing various viewpoints on religion and evolution. Our interviews add to a growing literature that indicates religious students will likely benefit if evolution instructors discuss varying viewpoints on religion and evolution (Barnes et al., in press; Brickhouse et al., 2000; Dagher & BouJaoude, 1997; Manwaring et al., 2015; Roth,

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1997). Acknowledging different viewpoints can serve several instructional purposes, outlined below.

First, educating students on the various viewpoints on evolution and religion may expand student perspectives on what is possible for them to simultaneously believe and ultimately increase their sense of belonging in biology. In fact, past research from our group shows that discussing multiple perspectives can reduce perceived conflict between religion and evolution among students (Barnes et al., 2017). Among our participants in this study, students who accepted evolution and saw no conflict between religion and evolution tended to say they were more comfortable when learning evolution and felt more like they belonged in evolution classes. If students are informed of the potential compatibility between religion and evolution, this may help them feel more comfortable in biology classes.

Also, a discussion of the various viewpoints on evolution can provide instructors with a potential opportunity to educate students on the nature of science (Smith, 1994; Southerland & Scharmann, 2013). Instructors can briefly outline varying viewpoints on the relationship between religion and evolution and place these views on a continuum from most consistent to least consistent with what is known from scientific exploration (for a review of common positions held by students and the scientific consistency of these views, see Yasri & Mancy, 2016). When instructors compare perspectives such as theistic evolution, agnostic evolution, and atheistic evolution, this can establish a framework for discussing what is science and what is not science. Therefore, students have an opportunity to reflect on their own position given their religious beliefs, but also understand more about the nature of scientific inquiry and what is the domain of science.

Further, by discussing various viewpoints, instructors can create what some researchers have termed "brave spaces", where students are provided with an environment in which they feel comfortable exploring different viewpoints and confronting potential conflicts (Arao & Clemens, 2013; Cook-Sather, 2016).

As we saw with our participants, some religious biology students may hold views that are in stark contrast to the accepted scientific view, such as special creationists who believe that humans were created by God in their current form, and this can pose a unique challenge for instructors who do not want to make their students uncomfortable when teaching evolution. However, discussing various viewpoints can serve a purpose for students with incompatible conceptions as well, if it is delivered in a manner that is sensitive to the students' beliefs. An instructor can acknowledge that some students in their class may hold special creationist beliefs, acknowledge that those beliefs are not consistent with what biologists currently accept, but also acknowledge that the instructor is going to respect all viewpoints in the class and welcome questions. It is important to make clear that we do not recommend that instructors give credibility to these viewpoints that are clearly in opposition to what we know from empirical observations and experimentation in biology. However, by making the student feel respected and heard, past research shows this will not only make the student feel more comfortable in class, but also may encourage them to become more positive about evolution (Dagher & BouJaoude, 1997; Hermann, 2012). The National Academy of Sciences book "Science, Evolution, and Creationism" can serve as a beginning resource for instructors who would like to incorporate this inclusive type of instruction when teaching evolution.

Religious scientist role models. One way to discuss varying viewpoints on religion and evolution is to present scientists who hold different views about religion and evolution. A frequently occurring theme from our interviews was that students perceived there are few role models in biology who hold their same religious beliefs. Our study adds to the growing body of research showing that religious scientist role models are potentially important for religious students in biology (Barnes et al., 2017; Winslow, Staver, & Scharmann, 2011). Showing students examples of individuals who have been successful in biology and also hold religious beliefs could provide these role models that students seek, while also acknowledging the diversity of religious viewpoints within biology. For instance, Dr. Francis Collins, the current director of the National Institute of Health and former director of the Human Genome Project has written a book called "The Language of God" and has founded the organization BioLogos to promote harmony between Evangelical Christianity and evolution (Collins, 2006). Additionally, Dr. Ken Miller is a biologist who served as a witness in the Dover Pennsylvania Evolution Trial to defend the teaching of evolution and exclusion of creationism in the biology curriculum. He is also a Catholic and authored the book "Finding Darwin's God: A Scientists Search for Common Ground between God and Evolution". Presenting these individuals to students as role models may help them feel more comfortable with holding a religious identity and accepting evolution (Miller, 2002).

Additionally, presenting religious scientist role models can be a particularly important strategy for instructors who may not relate to their students' struggles with evolution and religion. In a past study, we found that the majority of public college biology instructors we interviewed reported that they had not experienced a worldview

conflict with evolution and religion, which we attributed to lower levels of religiosity among instructors in our study (Barnes and Brownell, 2016). Indeed, the majority of instructors in our study took a purely atheistic view of evolution. Secular instructors may struggle with religious student viewpoints on evolution and using themselves as a role model for these religious students. However, these instructors can still provide support to religious students by referencing other scientists who have managed to reconcile their religious beliefs with evolution.

Importance of evolution for students pursuing medicine. Another potentially important finding from our interviews is that students who see a conflict with their religious beliefs and evolution may choose careers in the medical field, in part, because they do not see evolution as relevant to a career in medicine. This is concerning in that we may be inadvertently selecting for non-religious students in research careers. If we do not address the potential compatibility of religion and evolution with our students who may otherwise be interested in a research career if they did not see a conflict with religion and evolution, then this could lead to a disproportionate number of Judeo-Christian students in the medical sciences and a disproportionate number of non-Judeo-Christian students in research careers. However aside from concerns of exclusion from research careers, it is additionally concerning that Judeo-Christian students hold the notion that evolution is irrelevant for a medical career. Several researchers in evolutionary biology and medicine have indicated the importance of understanding the role of evolution in human disease, including some of the most prevalent ailments in human society today such as obesity, heart disease, and mental illness (Lieberman, 2013; Nesse, 1996). The importance of understanding evolution for practicing and researching medicine has

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become so apparent that some have suggested evolutionary medicine should be taught to all medical students (Nesse et al., 2010).

Ethics relevant content. Our interviews also revealed that instructors interested in helping religious students feel comfortable in biology classes may want to pay particular attention to their instructional practices when teaching topics related to ethics in biology such as stem cell research, abortion, and birth control. Given that many topics at the intersection of religion and bioethics have been a modern source of public and political debate (Charo, 2015; Liptak, 2016; NY Times, 2016) it is unsurprising that students see this content as relevant to their religious identity. However, similar to teaching evolution, this means instructors may have to take extra care to create an inclusive for religious students when teaching bioethical topics (Smith, 1994; Southerland & Scharmann, 2013). As with teaching evolution, acknowledging and respecting diverse viewpoints may make students feel more comfortable (Barnes et al., 2017; Smith, 1994; Southerland & Scharmann, 2013). Teaching content at the intersection of religion and bioethics could be an opportunity for instructors to encourage a discussion that includes diverse opinions. Instructors can model equity in science to their students by valuing diverse opinions and showing how this diversity can lead to new and interesting ways of understanding the ethical debates surrounding biology topics. Similar to other groups with cultural norms and values that differ from the scientific community (Brown et al., 2016), if religious students feel as though their values are respected and represented in the biology community, this could lead to their greater sense of belonging in biology.

Intersection of biology identity, religious identity, and belonging. Our interviews, along with past interview studies, indicate that there may be a complex reciprocal relationship between a student's religious identity and the development of a student's biology identity over a degree (Winslow et al., 2010). Ideally, biology students will develop a strong biology identity over the course of their major (Trujillo & Tanner, 2014). However, our interviews suggest that a students' religious identity can hinder the development of their biology identity. For instance, the students we interviewed said they restricted their biology identity to realms of biology in which they did not see a conflict with their religious identity, and this limited the types of biology-related careers they could pursue. Students who rejected evolution due to their religious beliefs did not see research, particularly in ecology and evolutionary biology, as viable career options. In addition, students who rejected evolution restricted their biology identity to certain classes and subjects that did not conflict with their religious identities. When students took classes that covered topics that conflicted with their religious identity, they said they were less excited about the material and learned it just for the grade but did not meaningfully engage with the material. Further, a students' religious identity may also be shaped by an emerging biology identity (Winslow et al., 2010). Many of our students discussed how they actually changed their religious beliefs in response to their experiences in biology classes. This indicates that biology classes inform both students' religious identities and their biology identities.

However, we did not ask students specifically about their biology identity in our interviews, so we feel as though our findings can only be interpreted as a preliminary indication of an interplay of religious and science identity. While we had many indirect

references in our interviews that indicated a biology identity among our students, we were not able to gauge the salience of that identity from the interviews. Future research should probe the saliency of students' religious and biology identities to see how these two identities influence one another over the course of the biology major and how experiences in biology classes can affect both of these identities.

Our interviews also indicate that religious identity could impact students' sense of belonging in class, which in turn can impact their biology identity. This study is a preliminary step towards illustrating ways in which religious identity might impact belonging. While there are survey instruments that could be used to measure sense of belonging (Trujillo and Tanner, 2014), we did not feel that a survey measure would be meaningful in the context of our study due to the small sample size and lack of a comparison group that would allow us to generalize the scores from a survey. Further, we found indication of a potential social desirability bias for students to report a higher sense of belonging that might influence survey responses. As reported previously, when we asked students if they felt as though they belonged in their biology classes, the majority of students said that they did feel as though they belonged. However, their responses to other questions indicated that at times they did not feel as though they belonged. When we asked students about specific experiences, such as times that instructors made them feel like they did not value religious beliefs or what disadvantages there are to being religious in biology, we received a wealth of responses that indicated experiences that would negatively impact sense of belonging. This indicates that although a student may report that they feel like they belong, they may have experiences that indicate a lower sense of belonging than other students who do not have those experiences.

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Limitations.

This study was conducted with students in a research-intensive public institution in the southwest. The results of this study could be unique to this demographic and geographic population. However, perceived conflict between religion and evolution has been documented among a wide range of student populations and demographics (Barnes et al., in press; Brem et al., 2003; Dagher & BouJaoude, 1997; Donnelly et al., 2008; Hermann, 2012; Martin-Hansen, 2006; Winslow et al., 2011a; Yasri & Mancy, 2016), so we suspect that religious students from a diverse array of institutions and geographic regions will grapple with some conflict in some biology classes. It will be important to extend these findings by exploring experiences of students at a wide range of institutions in different geographic regions in order to triangulate how institutional and regional factors may produce differential experiences among religious students in biology.

We have a sampling bias in our study by the nature of its design. We handed out flyers to every student attending our targeted classes, but it is impossible to know the characteristics and experiences of religious students who chose not participate in our study. We acknowledge that it could be possible that the pool of interviewees who were willing to talk are not necessarily reflective of the larger population of religious students, so our findings should be interpreted cautiously. However, it is possible that students who perceive a great amount of conflict between their religious identity and biology may have chosen not to participate because they may feel uncomfortable discussing such personal matters in an interview. Alternatively, it is also possible that students who perceived a great deal of conflict may have disproportionately responded to the flyers because the subject is important to them. We attempted to address this limitation by gathering a

diversity of responses to assess the landscape of experiences (Glesne & Peshkin, 1992) and by avoiding any quantitative generalizations based on the data.

These were self-reports of students' experiences and not observational data. Factors that influence the way individual's self-report, such as social desirability bias, could have influenced these results (Edwards, 1957) and some of the students' experiences and perceptions may not be accurately represented. Students may have experiences that they could not remember that could impact their sense of belonging in biology or they may have inaccurately recalled the experiences they could remember. However, this is a limitation of most interview studies, which are often seen as a first step in exploring a new research area in order to subsequently inform more systematic and observational research (Glesne & Peshkin, 1992).

Further, we did not explore the experiences of students from non-Judeo-Christian religious backgrounds. We did not intend to limit our sample, but merely were unable to recruit students from other religious belief systems. Future research should begin to explore differences among students from different religious traditions. Similar to how the term "underrepresented minority" (URM) refers to multiple groups of people with unique social identities and experiences, by referring to "religious students" we are not taking into account the differences among those students' beliefs. It will be important for future researchers to explore these populations and their experiences, to ascertain what may make them feel more included and supported in the biology community.

Finally, our study does not assess the causal impact of these students' experiences on their sense of belonging or their persistence in biology. Interview studies are seen as exploratory in novel areas of research, so our study was meant to illuminate potentially

interesting areas of inquiry within religious student experiences. In addition to exploring a greater number of students from different populations, future research should also establish if and how these experiences impact a students' sense of belonging and their retention as a biology major.

Conclusion

Our interview study serves as a source of information for college biology teachers, meant to illuminate the experiences that could contribute to how religious students feel they are perceived in biology classes. We hope that our findings will stimulate a discussion within the higher education biology community on the importance of making college biology equitable for all students, including those with religious beliefs. We hope by making biology more accessible to religious individuals we can progress further in our mission to meet the STEM workforce needs of the twenty first century.

Acknowledgements

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CHAPTER 5

EXPERIENCES AND PRACTICES OF EVOLUTION INSTRUCTORS AT

CHRISTIAN UNIVERSITIES THAT CAN INFORM CULTURALLY COMPETENT

EVOLUTION EDUCATION

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Abstract

Past research indicates that students' religious belief and religious culture are the main factors predicting whether they will accept evolution. However, past research also suggests that college biology instructors teaching evolution at public institutions often have different beliefs and cultures from their religious students. To explore when evolution instructors have similar religious cultures and beliefs as their students, we interviewed 32 evolution instructors at Christian universities nationwide about their practices and experiences teaching evolution. Christian University instructors emphasized teaching for acceptance of evolution while holding an inclusive teaching philosophy that they perceived led to a safe environment for students with a diversity of beliefs. Additionally, almost all instructors reported using practices that are known to reduce student conflict with evolution and increase student acceptance of evolution. Further, we confirmed that these instructors perceived that their own religious backgrounds have guided their decisions to teach evolution to their students in a culturally competent way. We discuss how these data combined with past research literature on public college instructors indicate that cultural competence could be a useful new framework for promoting effective evolution education in higher education institutions.

Background

Evolution is important, yet controversial. Evolution is simultaneously one of the most important components of undergraduate life science education and one of the most controversial among college biology students. The national report Vision and Change, a product of over 500 biologists and biology educators across the country, identified the theory of evolution as one of five core concepts of biology (AAAS, 2011). Evolution has been recommended to be integrated throughout the undergraduate biology curriculum (AAAS, 2011; Brownell, Freeman, Wenderoth, & Crowe, 2014) and is often called the grand unifying theory of biology (Dobzhansky, 1973; Gould, 2002; Mayr, 1982). However, over thirty years of public polls show that, consistently, approximately half of Americans reject evolution and report that they believe humans arrived on Earth in their present form (Newport, 2014). Further, research has shown that up to 50% of students in introductory biology classes can reject important aspects of evolution (Rice, Olson, & Colbert, 2010) and that ~15% of high school biology teachers, who have a college level education of biology, advocate for creationism in their classes for at least one hour per semester (Berkman & Plutzer, 2011). The lack of acceptance of evolution, the very foundation of biology, has led to a major research thrust to determine the sources of evolution rejection and effective interventions for increasing acceptance (Glaze & Goldston, 2015; Hermann, 2007; Lloyd-Strovas & Bernal, 2012; Smith, 2009, 2010).

