Evolution: Education and Outreach

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Acknowledging students' concerns about evolution: a proactive teaching strategy

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Abstract

Background: The religious or cultural objections by many people to the teaching of evolution in high school biology classrooms can impact both students' willingness to explore a scientific understanding of evolutionary theory and teachers' willingness to provide sound instruction on the topic. Pedagogical approaches designed to address this tension in the public or private US high school classroom during regular biology classroom instruction on evolution are needed. We developed a Cultural and Religious Sensitivity (CRS) Teaching Strategies Resource to aid teachers in acknowledging students' religious and cultural concerns about evolution, introducing the variety of possible relationships between science and religion, and focusing on the nature of science. The resource provides both background information for the teacher and activities to engage students in two 50–75 min directed classroom discussions. The CRS resource is part of a designed-based study, the Teaching Evolution through Human Examples (TEtHE) project that created and field tested four curriculum units for advanced placement high school biology classes that use human examples to teach evolution (Pobiner et al. Evol Educ Outreach. 2018;11:3 2018). Here we describe the design of the CRS resource and qualitative results of student focus groups that explore the extent to which the CRS resource activities helped to create a supportive classroom environment as well as more generally what benefits, if any, students derived from participating in these activities.

Results: Focus groups were conducted with students from five classes of four different teachers in both public and private US high schools. Focus group transcripts were analyzed to identify common themes expressed in relation to the students' experience of one of the two CRS activities. Benefits of participating in these activities noted by students included reduced tension around the topic of evolution, a recognition that evolution is not necessarily in conflict with religious belief, and an increased understanding of the cultural context of modern and historical views about evolution.

Conclusions: The themes identified through qualitative analyses of focus group transcripts support the conclusion that acknowledging students' concerns about evolution is a promising pedagogical approach to teaching evolution in conjunction with lessons designed to teach the content of evolutionary theory. The approach merits further research with general introductory high school biology classes.

Keywords: Evolution education, Evolution understanding, Acknowledging cultural controversy, Evolution and religion, High school biology students, Student focus groups

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Background

Although there is constant debate, refinement, and even occasional controversy among scientists about the details of evolution, there is no scientific controversy over whether evolution occurred in the past and continues today. There are, however, cultural objections by many in the United States to the teaching of evolution. These objections are largely defined by perceived conflict with religious belief, an important component of an individual's cultural identity. Religious objections, and the resulting controversies surrounding them, can impact both students' and high school teachers' willingness to engage with the subject of evolution (e.g. Berkman and Plutzer 2012; Goldston and Kyzer 2009; Griffith and Brem 2004; Meadows et al. 2000; Rutledge and Warden 2000). This outcome is a considerable disservice to students' understanding of both the nature of science, because they are left with the impression that science negatively targets religious beliefs, and the understanding and acceptance of evolutionary theory.

In the US, where the cultural milieu favors free speech and democratic processes, even those accepting of evolution may raise issues of fairness and support a call to "teach the controversy"(Scott 2004; Berkman and Plutzer 2012). Furthermore, the negative emotional and social connotations perceived to be associated with evolutionary theory, including increasing selfishness and racism (Brem et al. 2003), may be detrimental to the acceptance of evolution in some communities.

Cultural objections are not the only obstacles impacting the teaching and learning of evolution. Others include common misconceptions, cognitive challenges, and ambiguous language (for reviews see Pobiner 2016 and Glaze and Goldston 2015). However, real or perceived conflict between evolutionary theory and a religious worldview is a well-documented barrier to accepting evolution among both teachers and students (Borgerding et al. 2017; Glaze et al. 2015; Hermann 2011; Winslow et al. 2011; Smith 2010; Hokayem and BouJaoude 2008; Trani 2004; Rutledge and Mitchell 2002) and the public at large in the United States and globally (Heddy and Nadelson 2012, 2013). Religiosity, as a measurable variable, is often defined as the extent to which people state that religion is very important in their lives, or the frequency with which they attend weekly religious services. Among First World countries, the US public is both one of the most religious and one of the most resistant to accepting evolution (Coyne 2012). The religiosity of US college students has been shown to be negatively correlated with their understanding of evolution (Hawley et al. 2011) and is a stronger predictor of evolution understanding than the evolution content of their high school biology course (Rissler et al. 2014; Moore et al. 2011). That students with deeply held religious beliefs may fail to understand or accept evolutionary theory is reflective of a broader US cultural context.

