

Impact of a Short Evolution Module on Students' Perceived Conflict between Religion and Evolution

M. ELIZABETH BARNES, JAMES ELSE,
SARA E. 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.

Key Words: evolution; attitudes; religion; acceptance of evolution; curriculum.

○ 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),

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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 Magisteria (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, "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 affect how some religious students 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 (Barnes et al., in press). A lower sense of belonging can influence student retention in biology (Good et al., 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 whether 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 or appreciated discussions of religion in the module to determine whether these discussions were appropriate.

We also measured student religiosity to determine if the module had differential effects on religious and nonreligious 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 percent of the Catholic population still rejects evolution (Pew, 2009). Further, although the LDS Church has a neutral stance on evolution, 72 percent 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.

All questions on our assessment instrument that are reported in this manuscript are listed in Table 1.

○ Course Characteristics

The study took place in an introductory biology course for majors 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 et al., 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 that students would explore for homework, instruction on how to complete in-class learning activities, and then the majority of the time was spent on student-centered group

Table 1. Content of survey questions. All research was reviewed and approved by Arizona State University's Institutional Review Board, protocol #00001453.

Student Views on the Relationship between Religion and Evolution*
In a few sentences, briefly describe your views on the relationship between religion and evolutionary theory.
Student Discomfort with Discussions about Religion and Evolution**
Looking back at the evolution module, did anything in the lectures, videos, discussion boards, readings, or discussions with visitors about religion make you uncomfortable? If yes, please explain.
Student Demonstrated Appreciation of Discussions about Religion and Evolution**
Looking back at the evolution module—including visitors, lectures, discussion boards, and readings—was there anything that was presented about religion and evolution that you appreciated? If yes, please explain.
Student Religiosity*
Rate each of the following eight questions on a 5-point scale from strongly disagree (1) to strongly agree (5):
• My personal religious beliefs are very important to me.
• My religion or faith is an important part of my identity.
• If someone wanted to understand who I am as a person, my religion or faith would be very important in that.
• I attend religious services regularly.
• I practice the requirements of my religion or faith.
• I believe in God.
• I consider myself a religious person.
• I consider myself a spiritual person.

*Questions were asked both pre- and post-evolution module.

**Questions were asked post-evolution module.

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 2.

Guest Scientists

The students met with two guest scientists during the module. The first guest was a biologist who is 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 videoconferenced 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 videoconferenced 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 and to showcase that current researchers are working on evolutionary problems.

Table 2. 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 and diversification can account for the hierarchy of shared characteristics (including homologous traits, vestigial traits).
Students can describe Darwin's concept 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 and 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 and 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 the scientific status of evolution within biology.
Students can recognize the relevance of constitutional limits regarding public school instruction about creationism.

Readings and Videos

Students were required to read a chapter on natural selection and a chapter on speciation from their textbook *Biological Science* (Freeman et al., 2013). Students were also assigned to read a handbook from the 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 ideas 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, whereas 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 was bounded to address questions of only 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 had 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 this open-ended prompt: “In a few sentences, briefly describe your views on the relationship between religion and evolutionary theory.” (Table 1).

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 (Table 1).

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 (Table 1).

We used content analysis by classifying student answers as “something appreciated” or “nothing particularly appreciated” and determined the frequency of students in each category. To determine what students appreciated about the module, we used grounded theory to further classify the 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).

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 percent 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, and 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 percent of students on the pre-module survey stated that they perceived that religion and evolution are in conflict with one another, whereas only 26 percent of students on the post-module survey stated that they perceived evolution and religion to be in conflict (Figure 1). This indicates that the evolution module