Religious culture and beliefs determine acceptance of evolution more than understanding of evolution. We define student acceptance of evolution as the extent to which a student finds evolution to be an accurate scientific explanation for the diversity

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of life on Earth, which aligns with the definition given by the National Academy of Sciences (NAS, 2008). We define student understanding of evolution as the extent to which a student has an accurate conception of the tenets and processes of evolutionary theory (Barnes & Brownell, 2016). While some research has established a relationship between understanding of evolution and acceptance of evolution (Deniz, Donnelly, & Yilmaz, 2008; Nadelson & Sinatra, 2008; Nehm, Kim, & Sheppard, 2009; Spiegel et al., 2012), additional research indicates that an accurate understanding of evolution does not necessarily lead to acceptance of evolution (Brem, Ranney, & Schindel, 2003; Hermann, 2012; Sinatra, Southerland, McConaughy, & Demastes, 2003). Rejection of evolution is a complex phenomenon with which understanding is only a small component. Intuitive reasoning about natural phenomenon or "folk biology" can contribute to rejection of evolution. Just as a round Earth is initially unintuitive to children, evolution is also initially unintuitive to most people, which may make evolution seem implausible (Coley & Tanner, 2015; Evans, 2001; Sinatra, Brem, & Evans, 2008). However, these barriers are overcome relatively easily with education when there are no sociocultural norms present that oppose evolutionary thinking (Evans, 2001).

Although rejection of evolution can be attributed to multiple causal factors, a person's religious beliefs and religious culture are the greatest indicators of rejecting biological evolution (Barone, Petto, & Campbell, 2014; Rissler et al., 2014; Heddy & Nadelson, 2013; Nadelson & Hardy, 2015; Rice, Clough, Olson, Adams, & Colbert, 2015; Rissler, Duncan, & Caruso, 2014). By religious beliefs, we mean the specific religious beliefs that individuals hold about the existence of a deity. Individuals hold a wide range of religious beliefs about the existence of a deity, including this deity's role in

creating humankind and this deity's impact on their daily life. Some of these beliefs will create more of a barrier to accepting evolution than others. For instance, a belief in the literal story of Genesis will be a more difficult barrier to accepting evolution than a belief that the story of Genesis is an allegory or a belief that a deity had no role in creating human kind. Additionally, the strength of these religious beliefs is also important. For instance, individuals who believe that the story of Genesis is literal will have differences in the strength of this belief. Some may believe the literal story of Genesis as a result of listening to religious leaders who tell them to believe it, but they may not have thoroughly considered the validity of this belief and as such, may not be as strongly committed. Others may have spent time thinking deeply about whether they should interpret Genesis literally, and become strongly committed to this belief. The more committed one is to a belief that is antithetical to evolution, the harder it will be for that person to change their religious belief to accommodate evolution.

By religious culture we mean the sociocultural norms that individuals experience related to religion. Religious cultural norms can include shared values, attitudes, traditions, holidays, and celebrations; an individual can be part of a religious culture but have varying degrees of religious belief. For instance, a person can lack a belief in a deity, but still be culturally Jewish and eat foods that are kosher, culturally Hindi and participate in the religious festival Diwali, or culturally Christian and attend a Christmas Eve service. In the case of learning about evolution, a student may not have strong religious beliefs that are in opposition to evolution but can still be part of a religious culture that is anti-evolution and still choose to reject evolution based on the views of friends and family within their religious culture. Individuals who lack a religious culture

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that is opposed to evolution will not experience the same barriers to accepting evolution. Individuals who have both strong religious beliefs and religious cultures that are in opposition to evolution will likely feel the most resistance towards accepting evolution.

Rejection of evolution is tightly associated with sociocultural factors that are related to religious culture and religious beliefs such as trust in science and scientists (Nadelson & Hardy, 2015), attitudes of one's family and peer groups (Hill, 2014), and geographic location (Heddy & Nadelson, 2012, 2013). For instance, Rissler et al. (2014) found that an undergraduate's academic level was not a significant predictor of their acceptance of evolution, but that these students' church attendance was strongly negatively correlated with their acceptance of evolution (Rissler et al., 2014). Hill (2014) found that the main predictor for whether a rejecter of evolution will come to accept evolution is if someone within their immediate social group (e.g. close friends or family) accepts evolution (Hill, 2014). Similarly, Winslow and colleagues (2011) found that Christian undergraduate biology majors who changed from rejecting to accepting evolution cited their family and friends as most influential in contributing to their original views and then cited their professors who were religious and accepted evolution as one of the factors contributing to their decision to change their views (Winslow, Staver, & Scharmann, 2011). This growing literature base indicates that while knowledge of and understanding of evolution can be associated with evolution acceptance, sociocultural factors, particularly religious culture and religious beliefs, predict to a greater degree whether an individual will choose to accept evolution. Therefore, as many other science education researchers have pointed out, evolution instructors need to consider students' religious culture and religious beliefs if they are to teach students about evolution in a

way to increase their acceptance of evolution (Cobern, 1994; Hermann, 2012; Reiss, 2008; Settlage & Southerland, 2007; Smith, 1994; Southerland & Scharmann, 2013).

Acceptance of evolution is an important student outcome. Evolution is a core concept of biology (AAAS, 2011; Brownell et al., 2014), essential to an undergraduate biology major's understanding of biology. However, when a student understands evolution but does not accept this core concept, the student will likely not apply this concept to their greater understanding of biology. Specifically, students who understand but do not accept evolution are unlikely to apply evolutionary thinking when making public decisions related to biology (Sinatra et al., 2003; Southerland & Nadelson, 2012), such as wildlife and disease management, which can affect both biodiversity and global human health. Voters who do not incorporate deep time and the coevolution of species into their thinking may not be able to fully appreciate the complex interconnectedness of all organisms on Earth and thus the extent to which the extinction of one species, or the pollution of one environment, might affect global biodiversity. Additionally, physicians who do not accept evolution may not apply evolutionary thinking that is highly relevant to understanding and treating some of the most prevalent ailments affecting humans today, including obesity and heart disease (Nesse, 1996; Nesse et al., 2010). If instructors only focus on student understanding of evolution and avoid addressing student acceptance, then students are unlikely to incorporate evolutionary thinking into their scientific thinking. This is likely a major reason why there has been so much work on examining student acceptance of evolution. Our review of the literature showed that over 160 studies have been published over the past 35 years that examined student acceptance of evolution, yet public polls show that the needle on acceptance of evolution has not

been moved substantially in this time (Newport, 2014). This could be in part because instructors have not specifically approached teaching evolution with regard to students' religious culture and religious beliefs that influence their acceptance of evolution.

College biology instructors can struggle with helping religious students accept evolution. While many students have religious cultures and religious beliefs that could conflict with the basic tenets of evolution, most college level biology instructors are unlikely prepared to effectively address this conflict. Similar to the general public, the majority of college students hold religious beliefs, but college biology instructors are markedly irreligious; while 83% of the public believe in God and 75% of the public identify with a Christian religious denomination (Pew, 2009), only 32% of biologists believe in God and 25% identify with a Christian religious denomination (Ecklund & Scheitle, 2007; Pew, 2009). Further, our research group has conducted two studies with college biology instructors and religious biology students that highlight potential issues arising from misalignment between the religious cultures and religious beliefs of evolution instructors and their students.

We conducted an interview study with 32 college biology instructors who teach evolution at public universities and community colleges to gain insight into how they are attempting to mitigate perceived conflict between religion and evolution in their classroom (Barnes & Brownell, 2016). We found that the majority of instructors were not attempting to mitigate student religious conflict with evolution and that these instructors cited many barriers to doing so if they were to try. Although the issue of cultural religious differences between scientists and their students had been previously speculated upon in the literature (Jackson, Doster, Meadows, & Wood, 1995; Reiss, 2008), this was the first

study to empirically document this phenomena through interviews with biology instructors who were teaching evolution (Barnes & Brownell, 2016). These instructors thought that relatively few students struggle with evolution, although previous polls show that up to half of students in biology classes can perceive a conflict with evolution (Rice et al., 2010). Further, some instructors held negative stereotypes about religion and they described exposing their personal views to students by making negative remarks about religion during class. Many instructors said they did not have the knowledge or training necessary to implement strategies that would reduce student conflict with evolution. Interestingly, less than 20% of instructors said they had dealt with any personal conflicts with their own religious beliefs and evolution in their lifetime, so it was difficult for the majority of them to relate to their religious students' struggles with evolution. Further, the most cited barrier these instructors identified was their own personal beliefs about the incompatibility of religion and evolution. These incompatibility beliefs prevented them from teaching in a way that mitigated the perceived conflict between religion and evolution. Thus, we identified that differences between the religious culture and religious beliefs of biology instructors and their students were major factors that diminished the likelihood that an instructor used strategies to reduce a student's perceived conflict between religion and evolution. However, it was still unknown how these differences could impact religious student perceptions of their experiences with instructors and their learning of evolution.

To begin to answer this question, we conducted 28 interviews with Judeo-Christian students in undergraduate biology classes at a public R1 institution in Arizona to explore their experiences learning biology considering their religious identity (Barnes,

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Truong, & Brownell 2017). We found that these students were aware that most biology instructors were not religious and that these students lacked role models in biology who reflect their religious identity. Further, half of these students cited instances in which they had negative experiences with their instructors regarding their evolution instruction. Religious students in our interviews cited instances in which their biology instructors (1) made jokes at the expense of religion/religious students, (2) seemed angry towards religion/religious individuals, (3) dismissed religious students and their ideas as unintelligent, or (4) did not provide a classroom environment in which the religious student felt safe to freely discuss their viewpoints. Students highlighted that their identity as a religious individual was most relevant to them when learning evolution compared to other topics in biology and some students, in part because of these negative experiences, intentionally chose to learn evolution "just for the grade" and planned on forgetting about evolution completely once they finished the course (Barnes et al., 2017b). Some of the religious students who accepted evolution even went as far as to say that they perceived that they would be at a disadvantage in a career in biology because they believed that other biologists would negatively stereotype them due to their belief in God. This provides further evidence, from the perspectives of students themselves, that the different religious culture and religious beliefs of these instructors can present a barrier to effective evolution education for these students.

A potential solution: Using cultural competence to teach evolution more effectively to all students regardless of their religious cultures and religious beliefs. Because of the misalignment of religious cultures and religious beliefs between instructors teaching evolution and students learning evolution, we propose using a lens of

cultural competence to establish instructional practices to reduce student perceived

conflict between religion and evolution. Cultural competence has been used in a variety

of fields and is defined as the ability of people of one culture (in this case college

evolution instructors at public colleges who are primarily not religious) to understand,

communicate, operate, and provide effective services to people of another given culture

(in this case, religiously diverse biology students) (Tanner, 2013). Cultural competence is

a term used widely in medical care and medical education (Betancourt, Green, Carrillo, &

Ananeh-Firempong, 2003) (Kripalani, Bussey-Jones, Katz, & Genao, 2006; Pacquiao,

2007; Tervalon & Murray-García, 2010) and psychology and counseling education (Sue,

1998) to describe how doctors and counselors can provide effective services to patients of

various cultures and beliefs. More recently, science educators have used the lens of

cultural competence for constructing more inclusive science education for racial and

ethnic minority students as the growing racial diversity of college students is not

represented in the current demographics of professors (Boutte, Kelly-Jackson, &

Johnson, 2010; Krugly-Smolska, 1995; Settlage & Southerland, 2007).

   We are interested in identifying culturally competent instructional practices that

can address *religious* cultural and belief differences between instructors and students in

the context of evolution instruction. Because religiosity is the major factor influencing

whether a student accepts evolution, we propose that the effectiveness of biology

instructors' evolution instruction may depend on their ability to take into account the

religious cultural perspectives of their students and that culturally competent instruction

could be a way for instructors to teach in a more inclusive manner to promote decreased

student perceived conflict with evolution.

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There is empirical support for the effectiveness of culturally competent evolution instruction. There are several instructional practices that have been shown to decrease students' perceived conflict with evolution and increase their acceptance of evolution. These instructional practices could be considered culturally competent, although they have not yet been called this in the literature. Some authors have suggested these practices under the lenses of worldview theory (Cobern, 1994), theories of cultural border-crossing (Aikenhead, 1996), what people have called giving students "a place to stand" between their religious beliefs and the theory of evolution (Demastes, Settlage, & Good, 1995), and other educational theories that take into account students' various epistemological dispositions, religious cultures, and religious beliefs when teaching evolution. The Smithsonian institute has published a Cultural and Religious Sensitivity Teaching Resource for high school teachers teaching evolution to high school students (Smithsonian, 2015). Further, Lee Meadows has written about strategies for teaching students the "nonwarfare" model of religion and evolution in order to help religious students become more comfortable learning evolution (Meadows, 2009). Although cultural competence is similar to these other lenses in that it is taking students' religious beliefs into account when teaching evolution, it is distinct from these in that it is relevant for situations where there is a disconnect in cultures and beliefs between those teaching evolution and those learning evolution. Uniquely, cultural competence acknowledges the predominantly secular beliefs and cultures of biology instructors teaching evolution and the influence that can have on their ability to communicate to religious students.

One practice that has been shown to increase student acceptance of evolution is when students are provided with religious scientist role models who accept evolution,

either by instructors revealing their own religious beliefs or by instructors presenting an example of another scientist that is religious if an instructor does not have religious beliefs (Barnes et al., 2017a; Winslow et al., 2011). A second practice that can increase student acceptance of evolution is for instructors to discuss the nature of science and demarcate the questions that science can answer (processes and facts about the natural world) from questions that religion can answer (how one ought to live and the nature of supernatural existence) (Verhey, 2005; Wiles & Alters, 2011). Finally, a third practice that can increase student acceptance of evolution is that instructors can discuss a spectrum of viewpoints on the relationship between religion and evolution to show that religion and evolution can be compatible (Manwaring, Jensen, Gill, & Bybee, 2015; Verhey, 2005; Wiles & Alters, 2011).

We incorporated and assessed all three of these culturally competent instructional practices during a two-week evolution module for an introductory college biology course in which the instructor of the course was agnostic. Due to the disagreement in the literature on how to define and measure acceptance of evolution (Smith, 2010), we instead assessed change in a likely cause of rejection of evolution: whether a student perceived conflict between evolution and religion. Using students' written pre-and post-module responses, we found that by using the three culturally competent instructional practices, we were able to reduce the number of students who perceived conflict between religion and evolution by 50% (Barnes et al., 2017a). The collective work on these instructional practices highlight that they are effective at reducing student rejection of evolution and lessening students' perceived conflict with evolution and religion, even

when the instructors' religious culture and beliefs differed from the students, the latter providing direct evidence for the practices to be considered culturally competent.