The relationship between a students' understanding of evolution and acceptance of evolution is nuanced, with some studies finding a positive correlation between the two (Lawson and Worsnop 1992; Scharmann et al. 2005; Shtulman and Calabi 2012; Hawley et al. 2011) and some finding no significant correlation (Sinatra et al. 2003; Ingram and Nelson 2006). While science education researchers and biology teachers may disagree on whether or not acceptance of evolutionary theory is an appropriate goal of biology instruction (Glaze 2017; Barnes and Brownell 2016; Reiss 2009; Meadows 2009; Ingram and Nelson 2006), the biology classroom should provide students with an opportunity to understand evolutionary theory as the scientific community does: the best scientific explanation for the diversity and interrelatedness of species. Students may choose not to accept evolution, but to be scientifically literate, they should understand how and why scientists consider it a core unifying theme of biology. To that end, at minimum, teachers must be willing to teach the topic and students willing to try and understand the material. That said, the reality for both teachers and students may be that they are being asked to engage a topic that conflicts with their worldview. Simply stated, a "worldview provides a person with presuppositions about what the world is really like and what constitutes valid and important knowledge about the world" (Cobern 1996). For many people their religious worldview is a significant component of their social identity. People are unlikely to embrace a topic that is seen as likely to threaten significant social connections and relationships (Kahan 2010).

The importance of social connections and relationships to determining students' attitudes about evolution has been well documented. Woods and Scharmann (2001) interviewed high school students to investigate what factors influenced their attitudes about evolution. They reported that after religious factors, the most cited factor was personal relationships. Students derive their knowledge of evolution not only from teachers and other authority figures at school, but also from religion, family, peers and the media (Donnelly and Akerson 2008; Moore et al. 2011; Bramschreiber 2013). Bloom and Weisberg (2007) claim that the primary source of student's resistance to evolution instruction is related to what they know before their exposure to science in elementary school. Winslow et al. (2011) found that if biology-related majors at a Christian university reported that their family had negative attitudes toward evolution, they were more likely to reject it entirely without further consideration. In one study, a high school teacher noted that

for their students, evolution is not discussed at home and is "taboo" to mention at church (Hermann 2013). Bramschreiber (2013) notes that in areas of fundamentalist evangelicalism, students are taught from an early age to reject evolution and be suspicious of anyone who tries to teach it. Glaze and Goldston (2015) also reported that if preservice teachers in the southeastern US had been exposed to negative perceptions of evolution by family members, members of the clergy, or at Sunday school, they were more likely to reject evolution. Long (2011), in his study of how students at one southern university interacted with the topic of evolution, highlighted the social costs for students learning about evolution and possibly reframing their religious worldview. He emphasized that there is an important social dimension to the resistance to learn about evolution.

That students may be resistant to learning about evolution because they feel it is in conflict with their religious worldview, and the religious worldview held by those in their social network, is frustrating not only for many scientists and science educators, but also for many religious leaders and clergy whose traditions see no conflict between evolutionary theory and their religious worldview, and/or who are supportive of the teaching of evolution in high school science classrooms (Zimmerman 2010; Colburn and Henriques 2006). The most vocal opposition to the teaching of evolutionary theory in the United States has been from adherents of Christian religious worldviews. Using publicly available statements by Christian organizations and denominations in the US about the relationship between their religious tradition and science, or evolution, Martin (2010) suggests that most US Christians should view evolution as compatible with their religious tradition. However he notes several caveats, including that not all groups have official statements and that many members may not be aware of, or agree with, the official statements. Christian clergy from largely mainline denominations may well be frustrated by the recognition that there is a gap between their scholarly interpretation of their religion's tradition and the interpretation of the members of their congregations, some of whom mistakenly believe their religion does not accept evolution. The Pew Forum on Religion and Public Life (2013) reports that 26% of White and 31% of Hispanic Roman Catholics believe "humans and other living things have existed in their present form since the beginning of time." While the conflict between religious worldview and acceptance of evolution may be a "perceived" conflict for some individuals, for those who adopt a fundamentalist interpretation of Scripture, including many evangelical Protestants, the conflict between their religious worldview and evolutionary theory is very real. Evangelical Protestants, those who belong to churches in the evangelical Protestant tradition, or nondenominational congregations, comprise about 25% of Americans (The Pew Forum on Religion and Public Life 2015). Of all the major religious groups in the US, evangelical Protestants are most likely to reject evolution at 64% (Pew Forum on Religion and Public Life 2013).

Pedagogical approaches that increase students' willingness to engage in learning about evolution, particularly in cultural environments where opposition to evolutionary theory is prevalent, are needed. A survey of high school biology teachers in the US revealed that in order to avoid controversy in the classroom over the teaching of evolution, 60% of teachers relied on techniques that do a disservice to students' understanding of evolutionary theory (Berkman and Plutzer 2012). These techniques include focusing solely on microevolution, communicating to students that they must learn the material only because a state mandated test requires it rather than helping students understand that evolution is central to biology, and introducing creation accounts alongside evolutionary theory (implying that these accounts are alternative scientific theories and that students are free to choose between them). Berkman and Plutzer (2012) suggest that these approaches to avoiding the controversy, often taken by teachers who are not themselves opposed to evolution, are nonetheless supportive of the tactics employed by those who question the legitimacy of evolution. These approaches do nothing to challenge the assumption that the science of evolution, and in particular human evolution, is necessarily in conflict with religious and cultural beliefs. What is needed are alternative strategies for teachers that will help them both acknowledge the religious and cultural controversy surrounding evolution in the classroom and create a classroom environment that encourages a greater understanding of evolution.