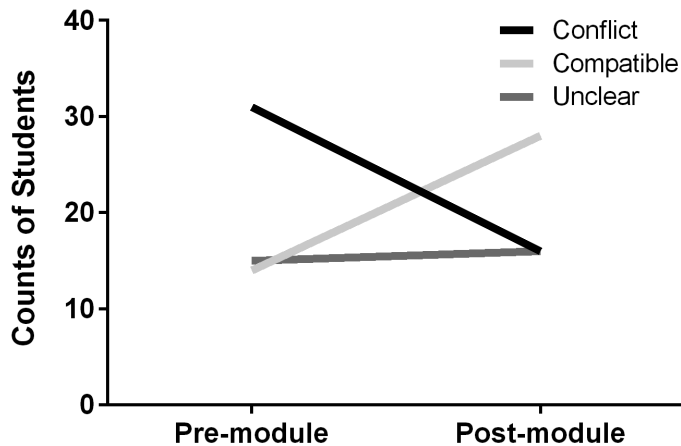


Figure 1. The number of students who had a perception of conflict or compatibility between religion and evolution pre- to post-evolution module. “Unclear” means the student’s answer could not be unambiguously characterized as whether they perceived religion and evolution to be in conflict or compatible.

Table 3. Summary of changes in students’ perceptions of the relationship between evolution and religion over a two-week evolution module. Percentages of individuals in each category are presented. Not all categories will add up to 100% due to rounding.

Change in Perception of Religion and Evolution	Religious Students	Nonreligious 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	Nonreligious Students	All students
Conflict to Conflict	28%	26%	27%
Compatibility to Compatibility	16%	14%	15%
Unclear to Unclear	16%	9%	12%

reduced the number of students who perceived a conflict between evolution and religion by half.

Of the 32 students who perceived conflict on the pre-module survey, 11 (32%) 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 provided responses on the post-module survey that indicated evolution and religion are compatible. Notably, no students who started with the perception that evolution and religion are compatible, ended with the perception that they are in conflict. Further, no students who started with an unclear perception, ended with a perception that they are in conflict (Table 3).

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 0 for nonreligious if they scored in the lower half of the religiosity scale (Green & Salkind, 2010). We then looked at the composition of religious/nonreligious students whose perceptions changed over the semester. Both religious and non-religious students’ responses indicated that their perception had changed (Table 3).

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, nonreligious 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, nonreligious 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, nonreligious 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 nonreligious and religious students shared an appreciation of the content on religion and evolution. Twenty-five out of the 35 students (71%) who were classified as nonreligious 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 examples of 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, nonreligious student:

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

Natalie, nonreligious 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 affected not only religious student perceptions of the relationship between religion and evolution but also the perceptions of nonreligious 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, nonreligious student:

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

Jason, nonreligious 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 ($t = 0.584$, $p = 0.561$, $df = 58$). 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 nonreligious

students' perceptions shifted to compatibility. Although this was an unexpected finding, we see several possible advantages that stem from changing nonreligious student views and can serve as a fruitful area for future research.

First, all of our students in biology classes, both religious and nonreligious, are potential future communicators of science (Brownell et al., 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 nonreligious students.

Second, even if our nonreligious students do not become teachers, they may have discussions about evolution and religion with others around them. By talking to their friends and families, some of whom may be religious, about how evolution and religion can be compatible, nonreligious students may positively affect 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, helping nonreligious students challenge their own negative stereotypes about religious individuals in biology could possibly ameliorate a lack of religious diversity in biology. Although 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 nonreligious individuals, which may cause Christian students to identify less with science (Rios et al., 2015). Nonreligious students who accept this stereotype and believe that religion and evolution are incompatible may inadvertently make their religious peers feel like they do not belong in biology. However, if nonreligious 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, 2016) 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 devout Catholic, and he has written a book on the reconciliation of his religious beliefs and evolution called *Finding Darwin's God* (2002). Further, Francis Collins, the director of The National Institute of Health, has also published a book, *The Language of God* (2006), on his reconciliation of evangelical Christianity and evolution. Both of these individuals would be excellent examples of scientists who were able to reconcile their religious beliefs with evolution, whom instructors could discuss with 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, 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 nonreligious 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 discussing the potential 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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M. Elizabeth Barnes (liz.barnes@asu.edu), Sara E. Brownell (sara.brownell@asu.edu), and James Elser (j.elser@asu.edu) are at the Center for Biology and Society, Arizona State University, Tempe, AZ 85287, USA.