It is important to make clear that even though we are promoting culturally competent evolution education, we are not advocating for instructors to "teach the controversy" or lend credibility to religious claims, such as special creationism, that are in obvious conflict with what we know from empirical study of the natural world. Rather, we maintain that acknowledging that there are students who may find evolution controversial, teaching about different positions that exist within the scientific community about the compatibility of religion and evolution, and contrasting these positions with what we can know from science is not at odds with an appropriate science curriculum and can benefit many religious students who are learning evolution. The deep divide between religion and evolution is historically complex, but religion and evolution are thought to be incompatible by many people in the public eye, including some religious leaders (Ham, 2010), scientists (Coyne, 2015; Dawkins, 2009; Harris, 2005), and politicians (Satlin, 2012), which may cause religious students to perceive that one must be an atheist to accept evolution. However, there are many others who have a different viewpoint that religion and evolution can be reconciled (Collins, 2006; Dobzhansky, 1973; Gould, 1999; Miller, 2002) and students may not be as familiar with these positions. We posit that increasing biology students' awareness of this diversity of views even within the scientific community, providing students the opportunity to reflect on their own views when learning evolution, and highlighting the nature of scientific inquiry as opposed to other ways of knowing are all strategies that we consider culturally

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competent and may reduce the perceived conflict between religion and evolution for many students.

Current study: Christian University evolution instructors as a population to explore culturally competent instructional strategies. Christian University evolution instructors are a unique population because their religious culture and religious beliefs are usually similar to that of their students and this makes them an ideal population to identify culturally competent practices in evolution education. In most cases, instructors at Christian universities must give a proclamation of Christian faith to obtain their faculty positions and they are aware that they are teaching biology classes that are largely composed of students who also have a Christian faith. These students will often come into the classroom with pre-conceptions about evolution that seem incompatible with their faith, and may lead them to reject evolution (Winslow et al., 2011). This presents an opportunity to explore the instructional practices of evolution instructors whose religious cultures and religious beliefs are similar to that of their students. We can potentially identify new culturally competent practices for religious students by exploring the instructional practices of religious evolution instructors. Additionally, we can examine their use of already identified practices that can be considered culturally competent that have been shown to increase student acceptance of evolution in previous literature. Given that previous research shows that as much as fifty percent of students in public college biology classes are Christian (Barnes & Brownell, 2017), the insights of Christian instructors teaching evolution to predominantly Christian students may shed light on new and potentially useful ways to teach evolution in culturally competent ways to Christian students at public colleges. To explore this possibility, we interviewed instructors

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teaching evolution at Christian universities about their experiences and perspectives on teaching evolution to Christian students.

Research Questions

1. What culturally competent instructional practices do Christian University instructors use to mitigate perceived conflict between religion and evolution among their students and what beliefs do Christian University instructors have about using these culturally competent practices?

2. What are the personal experiences of religious biology instructors and how have these experiences influenced their use of culturally competent practices when teaching evolution?

Methods

Instructor Recruitment. We recruited a convenience sample of instructors who teach evolution at Christian universities of higher education in the United States. We recruited from 120 Christian universities listed on the Council for Christian Colleges & Universities website (Council for Christian Colleges & Universities, 2015) and Forbes' "Christian Universities" website (Top Christian Colleges and Universities, 2015). We included a college in our recruitment if the college either had a mission statement that referred to a commitment to Christian values or if their biology degree program required chapel attendance. Instructors of college biology with full time positions at these universities were identified through their online institutional profiles and sent individual emails. Instructors were then sent a reminder email approximately two weeks later if they had not responded. We limited our study population to college instructors who teach

evolution with full time positions because we thought that the controversial nature of discussing religion and/or evolution in a classroom might limit the openness of instructors who were in adjunct or part-time positions. Our recruitment email asked instructors if they would participate in a 30-60-minute interview exploring their perspectives on how students might experience conflict between their worldviews and evolution and how they, as instructors at Christian universities, address this in their classrooms. Out of the instructors who responded to the email, we only interviewed instructors who taught an evolution lesson to undergraduates within the last five years. We did not include instructors who taught special creationism (the claim that all living things on Earth were created by God more or less in their current form over as a short period of time) as a scientific alternative to evolution because this is not in agreement with current scientific thinking.

Data Collection. Thirty-two semi-structured interviews were conducted via Skype by M.E.B between summer 2014 and fall 2015. The set of questions that guided the interview can be found in **Table I**. Interviews averaged 31 minutes, but many lasted an hour, and were audio recorded and subsequently transcribed.

Immediately after the interview, the participants were emailed a survey to record their demographic information including their gender, academic credentials, and current religious affiliation, as well as their childhood religious affiliation. The survey also explored the participants' perceptions of whether there is a role for God in evolution. We asked these questions in a survey after the interview so that we could focus on instructor practices and experiences during the interview. All research was approved by the Arizona State University's IRB, protocol #00000631.

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Table I: Interview questions that were used during semi-structured interviews with instructors.

Experiences and practices teaching evolution	How many years have you been teaching evolution to undergraduates?
	Are there specific strategies you use to teach evolution? What are they?
	Do you have any strategies related to religion when you teach evolution? What are they?
	Do you mention religion at all in your class? How?
	Have you ever been challenged by a student in class about evolution? If so, describe your experience.
Perception of student rejection rates	Would you be willing to guess what percent of students in your class reject evolution?
	Have you ever asked?
Goal when teaching evolution	As a biology educator, do you think it is part of your job or goal to help students become more comfortable with and accept evolution? Or do you only aim for students to understand evolution? Why?
Use of specific strategies when discussing religion and evolution	Do you discuss the spectrum of viewpoints that exist about the relationship between religion and evolution? If no, why not? Would you?
	Do you discuss that evolution does not mean atheism/ evolution is compatible with religion? If no, why not? Would you?
	Do you provide students with religious scientist role models who accept evolution? If no, why not? Would you?
Perception of what it means to "accept evolution"	What is "acceptance of evolution"?
	If a student says they accept common ancestry and natural selection but they believe god started or planned evolution, does that student accept or reject evolution? Why or why not?
Personal experiences learning evolution	Did you experience any worldview conflict with evolution when you learned about it? Any other time? Why or why not?

Data Analysis. After the interviews were transcribed, we used qualitative content analysis to systematically identify themes across our interview transcripts (Krippendorff, 2012; Cho & Lee, 2014). A combination of deductive and inductive qualitative content analysis was used to code the interview transcripts, depending on the nature of the research question being explored.

Deductive qualitative content analysis is used to code qualitative data when there are pre-determined categories of phenomena that researchers plan to identify in their data based on existing theory. Deductive qualitative content analysis is "appropriate when the objective of the study is to test existing theory or retest existing data in a new context" (Cho & Lee, 2014). For instance, in the evolution education literature, there are instructional practices such as providing religious scientist role models and addressing a spectrum of viewpoints that have been previously shown to be effective. However, we also know that sometimes instructors at public colleges struggle to utilize these practices and that there is evidence that their struggles may be related to the differing religious culture/beliefs between them and their students (see literature review). Since we wanted to explore the use of these already established practices in a new context with instructors teaching evolution at Christian universities who have similar religious cultures/beliefs as their students, deductive analysis was appropriate for this research question. Therefore, we designed our interview questions to ask specifically about these practices and whether they were providing religious scientist role models and addressing a spectrum of viewpoints when teaching evolution (see Table 1 under "use of specific strategies when discussing religion and evolution"). We coded for the specific presence of instructors' use of these practices when analyzing the interview transcripts. A coding rubric was created describing these categories and was then applied to the interview transcripts.

We also used inductive qualitative content analysis to code the transcripts to discover new phenomena that have not previously been established in the literature. Deductive qualitative analysis "is appropriate when prior knowledge regarding the phenomenon under investigation is limited or fragmented" (Cho & Lee, 2014). For

instance, we wanted to allow for the discovery of evolution instruction practices that have not been previously established in the literature because to our knowledge the practices of Christian University evolution instructors have never been studied. To discover new practices, inductive content analysis is appropriate. Therefore, we also asked the instructors broadly to explain their practices when teaching evolution (see Table 1 under "Experiences and practices teaching evolution"). From instructor responses to these more general open-ended questions, we analyzed the data using inductive content analysis. By inductive, we mean identifying new practices that we did not design the interviews or analysis to identify. Inductive qualitative content analysis was also used to explore instructors' goals when teaching evolution, their perception of what it means to accept evolution, and their personal experiences learning evolution. Further, different manifestations of our predetermined categories that were not expected *a priori* were identified using inductive qualitative content analysis. For instance, although providing religious scientist role models was a pre-determined category identified through deductive content analysis, instructors had different ways of implementing this strategy and those nuanced practices were identified using inductive content analysis.

The analyses were iterative for data emerging from inductive content analysis; themes and categories were slowly transformed after multiple readings of the interview transcripts using constant comparative methods. Constant comparative methods are most often used in grounded theory studies (Glaser & Strauss, 1967). Our study was not a pure grounded theory study because our data collection and interview questions were relatively standardized across all interviews and more specific and targeted than what researchers would generally consider appropriate for a pure grounded theory study (Cho

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& Lee, 2014). However, there are similarities between grounded theory approaches and that of inductive qualitative content analysis approaches in that they both aim to identify emerging themes from the data rather than to identify phenomena that were pre-determined before data collection (Cho & Lee, 2014). For this purpose, the constant comparative methods used in grounded theory are appropriate when conducting an inductive qualitative coding analysis because this method is used to identify themes that emerge from the qualitative data in a minimally biased fashion. Constant comparison includes "comparing" interviews (cases) and quotations (excerpts) and then categorizing these data based on similarities and/or differences over multiple iterations of readings. Once initial categories are created based on the first readings of the transcripts, researchers compare the cases and excerpts that have been categorized together to confirm that each case/excerpt represents the description of the category assigned by the researcher and that the cases/excerpts are not different enough from one another to warrant the creation of a new category.

In this study, the researchers employed inductive content analysis and constant comparative methods by first reading through a subset of transcripts before creating and assigning any codes to the transcripts. The researcher wrote memos on noticeable themes emerging from the data. Then, initial categories were created from these themes and subsequent readings of each transcript identified more themes. All transcripts were then systematically coded using a preliminary coding rubric. The constant comparison method was then used to modify the preliminary coding rubric. Next, the revised coding rubric was applied to the transcripts in an additional reading of the transcripts. The constant comparison method was used for a second time to make further revisions to the coding

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rubric and the revised rubric was then applied again to the transcripts through an additional reading. The constant comparison method was then used for a third time to conduct a final revision on the rubric, but there were very few substantial changes during this iteration, signifying that the inductive coding analysis was complete.

Interrater reliability. Using the coding rubric, a second researcher independently coded a random subset (10%) of the coded interview excerpts. Inter-rater reliability was high; for each category in the coding rubric, the two researchers' codes agreed 95% of the time or more (Krippendorff, 2004). Although there were few disagreements in coding, in most of the cases in which there was a disagreement, the two researchers discussed the code and came to consensus. In the very few cases in which the two raters did not come to consensus on a code, the code was used from the researcher who conducted the interviews and who had the most experience in qualitative data analysis and evolution education research because she was more familiar with the participants' narratives and how they relate to existing literature.

Results

Institutional and Participant Characteristics. Faculty members who participated in the interviews came from 22 different Christian universities in Arkansas, Arizona, California, Iowa, Indiana, Massachusetts, Minnesota, Mississippi, Oklahoma, Tennessee, Texas, Virginia, and Washington. To identify the religious affiliation of each institution, we referenced each university's website.

Thirty-two biology faculty members, 25 males and 7 females, participated in interviews. All participants were currently teaching evolution as part of a biology class or

had taught evolution within the last five years. Most instructors had taught evolution within the last two years. Only a few participants were teaching classes solely on the topic of evolution, so most instructors were teaching biology classes that included lessons on evolution. The most cited courses that instructors had taught that included at least one lesson on evolution included general biology, zoology, ecology, evolution, and genetics. Most instructors were teaching majors courses, but seven instructors said they also taught non-majors. Three participants earned Master's degrees as their highest degree and 29 participants held a Ph.D. The average participant's experience teaching college was 16 years. However, participants' individual teaching experience ranged from 1 to 42 years, indicating a diversity of teaching experience. On a scale from 1-10, one being the lowest and ten being the highest, participants, on average, rated themselves as highly experienced in teaching evolution (M=8, SD=2).

Pseudonyms have been given to each instructor to protect their identity.

Research Findings. Below we address our research questions and report the culturally competent practices that instructors use to mitigate perceived conflict between religion and evolution among their students, the attitudes and beliefs instructors have about teaching evolution to Christian students, and how the personal experiences of instructors reconciling evolution with their Christian faith has informed their instruction.

Instructional Practices. Using deductive content analysis, we identified that almost all Christian University instructors that we interviewed reported using strategies that have been outlined in the literature for increasing student acceptance of evolution and reducing students' perceived conflict between religion and evolution. There were subtle differences in the implementations of these practices; we identified these subtleties

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through our inductive analyses and those are reported below as well. We also report novel instructional practices for evolution education, which we determined using inductive content analysis. Mainly, instructors stressed the importance of adopting an inclusive teaching philosophy and creating a safe environment in which religious students feel comfortable and have the opportunity to explore and discuss how they feel about evolution. Further, instructors often said that evolution acceptance is a goal in their classroom; most often this is an implicit goal, meaning that instructors do not explicitly state to their students that acceptance of evolution is a goal because they perceive that this could alienate their students and solidify any negative perceptions students had about evolution prior to the class. Finally, most instructors said that they thought that students could accept evolution and still believe in a role for God in the creation of life. We consider all of these practices to reflect cultural competence when teaching evolution. Below we outline our findings in more detail.

Almost all instructors said they were using strategies to increase student acceptance of evolution. Among our participants teaching at a Christian University, only one instructor out of 32 was not using any of the three culturally competent instructional practices that we specifically asked about and most instructors were using all three instructional practices.

Instructors present students with religious scientist role models

Almost all instructors that we interviewed said that they provided students with role models in biology who were also religious. Most instructors described revealing their

own faith to their students and some said they even discussed with students their own

experiences reconciling religion and evolution, such as Thomas:

> Thomas: "I identify my background to my students. So they understand the beliefs I grew up with, the denominational affiliation I grew up with, and the way science and scripture were dealt with in my upbringing. I try to connect with them in that sense. And then I talk to them about the fact that my beliefs gradually changed as I gained a deeper understanding of the science and a different understanding of the relationship between faith and scripture, how scripture is read and interpreted. And then going from that to talk about how religion is not mutually exclusive with a career in science or with doing scientific research."

In addition to discussing their own faith with students, many instructors also provided

students with other examples of scientists and religious leaders who both accept evolution

and are religious, which is illustrated by Amy:

> Amy: "I also try and provide them other role models as well. People that they can look to outside of our institution. People like Francis Collins [the director of the NIH and an Evangelical Christian] would be a really obvious example of that type of person. Just so that they have other people to look to when they think about how to come to grips with these issues [their religious beliefs and evolution]."

Instructors teach the bounded nature of science

Most instructors we interviewed said that they discussed with students how

evolution and religion could be compatible because of the bounded nature of science.

Many instructors, including Brian, discussed with their students that science answers

questions about the natural world and does not address the same questions that religion

addresses about the existence of God and purpose in life.

> Brian: "So we have a whole module that … talks about the nature of science … what science is not, and the limitations of science. We draw Venn diagrams and say 'you know science and religion: do they overlap or do they not? Do they impact each other or not?' So, we take a look at various models of science and religion and their interaction with each

other. We say… that science is silent with respect to God but what we learn from science can have implications for faith but we can't put God in a test tube."

Other instructors took a broader approach and taught students about the nature of knowledge in general and the different ways of interpreting religious scripture:

> David: "One of the things that I do [is] help them think about what the purpose of the story of Genesis is about and I kind of say you can view the purpose of the creation story as one that establishes some relationships between God and his creation or you can try to use it to understand how things were made but that is kind of like using a computer to pound a nail."

These instructors felt that they not only had to discuss with students the nature of science in order to establish that science does not answer questions about God, but they also had to discuss the nature of religion to establish that religious texts do not answer questions about the development of the natural world. While it is unlikely that secular instructors at public colleges would be comfortable talking about the nature of theology in a biology class, this instructional practice seemed to reduce student conflict in the perception of these instructors and could be included as part of evolution instruction that is culturally competent.

Instructors present a spectrum of views on the relationship between religion and evolution

Most instructors that we interviewed said that they presented students with a spectrum of viewpoints about the relationship between religion and evolution. Most instructors said they contrasted views such as Young Earth Creationism, Intelligent

Design, Theistic Evolution, Agnostic Evolution and Atheistic Evolution[4] to show

students there are more options than just Creationism and Atheistic Evolution:

> Bill: "We go through, there's probably 6 or 7 different ones. I start with
> young Earth creation, progressive creation, gap theory, evolutionary
> creation… then, I talk about dysteleological evolution, which is more from
> an atheistic standpoint, leaving God out of it. I don't spend a lot of time on
> that but I do make them aware of what each of those are and what the
> major viewpoints are for each one of them."

Some instructors talked about how the denominational composition of the classroom will

matter for how they choose to discuss the spectrum of viewpoints. For instance, Alan

discussed that if one's entire class is composed of students from one denomination, then

he did not think that it would help to show them viewpoints of religious individuals from

other denominations:

> Alan: "I would say at least 90%, if not more of the students that we have
> here at [this Christian University] come from Evangelical backgrounds. In
> the Evangelical background, one of the main values of Evangelicalism is
> Evangelism. They have this idea that we need to share the Gospel with
> other people… so, with that understanding, if you just say to those
> students, 'Well this religion says evolution is okay and this religion says
> evolution is okay' that doesn't really impact them at all."

Alan goes on to say that in this case when students all come from a similar religious

culture, it is imperative that the spectrum of views focuses on people of that religious

culture:

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[4] Young earth creationism refers to the belief that species were created in their current form within the last 10,000 years. Intelligent design refers to the belief that a designer was required for the creation of species because life is irreducibly complex. Theistic Evolution refers to the belief that all of life shares a common ancestor and that a deity is somehow responsible for the evolutionary process. Agnostic evolution refers to the belief that all of life shares a common ancestor and there is uncertainty as to whether or not a deity is responsible for the evolutionary process. Atheistic evolution refers to the belief that all of life on earth shares a common ancestor and that a deity has nothing to do with the evolutionary process. See Yasri, 2016 for an overview of common positions held by students about the relationship between religion and evolution.

Alan: "What would be, I think, more valuable for the students that I particularly work with is to actually look for [views] from their particular background and understanding, from Evangelicalism, and say, 'Here is a prominent Evangelical who says that evolution is okay. Here's another prominent Evangelical who says it's okay.' That would be much more impressive to them than [views from] other religions."

This illustrates the importance of knowing one's students' religious cultures before teaching them evolution. Instructors may still show students positions from different religious denominations, so the students can see a wide range of beliefs within and across denominations, but perhaps it is important to make sure that the students' specific religious denominations are represented.

Instructors adopted an inclusive teaching philosophy for students of varying belief systems

We also discovered new culturally competent instructional practices that we did not expect to find. These instructional practices that instructors mentioned were primarily related to the affective aspects of the classroom environment and illustrated that these instructors had adopted an inclusive teaching philosophy for students of various religious cultures and religious beliefs. First, instructors often discussed how important they felt it was to create a safe learning environment for everyone in the classroom, regardless of the students' beliefs about evolution, as illustrate by Jeff:

Jeff: "By respecting and valuing the other [students'] opinions and acknowledging the value of their ideas really, I hope, helps create this atmosphere of mutual respect and really acceptance, that students can feel safe to be able to share what they're really thinking about, what they're struggling about, and questions that they might have."

Often instructors described creating a safe environment for students by being very explicit that all viewpoints are respected and welcomed in the classroom regarding

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religion and evolution. For instance, Jeff went on to talk about how he polled his students on their views and then had an open discussion about respecting the diverse viewpoints in the room:

> Jeff: "[I said] these are some of the views of your classmates. You know, there's 50, 60 of us in here and we wrote down all the [different views of the students] from a student who is agnostic or an atheist and doesn't understand why we're even talking about these things to a Young Earth Creationist, we've got everybody in between. I acknowledge that."

Additionally, many instructors emphasized the importance of giving students an opportunity to explore their thoughts and feelings about evolution. Instructors saw value in having students explore their conceptions about evolution and religion, so that students could work through any potential conflict they may be having. The method by which instructors provided students with the opportunity to explore their feelings about evolution varied widely but included: online discussion boards on evolution and religion, student essays on their thoughts about evolution (sometimes in a pre/post format), open classroom discussions about religion and evolution, and formal debates in which students argue for a particular view of religion and evolution or to argue for the view that is opposite their own.

Interestingly, many of these Christian University instructors said they had been challenged by students in class about evolution. However, many of these instructors did not interpret this as a disturbance in their classroom, but rather as an indication that students were comfortable expressing their genuine thoughts and feelings in class:

> Glenn: "I would say challenge is maybe too strong a word. I think that they [students] felt comfortable coming up to me and expressing their doubts. Expressing their discomfort. Yeah, I wouldn't say that they come up and challenge me and say, 'why don't you demonstrate to me, why

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don't you prove to me.' That's what I would say is a challenge. Rather they would come out and say, 'All my life I have been taught and I've accepted the fact that [evolution is false] but now you're telling me this. It's making me a little bit uncomfortable and I really want to resolve something. Let's talk about this more.' That sort of very gentle approach."

These instructors' reluctance to call these instances "challenges" further illustrates their commitment to creating an inclusive classroom environment that allows students to feel safe and comfortable expressing their feelings about evolution if they are struggling with a possible conflict.

<u>Instructors had different definitions of what "acceptance of evolution as a goal of instruction" means, but most instructors thought acceptance of evolution was an implicit goal of their evolution instruction</u>

We found that the majority of Christian University instructors said it is their goal to help students accept evolution. Only a minority of Christian University instructors were uncomfortable with acceptance of evolution as a goal because they interpreted this as "forcing" a perspective on their students. For instance, when we asked if acceptance was a goal of their instruction, instructors such as Chris said that trying to force students to accept evolution could alienate them:

> Chris: "I don't want to force acceptance on anyone, especially with the students we have, trying to force acceptance on them would definitely be a mistake. That would -- I think that would alienate them fairly quickly."

Most instructors agreed that forcing students to accept evolution would not be an appropriate approach, but they interpreted the question of "is acceptance of evolution a goal of your instruction?" differently. They did not interpret it as forcing students to accept evolution but interpreted a goal of acceptance of evolution as teaching in a way that would make students more likely to want to accept evolution. Some of these

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instructors stated that they tell students explicitly that acceptance is a goal of their

instruction, but make it clear that this does not mean students have to accept evolution:

> Brian: "We're pretty clear to students that we are teaching in such a way that you'll eventually accept [evolution]. You don't have to accept it, but we are presenting the evidence and we want you to decide. We will respect you if you decide to reject it in the end… but it is our explicit goal that by the end of the course that we would have presented it to you in such a way that not only would you to understand it, but that you would accept it."

Other instructors also saw acceptance of evolution as an instructional goal, but it was an

implicit goal, not explicitly stated to students, often couched in teaching students to use

the best scientific theory available to explain the evidence. These instructors who saw

acceptance of evolution as an implicit goal gave similar reasoning for making the goal

implicit as those who said acceptance was not their goal. For instance, Felicia said if she

told students that they have to accept evolution then she perceived that it would make

them more likely to reject evolution:

> Felicia: "[Acceptance of evolution is my goal] because I can't fathom putting biologists out there in the field that reject evolution. But as soon as you present students with, 'you have to accept evolution', you're done. They can memorize it. They can understand it. But they will reject it"

Further, many instructors said that although acceptance is a goal of their instruction, it is

something that has to be done slowly over time. For instance, Andrew said that

acceptance of evolution is something that has to be eased into the classroom conversation

slowly:

> Andrew: "I don't know how you do biology without evolution. So definitely, we try to change their [students'] views, but it's something that I personally have found is easier to do slowly. One step at a time. A lot of these kids have been very polarized about evolution. It's kind of the epitome of evil or something. And you can't just walk in and say, 'Okay, everything your parents taught you or everything, your pastor taught you

is just all wrong,'… it polarizes immediately. So our strategy is taking it very slowly where we get them to think more critically about everything that they've learned. And then, hopefully, by the time we get into some of the more hard core evolutionary concepts, they're ready to approach it a little more openly than they would have been."

Given these instructors insights, it may be important for religious student acceptance if learning evolution is slowly introduced into the curriculum.

Instructors said students could accept evolution and believe in God, but disagreed on the extent to which a student could believe that God influenced evolution

Given that most of the Christian University instructors believed God played/plays a role in evolution, it is unsurprising that they also believed their students could accept evolution and believe in the influence of God on evolution. However, instructors disagreed on the extent to which a student could believe in God's influence on evolution and still be considered as accepting of evolution. Some instructors thought that to accept evolution, a student could not believe that God guided evolution because this implies that evolution is no longer a naturalistic process. Others, however, said they would give these students "the benefit of the doubt" and say they accept evolution, as long as they accept common ancestry and natural selection. Chris describes both sides of the argument, illustrating the differences in instructor opinions, even within a single instructor, on this distinction:

> Chris: "The problem with [God guiding evolution] is that it's perceived differently by different people… Some people picture a person like you or I, but big and invisible that goes on and sort of physically pushes molecules and genes around. If that's how they're perceiving the work of God, I could see how some people could argue that that student doesn't believe evolution because all of the sudden the whole thing is not a naturalistic process. On the other hand, some people might say, 'well, divine guidance is a very mysterious thing. We can look, and things look

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like they're happening spontaneously according to the laws of chemistry and physics with all of the random elements that we ascribe to those processes. I accept all of that, but somewhere at a level that transcends that, I can still accept this being, who is much more than a giant human being in the sky that's invisible, somehow was able to have things turn out the way that being willed them to… it could go either way actually whether that person actually accepts evolution. My answer still is yes [they do accept evolution], because I give them the benefit of the doubt, if they really have understood physics and chemistry and biology."

These data illustrate that there are complex nuances in how these instructors define acceptance of evolution. While some instructors may think that God guiding evolution is compatible with accepting evolution, other instructors may not, which could have implications for whether a student decides that their own beliefs about God's involvement in evolution is compatible with accepting evolution.

Personal Experiences Reconciling Christianity and Evolution. Next, we report the participants' experiences reconciling Christianity and evolution. We found that almost all these instructors reported that they had struggled with a conflict between religion and evolution at some point in their life and almost all of these instructors had eventually reconciled their religious beliefs with evolution. Further, we found that the challenges that instructors had experienced and overcome have motivated their use of culturally competent practices while teaching evolution to their own students. Our findings are detailed below, with supporting data from instructors.

Internal struggle: Most instructors describe personally encountering challenges to reconciling evolution and their religious beliefs at some point in their life. A minority of instructors said they did not experience a conflict between religion and evolution. These instructors, who did not experience a conflict, often grew up in households that they

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described as "open-minded", in which the topic of evolution was not avoided nor seen as

antithetical to religious faith:

>Charles: "What I appreciated in my family upbringing was that they were open to the possibilities [of evolution], realizing that we are finite and limited in our understanding, to be respectful of others and the uncertainty of biblical interpretation… they were very religious but they were open and that helped."

However, most instructors described encountering personal worldview conflicts with

evolution at several time points in their lives. Instructors described these worldview

conflicts at different times during their scientific training. Some instructors described a

worldview conflict arising when they started learning about evolution in high school,

some talked about it happening in college, and some did not face it until graduate school

in biology. For instance, Michael, Felicia, and Alan all experienced and then overcame

worldview conflicts, but at different times during their high school, undergraduate, and

graduate education:

>Michael: "In high school I was given [an anti-evolution book] called: 'Evolution: The Fossils Say No,' I looked at that and talked about it with my pastor… I had this struggle with that… It was a process, but I'd say by the time I was a freshman in college, I was not a skeptic about evolution."

>Felicia: "I was in college… and I was a freshman and it was 'this is what evolution is and if you don't accept it then it's not okay and you can't accept this and religion. They're incompatible.' It was very clear to me from the first time that I ever heard about evolution, because I never heard about in high school, it was very clear to me that I had to pick."

>Alan: "I didn't really start struggling with it as a Christian myself until I was probably in graduate school. When I was in graduate school I really started struggling with the whole idea of 'how can I incorporate evolution into my understanding of faith and my Christian beliefs?'"

Although almost all of these instructors eventually found ways to reconcile their

religious beliefs with evolution, perhaps earlier culturally competent evolution

instruction could have helped them reconcile their religious beliefs with evolution sooner because instructors reported struggling as early as high school. These data also begin to suggest that culturally competent evolution instruction may be particularly important for a student's first introduction of evolution because that may be when they first experience a worldview conflict.

Challenges from both sides: Instructors describe encountering challenges about their beliefs from the religious community and from the biology community. Many instructors reported that they faced social challenges within their religious community regarding their acceptance of evolution and for some, like Bill, this was deeply troubling:

> Bill: "[My] Sunday school class was basically trying to convince people that what the Bible says is literally true, and that there's evidence for a 6,000 year old Earth. Every time I would try to bring up evidence to the contrary, people would look at me like I had 3 heads… I was eventually told by one of the pastoral staff that I could no longer bring up my opposing opinions. That really hurt me. That was a real struggle for me, because these are supposed to be my brothers and sisters, and they wouldn't even listen to what I had to say… that was a very formative time in my faith journey with regard to evolution."

However, more relevant to the dynamics of the science classroom was the finding that many of the instructors described facing challenges within the biology community about their religious beliefs:

> Anna: "One time I was in an evolution class and my professor was an unapologetic atheist and very vocal about his views. It was very demeaning and just did not respect any religion… I remember thinking 'this class does not have to be like this, this class could be better.'"

These data illustrate the potential difficulties that religious students may face both inside and outside of the classroom if they decide to incorporate biology, particularly evolution, into their professional identity. The majority of these instructors reported struggling with

cultural conflicts in the biology community and their religious community; however, role models who were religious and accepted evolution helped them reconcile their conflicts.

Instructors indicated that role models helped them reconcile their religious beliefs with evolution. The majority of instructors reported that role models who were both religious and accepted evolution were important to help them reconcile evolution and religion. Instructors cited pastors, family members, and biologists who modeled the ability to both accept evolution and be a Christian. For instance, Chris described how his father, a person of Christian faith, helped him accept evolution:

> Chris: "[I said to my father] 'well for evolution to be true it would have to mean that God used a lot of death, huge numbers of animals and plants died in order to bring about the creation. That doesn't seem really consistent with the God that we understand.' I remember my dad saying, 'Well, so what? Who are you to question God and how he brings creation about?' That was more of a turning point for me than anything else. Because I saw my own father, for whom I had profound respect, being able to be a Christian and accept that death had a lot to do with how life has come to diversify. That was the most memorable turning point in my whole journey probably."

George and Brian talked about the importance of knowing other biologists, including their own biology professors and their professional colleagues in biology, who were religious and accepted evolution:

> George: "My graduate adviser… is a Christian. We had a great lab in terms of a variety of different viewpoints… and we talked about these things over lunch… There were other Christians in the lab and they didn't have conflict either so, there was no conflict [for me]."

> Brian: "I was around Christians that were fellow biologists that were like 'yeah man, this [evolution] make sense' and so I was initially resistant, but seeing it in their lives… they're modeling it. Eventually, I really didn't have any problem with evolution."

These data support the idea that role models are potentially critical for helping students to reconcile their religious identity with the culture of biology. Further, these data reinforce the use of religious scientist role models as a culturally competent instructional strategy.

The personal struggles of instructors with evolution and religion make them want to help their religious students' own struggles with evolution and religion. Many instructors reported that their own struggles reconciling religion and evolution have motivated them to try to help their students who may be struggling. Andrew discussed how he believes his own personal experience having to overcome a conflict with his religious beliefs and evolution benefited his teaching of Christian students:

> Andrew: "Very definitely [I experienced a conflict], and it's part of the reason I'm so interested in how we teach [evolution] where I teach now. I feel like there would be value in someone who's been through that working with the students rather than someone who has never been through it… I've got absolutely wonderful friends who are atheists and teach evolution and they're not going to have the same ability to understand where the students are coming from and what they're struggling with that I might have, having come from a similar type of background."

Other instructors, including Brian, discussed how the lack of guidance they received from others in reconciling religion and evolution has motivated them to help their own students reconcile their belief systems:

> Brian: "I went to a Christian college and that college never really addressed the issues [of a potential conflict between religion and evolution] which is kind of crazy. I mean, I feel like I was cheated of an opportunity. My professors should have modeled it for me the same way I try to model it for my students."

Larry also discussed how his instructional decisions are influenced by his own personal experiences reconciling religion and evolution:

Interviewer: "Can you tell me why you've decided to make discussing religion a part of your instructional practices when you teach evolution?"

Larry: "Personally, I have been exploring this topic myself quite a bit. In my younger years… I struggled with the fact that there seemed to be a lot of conflict between religion and science, which was difficult for me because I was passionate about both. I had a lot of internal conflict… I've changed my philosophies on things and my views over time, and I see that as being okay. Wanting students to have the same opportunity to explore all the evidence and not be threatened by scientific information…how evolution…doesn't necessarily take away from our faith."

These data showcase how instructors' personal religious culture and beliefs can be important for determining whether the instructors will be aware of religious student struggles with evolution and whether they may implement evolution education instruction that is inclusive of their religious students. Since most instructors teaching evolution at public colleges are not religious and have not experienced their own conflicts with evolution, this finding further supports a need for a lens of cultural competence in evolution education at public colleges because these instructors will be more likely to underemphasize the importance of their students' religious backgrounds when teaching evolution.

Discussion

This study is the first to our knowledge to document the experiences and instructional practices of instructors teaching evolution at Christian universities across the United States. From our interviews, we found that these instructors regularly use culturally competent practices that have been shown to reduce students' conflict between religion and evolution and increase student acceptance of evolution. Further, we found that these instructors were aware of their students' struggles with evolution, considered

acceptance of evolution a goal of their instruction, and cited their own personal experiences with reconciling their religious beliefs with evolution as informing their instructional practices. Instructors greatly emphasized the importance of creating a safe classroom environment in which students with a diversity of belief systems could benefit from learning evolution. Finally, we found additional evidence for a need for cultural competence in evolution education based on (1) these instructors' personal experiences learning evolution and (2) how the instructors' personal religious culture and beliefs have shaped their own practices teaching evolution. Instructors reported that when they learned evolution they had negative experiences learning evolution in the absence of culturally competent instruction. Additionally, these interviews provide support for the idea that when an instructor shares a similar Christian religious culture and similar beliefs as their students, it contributes to their motivation for using strategies that reduce perceived conflict with evolution among their students. This builds on our previous interview study that illustrated that evolution instructors may struggle with using these strategies when their religious culture and beliefs are different from their students (Barnes & Brownell, 2016).

A classroom environment for all students to learn evolution: developing an inclusive evolution teaching philosophy. A way that Christian University instructors reported that they facilitated productive engagement with evolution among their religious students was to create a safe learning environment for all students learning evolution regardless of the students' beliefs about religion and evolution. This indicated that the instructors had adopted an inclusive teaching philosophy, in which they were committed to teaching evolution in a way that can be effective for students with different religious

beliefs about evolution. First, many instructors made it explicit to their students that no perspective in their class would be judged negatively. Although most instructors saw student acceptance of evolution as an implicit goal of their instruction, they also told students it would be OK if they did not accept evolution. The majority of these Christian University instructors believed that if they took an approach with students in which they told students they were required to or "should" believe evolution, that this would alienate students, and solidify any negative perceptions about evolution they had prior to class. Indeed in prior research from our group, we found that religious students reported feeling negative towards evolution after instructors told the class that they must accept evolution (Barnes et al., 2017b). Although our other findings suggest that personal experiences with a religious culture and religious beliefs can help inform instructors' culturally competent practices, this finding suggests that developing an inclusive teaching philosophy may also provide additional support for implementing culturally competent practices. Perhaps if an instructor does not have personal experience with a religious cultural and religious beliefs, they may be able to implement effective culturally competent evolution education if they adopt an inclusive teaching philosophy in which they are aware of and tend to differences in students' religious backgrounds.

Our data indicate that student "challenges" about evolution in class may actually be an indication of an inclusive classroom environment. An interesting difference we found between the instructors we interviewed at Christian universities and our prior study focused on instructors at public colleges was that Christian University instructors reported that students challenged them about evolution in class more often. In our past study, very few instructors at public colleges reported that they had been challenged

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about evolution in their classes (Barnes & Brownell, 2016). However, instructors in this study at Christian universities reported that students generally seemed comfortable being open with the instructor if they felt evolution was in conflict with their religious beliefs. Rather than interpret these instances as "challenges," Christian University instructors often corrected the interviewer and said they saw these discussions as an opportunity for growth and reflection on the student's part. Given that prior research shows that many students in public college biology classes struggle with evolution (Rice et al., 2015), it is likely that there are many students who do struggle in these instructors' classes, even though they are not openly challenging their instructors in class. Perhaps the extent to which students "challenge" the instructor about evolution reflects the extent to which the students feel comfortable expressing their opinions in class rather than the extent to which the class as a whole accepts evolution.

Affective components of evolution instruction. Instructors at Christian universities were particularly cognizant of the affective components of evolution education and prior research supports the efficacy of these practices. Research in educational psychology has long demonstrated that learning does not occur separate from our emotions about a topic. True conceptual change from novice to expert mindsets are facilitated by cognitive and emotional processes (Pintrich, Marx, & Boyle, 1993; Sinatra, 2005; Sinatra & Pintrich, 2003). If a student only receives instruction on the "cold concepts" of evolution (e.g. the processes of natural selection and genetic drift), but the instructor does not attend to the "hot" motivational factors of learning evolution (e.g. students' perception that they must reject God to accept evolution), then we may lose the opportunity to increase student engagement with evolution. Students may learn the facts

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about evolution, but whether they find use for those facts will depend on whether they have been motivated to do so (Sinatra & Pintrich, 2003). If some students come into the classroom with negative attitudes towards evolution, as previous literature supports that they do, then their motivation for learning will likely be low and their subsequent engagement with the material will likely be low (Dole & Sinatra, 1998). This implies that we as instructors need to attend to the affective aspects of evolution education and provide an inclusive learning environment that supports the engagement of learning evolution for all students, not just those who come into the classroom without a conflict with evolution.

Preliminary comparisons: practices of evolution instructors at public and Christian colleges. In our previous research, we explored the practices and perspectives of instructors teaching evolution at public colleges in Arizona (Barnes & Brownell, 2016). There are limitations in our ability to compare the two sets of findings due to differences in the cultures between public and religious institutions as well as geographical differences. We consider it is worth reporting preliminary comparisons to inform future research and theory, but these comparisons must be interpreted cautiously. First, instructors at Christian universities more often reported that they attend to emotional aspects of learning evolution when teaching their students and more often reported that they utilized strategies outlined in the literature for reducing students' conflict between religion and evolution. That is, these instructors at Christian universities emphasized the importance of addressing how students may feel about evolution when teaching and provided students with resources to bridge religious beliefs with evolution. Second, compared to instructors at public colleges, instructors at Christian universities

more often emphasized making the classroom a safe and comfortable place for all students in their classes so that students could reflect on their conceptions of evolution and religion, regardless of whether the student accepted evolution or not. They perceived that this component of their instruction was important for their Christian students when learning evolution. Also, instructors we interviewed at Christian universities most often said that they considered acceptance of evolution a goal of their evolution instruction but instructors in our past study at public colleges most often said acceptance of evolution was not their goal. Last, we found that while instructors at public colleges referenced their personal beliefs for why they did not use strategies to reduce religious students' perceived conflict with evolution, instructors at Christian universities also indicated that their own personal beliefs and experiences informed their instructional practice – but in a way that increased their use of strategies to reduce students' perceived conflict with evolution.

These preliminary comparisons add to accumulating evidence, which illustrates that the misalignment between the religious cultures and religious beliefs of instructors and students may be critical to consider when teaching evolution. When there is misalignment between instructors' and students' religious cultures and religious beliefs, we believe that cultural competence in evolution education can improve these instructors' ability to teach evolution to a wide range of students of different religious cultures and religious beliefs. As such, we propose that cultural competence could be a lens by which to develop, organize, and promote instructional practices that could lead to more effective evolution education, particularly for religious students being taught by instructors who are not religious.

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Limitations and future research

Our findings were self-reports and not observational data. Factors that influence the way individual's self-report, such as social desirability bias, could have influenced the results of our interviews (Edwards, 1957) and some of the instructors' experiences and perceptions may not be accurately represented. However, this is a limitation of most interview studies, which are often seen as exploring avenues for new research area in order to subsequently inform more systematic and observational research (Glesne & Peshkin, 1992). Future research should confirm self-reports of instructors through classroom observations.

As with all non-randomly sampled populations, we may have a sampling bias. In interview studies, participation in the study is self-selected so, we may have a self-selection issue that may bias the results (Brownell, Kloser, Fukami, & Shavelson, 2013; Rosenthal & Rosnow, 1975). We acknowledge that it could be possible that the pool of interviewees who were willing to talk about their instructional practices are not necessarily reflective of the larger population of instructors, so our findings should be interpreted cautiously. However, interview studies are often designed to characterize the landscape and diversity of experiences and perspectives rather than to make generalizations about the population as a whole (Glesne & Peshkin, 1992). Future research surveying a larger population of instructors could help to generalize and extend our findings.

Conclusion

Our study is the first to characterize the instructional practices and experiences of instructors at Christian universities who teach evolution. We found that instructors' religious culture and religious beliefs inform their use of evolution instruction that is culturally competent. Additionally, these Christian university instructors maintain an inclusive teaching philosophy by emphasizing the importance of creating a safe, open environment for students of all belief systems to encourage a reflective environment in which students can feel comfortable exploring their beliefs and asking questions about their beliefs in class. We hope that the experiences of these instructors, who teach evolution to primarily religious students, can inform the practices of college instructors more broadly who also have a large number of religious students in their biology classes.

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CHAPTER 6

INTRODUCING RELIGIOUS CULTURAL COMPETENCE IN EVOLUTION

EDUCATION (RECCEE)

M. Elizabeth Barnes and Sara E. Brownell

Abstract

Low acceptance of evolution among undergraduate students is common and is best predicted by religious beliefs. Decreasing students' perceived conflict between religion and evolution could increase their acceptance of evolution. However, college biology instructors may struggle with trying to decrease the perceived conflict, perhaps because their own religious cultures and beliefs are often very different from their students'. For instance, although upwards of 50% of undergraduate students learning evolution are religious, most instructors teaching evolution are not. To consider this difference between the secular culture of many college instructors and the religious culture of many students, we propose using a lens of cultural competence to create effective evolution education. Cultural competence is the ability of individuals from one culture (in this case, primarily secular instructors who are teaching evolution) to bridge cultural differences and effectively communicate to individuals from a different culture (in this case, primarily religious undergraduate biology students). We call this new framework Religious Cultural Competence in Evolution Education (ReCCEE). In this essay, we describe a suite of ReCCEE practices that can help instructors who are teaching evolution reduce perceived conflict between evolution and religion, increase acceptance of evolution, and help create more inclusive undergraduate biology classrooms.

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Introduction

"If 80-90% of Americans profess that (they believe in God) and they think that evolution is against religion, then we (scientists) are not going to get very far... so the main reason we have to keep stressing that science is a different matter and is not opposed to religion...is that it happens to be right logically, but we should also be aware that it is very practical"

–Stephen J. Gould, Annual meeting of the American Institute of Biological Sciences in the Museum of Natural History, Smithsonian Institution, Washington DC, 2000

In March 2000 at the annual meeting of the American Institute of Biological Sciences, Stephen J. Gould, a champion of evolutionary theory, highlighted his distress to biologists about the current state of evolution education. He noted that a large percentage of the American public rejected evolution because of a perceived conflict between religion and science. Despite Gould's own agnostic beliefs, he insisted that the scientific community take steps to relieve the tension between scientific and religious communities to advance evolution education. He predicted that if the scientific community continued to assert that evolutionary theory must be in opposition to religion, that we would not see a change in the rates of rejection of evolution.

When Gould brought attention to this issue almost 20 years ago, the national Gallup poll reported that 44% of Americans believed that "Humans were created in their current form by God in the last 10,000 years" (Gallup, 2014). As Gould predicted would happen without changing the dialogue surrounding evolution and religion, rates of rejection of evolution in the United States have remained around 40% (Gallup, 2014;

Gallup, 2017). Further, the research literature indicates that the perceived conflict between evolution and religion may be exacerbated by the differences in the religious cultures and religious beliefs of scientists and the public. If we are to change the public's attitude towards evolution, we must find a way to bridge this cultural divide.

In this essay, we will introduce the use of cultural competence as a way to bridge the religious cultural gap between scientists and the public. Cultural competence could be particularly effective for helping secular college instructors teach evolution to religious undergraduate biology students. We will use cultural competence as a lens to build a new framework of instructional practices that evolution instructors can use to more effectively teach evolution to religious students: **Re**ligious **C**ultural **C**ompetence in **E**volution **E**ducation (ReCCEE, pronounced "reesee"). This framework encompasses a suite of evidence-based instructional practices that can help minimize the negative impact of the differences between the predominantly secular cultures of evolution instructors and the religious cultures of upwards of 50% of their students. The goal of this essay is to encourage conversations and research efforts aimed at mitigating the cultural conflicts between scientists and the public related to the teaching of evolution. Specifically, we hope to convince readers that the use of cultural competence in undergraduate evolution education can decrease students' perceived conflict between evolution and religion, increase students' acceptance of evolution, and enable religious students to feel more included in undergraduate biology classrooms.

Religiosity is the main factor that negatively predicts acceptance of evolution. Evolution is simultaneously one of the most influential theories in science and one of the most controversial among the public. Over 30 years of public polls show

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that, consistently, only approximately 60% of Americans accept that humans have developed from previous species (Gallup, 2014, Gallup 2017). This controversy over the legitimacy of evolution extends to college students. Although rates of acceptance of evolution among undergraduates vary by geographic region and institution, and some of this reported variation may be due to different methods of measuring acceptance of evolution[5], research has shown that acceptance of evolution is weak among college students. For instance, one study found that approximately half of students at a large research university did not accept that evolution could occur without the intervention of an intelligent designer (Brem, Ranney, and Schindel, 2003). Another study demonstrated that students in a non-major's biology course had low to moderate acceptance of evolution, according to their scores on the Measure of Acceptance of the Theory of Evolution (MATE) (Walter, Halverson, and Boyce 2013; Rutledge and Sadler, 2007). Even among junior and senior-level biology majors, one study identified that 28% did not accept that life on earth shares a common ancestor (Ingram and Nelson 2006). Further, students' low acceptance of evolution can be impervious to instruction about evolution. Some studies have shown that students do not show a statistically significant increase of their acceptance of evolution scores after being taught about evolution (Walter, Halverson, and Boyce 2013; Short and Hawley, 2015). For a review

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[5] Acceptance of evolution is a construct that has been frequently measured using different instruments. The different ways that researchers measure acceptance of evolution that can lead to different results across studies because the items and the way items are worded are different. Examples of instruments include the MATE (Rutledge and Sadler, 2007) the Inventory of Student Acceptance of Evolution (I-SEA) (Nadelson and Southerland, 2012), The Generalized Acceptance of Evolution Evaluation (GAENE) (Smith, Snyder, and Devereaux, 2016). Additionally, many studies use instructor generated single item questions about acceptance of evolution. The lack of consistency in the definition and measures of acceptance of evolution has been critiqued in the literature (Smith, 2009a). These different measures make it difficult to draw conclusions about student acceptance of evolution across studies.

that summaries low acceptance rates of evolution among college students, see Rice,

Olson & Colbert, 2010

        Why is it that the public, and even our college biology students, demonstrate low

levels of acceptance of evolution? Thus far, research illustrates that acceptance of

evolution is a multifaceted and complex phenomenon with many causal factors

(Rutledge & Warden, 2000; Wiles & Alters, 2011; Winslow, Staver, & Scharmann,

2011), but a person's religious beliefs and how important those beliefs are to them –

defined as religiosity - is the greatest predictor of whether someone will accept evolution

(Hill, 2014; Rissler, Duncan, & Caruso, 2014, Glaze, Goldston, and Dantzler, 2014).

Studies have shown that student understanding of evolution is not associated, or only

weakly associated, with student levels of acceptance of evolution. For instance,

Nadelson and Sinatra (2010) found no correlation between pre-service teachers' scores

on the Conceptual Inventory of Natural Selection (CINS) (Anderson, Fisher, & Norman,

2002) and their scores on the Measure of Acceptance of the Theory of evolution

(MATE). Bishop and Anderson (1990) found that students' ability to explain natural

selection and changes in populations were unrelated to whether they accepted that the

theory of evolution was true. Another study showed no relationship between students'

scores on the Understanding Biological Change (UBC) survey (Settlage & Jensen, 1996)

and their beliefs about the credibility of evolution (Sinatra, Southerland, MacConaughy,

and Demastes, 2003). While some studies have shown weak relationships between

acceptance of evolution and understanding of evolution (Athanasiou & Papadopoulou,

2012; Cavallo, White, & McCall, David, 2011; Deniz, Donnelly, & Yilmaz, 2008;

Großschedl, Konnemann, & Basel, 2014; Nadelson & Sinatra, 2008), the research is

clear that students' religious beliefs and the beliefs of their family and friends strongly predict whether they will accept evolution. For instance, Glaze, Goldston, and Dantzler, 2014 used multiple regression analysis to determine that religiosity was the most predictive factor for acceptance of evolution, explaining twice as much variance in students' acceptance of evolution as their understanding of evolution. Also, Hill (2014) showed that special creationists who were in their teens were approximately three times more likely to end up accepting evolution by the time they were in their twenties if they were not strongly committed to their religious beliefs. These same individuals were seven times more likely to change to accepting evolution if one of their close friends or family members accepted evolution. Interestingly, increased education levels (i.e. obtaining a bachelor or graduate degree) were not predictive of whether these teens would change to accepting evolution. These findings bring up the question as to why one's religiosity and social affiliation so strongly determine someone's acceptance of evolution.

It is possible that many people perceive a conflict between their religious beliefs and evolution because this message of conflict is often propagated in classrooms, religious institutions, popular culture, and the media by scientists, teachers, religious leaders, and politicians. Some evolutionary biologists have written entire books that claim evolution and religion must be in conflict (Coyne, 2015; Dawkins, 2009) and some religious leaders position religion against evolution so that one must relinquish one's faith to accept evolution (Ham, 2010). There has even been a multi-million-dollar creationist museum created with the purpose of discrediting evolutionary theory based on religious claims (Kopplin, Levin, Pesca, & Steinberg, 2016). Further, politicians at

the state and national levels have advocated for the teaching of creationism as an alternative to evolution in public schools, further stoking the belief that religion and science have to be opposed (Kaplan, 2016; Satlin, 2012). Due to the visibility of these polarizing positions, it is not surprising that individuals may feel as though they must reject their religious beliefs if they are to accept evolution.

Although it may sometimes seem as if there are the only two extreme positions that exist, there is room for reconciliation between evolution and religion. The call for acknowledging the potential compatibility between evolution and religion has been prevalent in the evolution education literature (Cobern, 1994; Jackson, Doster, Meadows, & Wood, 1995; Scott, 2014; Smith, 2009a, 2009b; Southerland & Scharmann, 2013). The Catholic church has made official statements that the Catholic religious doctrines are compatible with evolution (Tharoor, 2014) and over 13,000 Christian religious leaders have signed a letter supporting potential compatibility between evolution and religion (The Clergy Letter Project, 2016). Similarly, national scientific agencies such as The National Academy of Sciences have produced reports that highlight the potential compatibility of evolution and religion (NAS, 1998, 2008). In fact, studies show that taking a stance of potential compatibility between evolution and religion can have large impacts on increasing student acceptance of evolution (Manwaring, Jensen, Gill, & Bybee, 2015) and decreasing perceived conflict between evolution and religion (Barnes, Elser, & Brownell, 2017; Barnes, Truong, & Brownell, under review). Even the Smithsonian Institute has released documents outlining how high school teachers can teach evolution to high school students while remaining sensitive to these students' religious beliefs (Smithsonian Institute, 2015). However,

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emerging research is illustrating that scientists teaching evolution to college students may struggle with acknowledging the potential compatibility between religion and evolution (Barnes & Brownell, 2016).

The difference between the religious beliefs and cultures of students and instructors in college biology classes. The majority of the public hold religious beliefs (Gallup, 2014; Pew, 2010). When we surveyed over 3,000 college students in biology classes at a large research university, we found that the majority of them also hold religious beliefs (**Table I**). However, the majority of biologists do not hold religious beliefs (Pew, 2009; Ecklund and Scheitle, 2007). Religious beliefs are diverse and therefore the term "religious beliefs" is hard to define (Hill & Pargament, 2003). As such, we define religious beliefs very broadly as the specific beliefs one holds about the existence and influence of a deity (Webster-Merriam, 2017a). We define being religious as having faithful devotion to an acknowledged ultimate reality or deity (Webster-Merriam, 2017b). In contrast to the large numbers of undergraduates who report being religious, it has been shown that only 25% of biologists are religious (Ecklund & Scheitle, 2007) and evolutionary biologists in particular are markedly irreligious: only 10% of evolutionary biologists say that they believe in a God/god(s) (Graffin & Provine, 2007). Yet, religious identity can include both religious beliefs and religious culture. Table I: Rates of religiosity among students in biology classes at a large southwestern R1 university in Arizona. Arizona ranks 24th in religiosity among all US states with 51% of residents reporting that religion is important to their lives. Students completed an electronic survey which asked students to self-identify their religious affiliation and to what extent that religious affiliation was important to their identity. Students were

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able to decline to state.

Table I: Rates of Religiosity Among Students

Semester	Population	Sample Size	% of students who self-identified with a religion	% of students who agreed that religion is an important part of their life/identity
2014 Fall	Intro bio students	1440	64%	55%
2016 Spring	Intro bio students	1335	Not collected	42%
2016 Fall	Intro and upper level bio students	462	79%	45%
2017 Spring	Upper level evolution students	389	77%	40%

In line with broader definitions of culture (Webster-Merriam, 2017c), we define religious culture as the sociocultural norms and expectations that an individual has and continues to experience that is related to religion. Religious cultural norms can include shared values, attitudes, traditions, holidays, and celebrations; an individual who is religious would likely participate in some if not most of their religion's customs. However, an individual can be culturally religious, but not ascribe to the specific religious beliefs of that religion. For example, an individual may participate in religious events or customs (e.g. attending church services on Christmas Eve, observing Passover, giving up chocolate for Lent), but not believe in the existence of a deity. Although many evolution instructors may not hold specific religious beliefs, they may have previously ascribed to or even currently ascribe to a religious culture, which could influence their awareness of and sensitivity to religious objections to evolution.

Further, an individual can be part of a culture that is secular. A secular culture can include a culture that has no social norms or expectations regarding religion or a

secular culture can include sociocultural norms that are opposed to religion and religious groups. While to our knowledge there have been no specific studies exploring the differences in religious cultures between biology instructors and biology students, the pursuit of science is often assumed to be a secular endeavor (Jackson et al., 1995) and many evolutionary biologists who model the culture of science to the public often espouse views that are opposed to religion and religious individuals (Dawkins, 2009; Coyne, 2015). Therefore, instructors of evolution may also ascribe to a secular culture that includes norms and expectations that are opposed to religion or promote negative stereotypes about religious individuals, which could influence their ability to effectively communicate evolution to religious individuals.

Even though there is a notable gap between the percentages of religious students in biology classes and the percentages of biologists with a religious identity, the question remains whether this difference in religious beliefs and cultures matters for instructional practices when teaching evolution. There is an emerging research literature that suggests that it does.

Prior research from our group indicates that a college evolution instructor's previous and current religious beliefs and cultures may impact their teaching of evolution and the degree to which they are willing to help students with religious beliefs become more comfortable with evolution. In an interview study with college biology instructors who teach evolution at public institutions, we found that many instructors were reluctant to address potential compatibility between evolution and religion because they did not feel that discussions about religion had a place in the biology classroom (Barnes & Brownell, 2016). Yet, many of these instructors seemed to be unaware of the

struggles of religious students in their biology classes. This may be because many of these instructors did not know how many of their students were religious or to what degree these students perceived a conflict between their religious beliefs and evolution. Additionally, most of the instructors were not religious themselves and had never experienced their own worldview conflict with evolution and their religious beliefs, which mirrors what we know about biologists broadly (Pew, 2009; Ecklund and Scheitle, 2007). Notably, many instructors had their own beliefs that evolution and religion must be in conflict; some of these instructors taught evolution as fundamentally atheistic and even overtly made disparaging remarks about religious beliefs during class. These factors likely contribute to the instructional decisions that these instructors made when teaching evolution, which was often to avoid discussions about religion and rarely to present the possible compatibility of evolution and religion.

However, not acknowledging religious beliefs can be alienating for religious students (Barnes, Truong, & Brownell, 2017; Hermann, 2012). In an interview study with religious students in undergraduate biology classes, we found that students perceived that when instructors avoided discussion about religious beliefs when teaching evolution that it implied that instructors were not accepting of student religious beliefs. Religious students also assumed that most biology instructors are not religious and as a result, some of these students felt as though they are the minority in the classroom and did not know of scientist role models who reflect their own religious identity and accept evolution (Barnes et al., 2017). Similarly, an interview study done with high school students learning evolution demonstrated that when instructors did not acknowledge religious beliefs, the religious students in the class said it made them feel left out

(Hermann, 2012). This small, yet growing literature base illustrates that we may be creating less inclusive classroom environments by not addressing religious beliefs when teaching evolution.

Our work and the work of others are beginning to paint a picture that students' perceived conflict between evolution and religion, their rejection of evolution, and their feelings of not belonging in the biology classroom may be, in part, the result of the difference in culture between mostly secular instructors and mostly religious students (Barnes & Brownell, 2016; Hermann, 2012; Jackson et al., 1995; Smith, 2009b; Southerland & Scharmann, 2013). A potential solution is to try to help secular evolution instructors better understand and relate to the culture of religious students.

The use of cultural competence to bridge the religious cultural gap: Religious Cultural Competence in Evolution Education (ReCCEE). Cultural competence refers to the ability of people of one culture to understand and relate to the people of another culture (Tanner & Allen, 2007). Cultural differences, including differences in gender, ethnicity, country of origin, LGBTQIA identity, or religion, can make it harder for two people to understand each other, communicate with each other, and work effectively with each other. Cultural competence has been called for as a lens to help people bridge cultural gaps and better appreciate cultural differences among one another so they can communicate with one another effectively. Cultural competence has been previously discussed in the context of doctors treating patients (Betancourt, Green, Carrillo, & Ananeh-Firempong, 2003; Tervalon & Murray-García, 2010), managers supervising employees (Johnson, Lenartowicz, & Apud, 2006), and instructors teaching students (Tanner & Allen, 2007). Betancourt et. al, 2003 has defined a system that

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includes cultural competence as one that "acknowledges and incorporates…the importance of culture, assessment of cross-cultural relations, vigilance toward the dynamics that result from cultural differences, expansion of cultural knowledge, and adaptation of services to meet culturally unique needs". Although cultural competence has been discussed in the context of biology instructors and students (Tanner & Allen, 2007), to our knowledge it has never been specifically advocated for as a lens to bridge the cultural gap between religious students and non-religious instructors teaching evolution, even though student religious beliefs are a major factor for why students do not accept evolution.

Studies have shown that cultural competence training can improve provider and patient outcomes in medicine and counseling. In 2010, one study showed that physicians who underwent cultural competence training became more aware of racial disparities in the healthcare of their Black patients compared to physicians who did not complete training (Sequist et al., 2010). A 2005 study of the effect of cultural competence training among physicians showed evidence that this training led to mutual understandings between physicians and patients and improved racial minority patients' perceptions of physicians (Harmsen et al., 2005). Another study found that when counselors were trained in cultural competence, their Black female patients returned for appointments more often, showed greater satisfaction with counseling services, perceived their counselors as more credible, and scored higher on patient-counselor relationship measures than did Black female patients with counselors that were not trained in cultural competence (Wade and Bernstein, 1991). Given that student perceptions of scientists, including their trust in scientists, has been shown to influence students' acceptance of

evolution (Nadelson & Hardy, 2015) the results from cultural competence training with physicians/counselors on patient relational measures are promising for evolution education.

The lens of cultural competence can be used to help organize evidence-based evolution education teaching practices that may bridge the gap between the predominantly secular cultures of college biology instructors and the religious cultures of many students. Although these evidence-based practices have already been reported in the literature as impactful for increasing student acceptance of evolution or decreasing perceived conflict between evolution and religion, a framework that organizes these practices does not currently exist. To help the community see the commonalities among these practices and to encourage the use of these practices as a whole, we define **Re**ligious **C**ultural **C**ompetence in **E**volution **E**ducation (ReCCEE) as a framework for culturally competent evolution education. Below we describe ReCCEE practices and the empirical support for each of these practices (See **Table II** for a summary). While few studies have examined any single practice in isolation, there is a growing literature base for the positive impact of combinations of these practices. Although these interventions vary in the instructional time required, we have found that even a five-minute module that encompasses some of these practices can help reduce students' perceived conflict between religion and evolution (Barnes et al., under review). Below we outline six evidence-based culturally competent practices that instructors can use when teaching evolution to undergraduate students to help reduce students' perceived conflict between evolution and religion, increase their acceptance of evolution, and create a more inclusive classroom environment for students with a diversity of religious backgrounds.

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Acknowledge that some students may see a conflict between their religious beliefs and evolution. A culturally competent instructional practice that evolution instructors can use is to simply acknowledge that students may experience a conflict with their religious beliefs when learning evolution. Interview studies with students from a wide range of religious cultural backgrounds, including Muslim and Christian students in high school and college, have revealed that students appreciate when an instructor acknowledges that a student can experience a conflict; instructors acknowledging a possible conflict can then help students develop more positive attitudes towards evolution (Brickhouse, Dagher, Letts, & Shipman, 2000; Dagher & BouJaoude, 1997). This strategy can help religious students feel acknowledged and respected by their instructor.

Explore students' personal views on evolution and religion. Another culturally competent instructional practice for evolution instructors is to provide opportunities for students to discuss/reflect on their own and other students' views on evolution and religion. More so than simply acknowledging that students have different beliefs, this practice allows students to engage and reflect critically on their personal views on evolution. In one study, Winslow et al., 2011 interviewed biology majors who took a class in which they had to extensively reflect on their own and others' views on evolution and found that almost every one of these students changed from a special creationist view to accepting evolution by the time they graduated. In another study, Scharmann and Butler, 2015 tested the effect of students' journaling about their views on evolution, which included an in-class discussion about what students had written in their journals. They found a statistically significant increase in students' attitudes towards evolution over their journaling experience. Finally, Scharmann (1990) has argued for student-

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centered discussions in class as a means for students to carefully examine their own beliefs and potentially construct their own means of reconciling their personal beliefs with evolution.

Describe to students the bounded nature of science and different ways of knowing. A way to bridge the cultural gap between religious individuals and non-religious individuals in a biology class is to discuss the nature of knowledge, different ways of knowing, and the bounded nature of science. There have been several studies that have explored the impact of these practices on students. Martin-Hansen (2006) conducted a study in which extensive instruction on the nature of science, including the appropriate methods that science uses to test hypotheses and the relationship between science and religion, led to increased positive attitudes of students towards evolution. Further, Ladine (2009) found that Christian students preferred that evolution instructors use the nature of science to describe the characteristics of special creationism and intelligent design that classify them as non-scientific. Ingram & Nelson (2006) demonstrated statistically significant gains in students' pre- to post-course acceptance of evolution after incorporating a focus on the nature and limits of scientific knowledge into their evolution instruction. Similarly, Nehm and Schonfeld (2007) found that they were able to reduce high school teachers' perceived conflict between evolution and religion if they implemented discussions about the nature of science. Finally, several other studies show a generally positive relationship between a student's understanding of the nature of science and their acceptance of evolution (Carter & Wiles, 2014; Cavallo et. al, 2011; Rutledge & Warden, 2000; Scharmann, Smith, James, & Jensen, 2005). These studies suggest that instructing on the nature of science can help instructors be more culturally

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competent in their evolution instruction.

   Outline a spectrum of viewpoints on religion and evolution. College evolution instructors can reduce students' perceived conflict between evolution and religion by helping students become aware that there is a spectrum of viewpoints on the relationship between evolution and religion. Due to the polarizing viewpoints often presented, many students are unaware that there are more viewpoints than just atheistic evolution and special creationism[6]. Past research illustrates that by acknowledging and describing other viewpoints, instructors can help students decrease their perceived conflict with evolution (Barnes et al., 2017) and potentially find a way to allow their religious beliefs to co-exist with evolution (e.g. theistic evolution (Miller, 2002)). A study where instructors taught students about different ways that people have chosen to interpret the Bible found that it increased students' acceptance of evolution (Martin-Hansen, 2006). Specifically, they told students that if they did not interpret certain parts of the Bible literally, as many religious leaders and scientists have chosen not to, then they did not have to reject evolution. This research highlights how discussing multiple viewpoints can help students reconcile their religious beliefs with evolution.

   Provide Students with Religious Role Models Who Accept Evolution. Evolution

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[6] Atheistic evolution refers to the belief that life on earth evolved from a common ancestor and there was no involvement of a God/god(s) in the process of evolution. Special creationism refers to the belief that species were created in their current form by a God/god(s). There are many more viewpoints on the relationship between evolution and religion that fall in between special creationism and evolution, but theistic evolution is the only one, from a philosophy of science perspective, that can be reconciled with the scientific evidence for evolution. There are some biologists, however, who do not believe theistic evolution is compatible with evolution. Theistic evolution refers to the belief that life on earth evolved from a common ancestor and that a God/god(s) planned, influenced, or guided the evolutionary process. For a more exhaustive review of positions on religion and evolution see Yasri & Mancy, 2016. Further, for a relevant review of viewpoints on the relationship between science and religion broadly, see Barbour, 1990.

instructors can also reduce perceived conflict between evolution and religion by helping students become aware of role models who are religious and accept evolution. Many students come into our classrooms with the misconception that one must either be an atheist who accepts evolution, or a person of faith who rejects evolution (Barnes et. al, 2017). Although secular instructors cannot present themselves as religious role models, they can offer examples of other scientists who are religious and accept evolution or religious leaders who accept evolution. For instance, Winslow et al., 2011 interviewed students who changed from believing special creationism to accepting evolution by the end of their biology degree and asked them what the most important factor was in their decision to change. These students said one of the most important factors was positive role models in the form of their religious professors who accepted evolution. In a study done with high school students, researchers showed an increase in acceptance of evolution as measured by the MATE after they attended a seminar series in which the hosts described several individuals who represented a diversity of religious denominations and were also accepting of evolution (Wiles and Alters, 2011) Additionally, in a study out of our research group, we reduced the number of introductory biology students who saw a conflict between evolution and religion by half when we had a Catholic biologist discuss his acceptance of evolution and his Catholic faith. Notably, one-third of our students specifically mentioned that they appreciated the perspective of the religious biologist visitor during the evolution instruction (Barnes et. al, 2017).

     Highlight the potential compatibility between evolution and religion. Embedded in all the previous sections is the idea that instructors can reduce perceived conflict between evolution and religion by explicitly showing students examples of how evolution

and religion can be compatible. One of the best ways to decrease this conflict between evolution and religion is to be explicit about the potential compatibility between evolution and religion and to address the false dichotomy between evolution and religion (Martin-Hansen, 2006; Robbins & Roy, 2007; Scharmann & Butler Jr, 2015; Wiles & Alters, 2011). In fact, beyond empirical studies, highlighting potential compatibility is cited across the literature in numerous essays and critical reviews as a recommended practice in evolution education (Astley & Francis, 2010; Cobern, 2004; Cobern, 1994, 1994; Glaze & Goldston, 2015; Scott, 2014; Smith, Siegel, & McInerney, 1995; Southerland & Scharmann, 2013).

Table II: ReCCEE practices and citations supporting them.

ReCCEE practice	Description	Empirical Support
Acknowledge	Acknowledge that some students may see a conflict between evolution and their religious beliefs.	Brickhouse et al., 2000; Dagher & BouJaoude, 1997; Donnelly et al., 2008; Jackson et al., 1995
Explore	Discuss and encourage the exploration of students' personal views on evolution and religion.	Ingram & Nelson, 2006; Manwaring et al., 2015; Scharmann, 1993, 1994; Scharmann & Butler Jr, 2015; Wiles & Alters, 2011; Winslow et al., 2011
Teach the Nature of Science	Describe to students the bounded nature of science and different ways of knowing.	Carter & Wiles, 2014; Cavallo et al., 2011; Ingram & Nelson, 2006; Ladine, 2009; Martin-Hansen, 2006; Nehm & Schonfeld, 2007; Rutledge & Warden, 2000; Scharmann et al., 2005
Outline the Spectrum of	Describe that there is a diversity of viewpoints on evolution and religion and that	Barnes et al., 2017; Donnelly et al., 2008;

Viewpoints	viewpoints are not restricted to atheistic evolution and special creationism. Discuss the possibility of theistic evolution.	Ingram & Nelson, 2006; Martin-Hansen, 2006; Verhey, 2005; Wiles & Alters, 2011
Provide Role Models	Highlight religious leaders and biologists who accept evolution.	Barnes, Elser, et al., 2017; Winslow et al., 2011
Highlight Potential Compatibility	Explicitly discuss the potential compatibility between evolution and religion.	Martin-Hansen, 2006; Robbins & Roy, 2007; Scharmann & Butler, 2015; Wiles & Alters, 2011

Why an inclusive teaching environment could matter in evolution education.

While the ReCCEE practices described above are specific to the perceived conflict between evolution and religion, the foundation of a culturally competent teaching approach is to create an inclusive teaching environment for all students in any setting. If an instructor has an inclusive teaching philosophy, then an instructor should be trying to effectively teach all their students regardless of the differences between their students and themselves. The instructor should make every effort to create a safe and welcoming teaching environment for all students - regardless of gender, race/ethnicity, disAbility status, LGBTQIA status, or religion. Students with certain social identities that could be perceived as stigmatized in the biology community may not feel as though their identity is welcome in the biology community (Cooper and Brownell 2016; Barnes, Truong, and Brownell 2017). One way to help this would be for instructors to become aware of the social identities of students in their class and then identify ways to help make those students feel more represented and included in the larger discipline of biology (Schinske, Perkins, Snyder, and Wyer, 2016). Perhaps the most important shift in mindset for instructors teaching evolution to religious students is to conceptualize religious beliefs as a social identity of students that is unlikely to change over the course of a semester in

response to evolution instruction. Since religious students may come into the classroom with the pre-conception that evolution and religion must be in conflict, they will likely feel more included and respected in the evolution learning environment if this perceived conflict is addressed.

Another factor that makes using cultural competence important when teaching evolution is that religious beliefs are correlated with race/ethnicity. African American students are on average more religious than their peers and also tend to have higher rejection rates of evolution (Mead, Clarke, Forcino, & Graves, 2015; Taylor, Chatters, & Levin, 2003). In fact, preliminary research is suggesting that the higher rates of religiosity among African Americans, and potentially their higher rates of rejection of evolution, could contribute to the underrepresentation of African Americans in biology, as indicated by the fact that almost no PhDs are awarded to African Americans in evolutionary biology (Mead et al., 2015; National Science Foundation, National Center for Science and Engineering Statistics, 2011). We may be disproportionately disadvantaging African American students if we continue to teach evolution in ways that lack religious cultural competence.

Thus, culturally competent evolution instruction has implications beyond decreasing students' perceived conflict between evolution and religion or increasing their acceptance of evolution. Culturally competent evolution instruction may be able to help the upwards of 50% of religious students in public institutions feel more comfortable and included in their biology classes, which could contribute to their retention in biology and pursuit of scientific careers. Ultimately, this can be a way to diversify who persists in science. Even if an instructor does not perceive that it is their responsibility to teach

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acceptance of evolution to students, culturally competent evolution education could help instructors reach their goal of inclusive teaching.

While culturally competent evolution education would be primarily directed towards religious students, it could also have positive impacts on non-religious students. We have found that culturally competent evolution education can reduce perceived conflict between evolution and religion for non-religious students in addition to religious students (Barnes, Elser, & Brownell, 2017). In an introductory biology class for majors, we found evidence that culturally competent evolution education may have reduced non-religious students' negative stereotypes about religious people in biology (e.g. religious individuals cannot do credible science, an individual cannot be both a biologist and religious). Thus, culturally competent evolution education could encourage non-religious individuals who end up as evolution instructors to teach in more culturally competent ways, creating a positive feedback cycle of cultural competence.

Additional Resources to help promote culturally competent evolution instruction. To help instructors become more culturally competent in their evolution instruction, we have compiled a set of available resources. Table III provides examples of simple ReCCEE exercises that instructors can use in their classes that require only a minimal time commitment. An additional relevant resource is The Smithsonian Institute and The National Academy of Sciences (NAS) "Cultural and Religious Sensitivity (CRS) Teaching Strategies Resource" booklet (Smithsonian Institute, 2015): http://humanorigins.si.edu/education/teaching-evolution-through-human-examples. This booklet provides useful examples of in class activities for high school instructors to use while teaching evolution to create a comfortable and supportive classroom environment.

Even though the audience is for high school instructors, college instructors interested in teaching in an inclusive way could also benefit from this resource. For additional in-class activities for teaching the nature of science that are culturally competent, instructors can refer to Chapter 6 of the NAS resource "Teaching about Evolution and the Nature of Science" (NAS, 1998), which is freely downloadable on the National Academies Press website: https://www.nap.edu/catalog/5787/teaching-about-evolution-and-the-nature-of-science. The NAS has also published the resource "Science, Evolution, and Creationism" (NAS, 2008) (freely downloadable on the National Academies Press website: https://www.nap.edu/catalog/11876/science-evolution-and-creationism) which gives a basic overview of the nature of science related to religion, the spectrum of creationist viewpoints on evolution, and several examples of how individuals have reconciled their religious faith with evolution. Science, Evolution, and Creationism can serve as an overview for instructors who are not used to thinking about religious beliefs when teaching evolution and are apprehensive about their knowledge of ideas surrounding the relationship between religion and evolution. Finally, if instructors are interested in exploring the potential experiences that their Christian students may have learning evolution and how those students might reconcile their religious beliefs and evolution, "The Evolution Dialogues: Science, Christianity, and the Quest for Understanding" (Baker & Miller, 2006) is a useful resource published by The American Association for the Advancement of Science (AAAS) and their program on the Dialogue of Science, Ethics, and Religion (DoSER): https://www.aaas.org/page/doser-books. This book is an overview of issues related to Christianity and evolution interspersed with a narrative about a Christian biology student who is struggling with learning about

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evolution. Even though these resources do not refer specifically to cultural competence,

using one or all of these existing resources would be an excellent start to becoming a

more culturally competent evolution instructor.

Table III: Examples of ReCCEE activities that could be implemented when teaching

evolution.

Activity	Description	ReCCEE practice
Surveys	Survey your students on their beliefs about religion and evolution so you know your audience and can acknowledge them. Are they religious? Which denomination of religion do they identify with? Do they see a conflict between their religious beliefs and evolution? Do they accept evolution? Then acknowledge the different views that students have in class while keeping specific student beliefs confidential.	Acknowledge, Explore
Journals	Have students journal during their evolution instruction to encourage them to reflect on their stances. Possible prompts include: In your view, do you see a conflict between your personal beliefs and evolution? Have your views on the relationship between religion and evolution changed? Why or why not?	Explore
Reading	Have students read biographies from scientists who are religious and accept evolution. It is best to make sure students read biographies from a variety of scientists from different religious denominations so that many students can see their identity reflected in at least one scientist. To make sure you are representative of all students in the class, including those without religious beliefs, also include secular scientists who accept evolution.	Provide role models who accept evolution, Highlight potential compatibility
Instructor Presentation	Show the official stances of different religious denominations on evolution. For instance, the Catholic church officially supports evolution while the Mormon church is silent with respect to evolution. It is best to know which religious denominations your students identify with to tailor the denominations you present to be relevant to most of your students.	Outline spectrum of views. Highlight potential compatibility
Group work	Make a list of questions such as "Does God exist?", "How old is life on Earth?", "Did God create humankind?", "Do human's share a common ancestor with Chimpanzees?" and have students categorize and	Teach the nature of science

	discuss which questions are subject to scientific analysis, which are not, and why.	
Instructor Presentation	Show different positions on the relationship between religion and evolution including special creationism, theistic evolution, agnostic evolution, and atheistic evolution. Distinguish which of these positions is philosophically compatible with the evidence from science and which are not.	Outline the spectrum of views, Teach the nature of Science, Highlight potential compatibility
Guest visitors	Have religious scientists visit the class and facilitate discussion with the scientist and students about how s/he reconciles religious beliefs and evolution	Provide role models, Highlight potential compatibility

Extending cultural competence to communication about evolution more

broadly. Our essay is primarily focused on the use of ReCCEE among college evolution instructors, but this framework has broader implications for evolution communication to the public. Since most public communicators of science hold similar religious cultures and religious beliefs as college instructors, we propose that they would also benefit from using culturally competent communication about evolution. In fact, some of the most well-known contemporary science communicators are infamous for their anti-religious stances and often propagate negative stereotypes about religion and religious individuals while they are communicating with the public in videos, books, news articles, and public appearances. Although these scientists may see this strategy as aligning with a goal of decreasing the prevalence of religious beliefs within the Unites States, the evolution education literature suggests that by insisting that evolution and religious beliefs are fundamentally and necessarily conflictual that these scientists, at best, are leaving acceptance of evolution rates stagnant, and at worst, may even be creating more negative attitudes towards evolution. For this reason, we encourage the use of cultural competence and ReCCEE methods for both college evolution instructors and public communicators of evolution more broadly.

Conclusion

We encourage instructors to consider the use of the Religious Cultural Competence in Evolution Education (ReCCEE) framework in the teaching of evolution at the college level. Instead of trying to change the religious beliefs of either instructors or students, we hope to bridge these gaps between secular and religious cultures when teaching evolution in hopes of increasing student acceptance of evolution, decreasing perceived conflict between evolution and religion, and increasing inclusivity in biology classes.

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CHAPTER 7

CONCLUSION AND FUTURE DIRECTIONS

The National Academy of Sciences (NAS, 1998, 2008) and the Smithsonian Institution (Smithsonian Institute, 2015), in addition to over 61 peer-reviewed publications, have recommended instructional practices in evolution education that could be considered ReCCEE practices (Barnes & Brownell, 2017). However, studies that explore the efficacy of ReCCEE practices have four major limitations that need to be addressed before cultural competence should be further recommended as an evidence-based framework for evolution education: (1) researchers use different measurement tools, which make results incomparable across studies, (2) researchers study different types of ReCCEE practices, often in combination with one another, which makes it difficult to discern which specific ReCCEE practices are important for student outcomes, (3) almost all studies lack pre-post designs and/or comparison groups that did not receive ReCCEE practices, which makes it impossible to disentangle the specific effect of ReCCEE practices from the evolution instruction broadly, and (4) no studies collect data from a variety of contexts to demonstrate that the efficacy of ReCCEE practices is generalizable in different course contexts (e.g., majors vs. non-majors), in different types of institutions (e.g. religious vs. secular), or for different instructors. Future research should address these gaps in the literature and systematically test ReCCEE practices that have been widely recommended by (1) creating standardized instruments to measure ReCCEE practices and their potential outcomes for students and (2) using these instruments to explore the efficacy of the current ReCCEE practices being used by instructors nationwide.

Despite the theoretical and preliminary support for ReCCEE practices, published

studies lack the experimental designs needed to provide sufficient evidence that these

practices are effective. In a literature review conducted, among the 61 papers identified as

prescribjng ReCCEE practices, surprisingly 41 of them provide no data to support the

efficacy of these practices. For instance, some studies examined acceptance of evolution

and religiosity and discovered there is a negative relationship between the two (Deniz &

Sahin, 2016; Glaze, Goldston, & Dantzler, 2014). The researchers then assume, based on

the negative relationship between religiosity and acceptance of evolution, that ReCCEE

practices will help students bridge their religious beliefs with evolution and therefore

increase acceptance of evolution, but they do not provide empirical data to support this

claim (Deniz & Sahin, 2016; Glaze et al., 2014). Other papers are qualitative in nature

and use interviews with students and teachers to gather data about their perceptions of

evolution (Borgerding, Deniz, & Anderson, 2017; Dagher & Boujaoude, 2005; Hokayem

& BouJaoude, 2008). These studies often find that there are concerns about the

compatibility of religious beliefs with evolution, and based on these concerns, the

researchers prescribe ReCCEE practices to increase acceptance of evolution. While these

studies are useful for generating hypotheses about potentially effective instruction, they

do not directly tell us about the efficacy of these practices: we need studies to test their

impact.

In a review of the literature, 19 studies were identified that collected data directly

related to the impact of ReCCEE practices, but 9 of these relied on only post-instruction

data, meaning that data were only collected from students after they had already learned

evolution and asked how their instruction influenced them (Brickhouse, Dagher, Letts IV, & Shipman, 2000; Dagher & BouJaoude, 1997; Verhey, 2005).

Often students were asked to reflect on multiple courses or an entire undergraduate experience, rather than exploring specific instructional contexts (Donnelly, Kazempour, & Amirshokoohi, 2008; Ladine, 2009; Winslow, Staver, & Scharmann, 2011). This means that researchers are relying on the students not only to remember what their views were before they learned evolution, but also to accurately report how instruction changed their views over time. Attribution bias in psychology has long determined that people are not accurate at determining the specific causes of their decisions and behaviors (Nisbett & Ross, 1980), so these self-reports are likely unreliable. The other 10 studies measured gains in student outcomes pre-post instruction, but nine out of 10 studies lacked a comparison group of students that did not receive ReCCEE practices (Barnes, Elser, & Brownell, 2017; Ingram & Nelson, 2006; Martin-Hansen, 2006; Nehm & Schonfeld, 2007; Robbins & Roy, 2007; Scharmann & Butler Jr, 2015; Scharmann & Harris, 1992; Wiles & Alters, 2011). Without a comparison group that did not receive ReCCEE practices, we cannot know whether it was the ReCCEE practices or some other aspect of the instruction that led to positive student outcomes.

Thus, we only have one study at one institution that shows a positive impact of ReCCEE practices on student acceptance of evolution using comparison groups and a pre-post design (Manwaring, Jensen, Gill, & Bybee, 2015). However, even this one study was conducted in a very narrow context, at a LDS institution in which one group of students learning evolution was taught that the official stance of the Mormon Church on evolution was neutral, highlighting that evolution did not necessarily have to conflict

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with the students' religious beliefs. The overall lack of robust evidence indicates that the broad recommendations for ReCCEE practices are premature. Institutional, course-level, instructor-level, and student-level characteristics may be influencing the effectiveness of ReCCEE practices in ways that are more nuanced than current recommendations acknowledge. Further, due to the lack of comparison groups in the current literature, the positive results reported in these studies may not even be due to the ReCCEE practices they are reporting, but other characteristics of the instruction that are not reported.

Another limitation of the current literature is that different researchers use different instruments to measure student acceptance of evolution. A literature review of hundreds of studies that have measured acceptance of evolution found ~70 different instruments that have been previously used, many of which were self-made by researchers for their single study and they did not take steps to validate their instrument. Evolution education researchers have long been aware of this issue and have cited it as a major limitation of the field (Smith, 2009, 2010). So, in addition to the lack of comparison groups within the same study, it is almost impossible to directly compare studies from different researchers and make generalizations.

Thus, this review of the literature has identified key methodological issues that need to be addressed before researchers can continue to make widespread recommendations about the use of ReCCEE practices and before instructors spend unnecessary energy and instructional time using ReCCEE practices: (1) standard ways to measure the use of ReCCEE practices, (2) standard ways of measuring the impact of ReCCEE practices on potential student outcomes, (3) studies that test ReCCEE practices across different contexts, with a large sample of students, to determine generalizability in

the efficacy of ReCCEE practices and (4) studies that use a pre-post survey design with comparison groups to determine whether ReCCEE practices are actually effective, separate from instruction without ReCCEE practices.

Next steps: filling the gap with rigorous evaluation of ReCCEE practices in evolution education.

The next project I conduct will aim to push the field of evolution education past the exploration stage and provide more generalizable and rigorous evidence-based recommendations for how to increase acceptance of evolution, decrease students' perceived conflict between religion and evolution, and transform evolution education environments to be more comfortable and inclusive for those who may struggle the most when learning evolution. First, I will create standardized measurement tools for both the use of ReCCEE practices and their potential student outcomes. Then, these measurement tools will be implemented in a pre-post instruction quasi-experimental design, which included sampling of existing classes where some instructors are already using ReCCEE practices while teaching evolution and other instructors are not. Surveys pre-post instruction, with this natural variation in instructor use of ReCCEE practices, can show in which classes, using which ReCCEE practices, we see significant positive student outcomes. Further, it can be determined whether these outcomes differ between different types of instructors, students, and institutional/course characteristics. By using a pre-post quasi-experimental design, more specific and evidence-based recommendations can be made for evolution education. [the repeated passive is deadly; it's easy to fix if you try]

Conclusion

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Twenty years ago, low acceptance rates of evolution among students and the public was regarded as one of the biggest failures of science education in the United States (Christensen, 1998). To this day, despite over 300 articles published exploring acceptance of evolution, we have seen very little change in these low acceptance rates (Gallup, 2014, 2017). This research using cultural competence as a framework for evolution education has the potential to lead to greater acceptance of evolution among our students, which hopefully will translate to greater acceptance of evolution among the general population. By increasing acceptance of evolution, students and the public alike will be more likely to be engaged with learning evolution and incorporate evolution into their scientific thinking.

By reducing perceived conflict and creating more inclusive evolution learning environments, we may be able to help the large percentage of religious undergraduates feel more comfortable and included in their biology classes, which could contribute to their retention in biology and pursuit of scientific careers. Given that a recent national survey of undergraduate students learning evolution revealed that upwards of half of students learning evolution in undergraduate biology classes report that they are religious (Glaze, 2017), this research has the potential to impact a significant proportion of students who are learning evolution. Even if an instructor does not perceive that it is their responsibility to teach acceptance of evolution to students, instruction that reduces perceived conflict between religion and evolution and creates more inclusive evolution learning environments could help instructors reach their goal of inclusive teaching.

While culturally competent evolution education would be primarily directed towards religious students, it could also have positive impacts on non-religious students. I

have found that culturally competent evolution education can reduce non-religious students' negative stereotypes about religious people in biology (e.g. religious individuals cannot do credible science, an individual cannot be both a biologist and religious) (Barnes et al., 2017). Thus, culturally competent evolution education could encourage non-religious individuals, who may become instructors, to teach in more culturally competent ways, creating a feedback cycle of cultural competence, which could have a cascading positive impact on increasing acceptance of evolution. Perhaps by using cultural competence as a framework for evolution education, we may finally see thirty years of stagnant rates of acceptance of evolution start to rise.

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APPENDIX A

PERMISSION TO USE PUBLISHED WORKS

All co-authors of published articles have granted their permission to have the articles

included as part of this dissertation.

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