Increasingly, science educators are proposing that the most effective classroom environment for increasing students' understanding of evolution, and at least laying the foundation for the possibility of increased acceptance, is not one in which anti-evolutionary views that stem from religious and cultural concerns are considered "misconceptions to be corrected," but instead are recognized as part of the students' worldview that should be acknowledged in some way (Scharmann 1993; Smith 1994; Dagher and BouJaoude 1997; Woods and Scharmann 2001; Scharmann 2005; Verhey 2005; Smith 2010; Southerland and Scharmann 2013). Failing to acknowledge and address religious and cultural concerns when teaching evolution can lead to students in the classroom with a religious worldview feeling uncomfortable and excluded (Hermann 2012; Barnes et al. 2017). The tension between a student's or teacher's religious worldview and the science of evolution may best be managed in a classroom

environment which acknowledges the religious and cultural controversies, but focuses on an increased *scientific understanding* of evolution (specifically the recognition of processes and concepts central to the theory of evolution) rather than an *acceptance* of evolution (Meadows 2009; Reiss 2009; Scharmann 2005; Southerland and Scharmann 2013) and includes instruction that can reduce the perceived conflict between evolution and religion (Wiles and Alters 2011; Wiles 2014; Yasri and Mancy 2016; Manwaring et al. 2015; Barnes et al. 2017; Barnes and Brownell 2017; Troung et al. 2018).

At the level of high school instruction, there are few concrete examples in the literature of how a teacher might acknowledge the religious and cultural controversies while advancing an understanding of evolutionary science, that also include quantitative or qualitative measures of the impact of this approach (Hermann 2008). Recent exceptions are the work of Wiles and Alters (2011) and Wiles (2014) with gifted high school students in an intensive summer program and Yasri and Mancy (2016) in a study with high school students at a Christian school in Thailand. Manwaring et al. (2015), Barnes et al. (2017) and Troung et al. (2018) have explored this approach and measured its impact with college undergraduates in the United States. However, many of the specific activities described in these studies would be inappropriate and possibly illegal in a public US high school classroom.

Previous research

Three recent studies with introductory biology students at the college level, all of which directly address religious concerns about evolution and include quantitative or qualitative measures, are noteworthy. The first was undertaken with a highly religious population, students who are members of The Church of Jesus Christ of Latter-day Saints (LDS or Mormon) at Brigham Young University, and explored the impact of students' knowledge of the neutral LDS doctrine on evolution on the students' acceptance of evolution (Manwaring et al. 2015). In this study, in all but one control section, the instruction on evolution also included a 50 to 75 min class period devoted to a lecture and discussion about the official LDS church stance on human origins using materials that introduce students to official LDS church statements on the topic and the history of the materials. This study also examined the relationships between conceptual understanding of evolutionary theory and religiosity with acceptance of evolution. As in previous studies, these researchers found that student religiosity impacts initial acceptance of evolution, with the two negatively correlated, but after instruction on evolutionary theory the study documented a positive relationship between conceptual understanding and acceptance regardless of student religiosity. Acceptance rates, however, were significantly greater for those students who also received the one class period instruction on the LDS stance on evolution.

Another study with introductory biology students at the college level, in a public university in the southwest US, focused on challenging the idea that evolution and religion are necessarily in conflict by using several activities to introduce students to the possibility of compatibility between the two (Barnes et al. 2017). Over the course of a 2-week unit on evolution students participated in three activities; they (1) heard from a guest scientist who was both a biologist and religious and could speak to their own experience of reconciling their faith with evolution, (2) read the National Academy of Sciences handbook *Science, Evolution, and Creationism* (National Academy of Sciences 2008) which stresses the idea that evolution and religion can be compatible, and (3) participated in a lecture on the variety of creationists' beliefs and the extent to which these beliefs are consistent with the theory of evolution with a focus on the different types of questions explored by science and religion. Students were surveyed both before and after the evolution unit on whether they thought evolution and religion could be compatible, and the number of both religious and nonreligious students who perceived a conflict between the two decreased by 50% after this instruction. The study did not document how this decrease in perceived conflict related to students' conceptual understanding or acceptance of evolution, but assumes the importance of addressing the subject of conflict between science and religion for achieving positive learning goals.

More recently Troung et al. (2018) conducted a study with incoming first-year biology students in a public university in the southwest US. These students were participating in an intensive 9-day summer course to prepare them for the introductory biology course they would take in the fall semester. Unlike the previous study by Barnes et al. (2017) in which a 2 week unit on evolution included about 2 h of instruction aimed at introducing students to the possibility of compatibility between evolution and religion, the intensive summer course included only 6 min of this instruction. Qualitative analyses of interview data with ten students, all of whom were identified as perceiving a conflict between evolution and religion prior to the course, was used to show that after the course the level of perceived conflict was reduced for eight of these students. This study also identified distinct aspects of the instruction that students indicated decreased their perception of conflict. The aspects of instruction noted most frequently were that students did not feel the instructor was forcing them to accept evolution, that the instructor was respectful of student viewpoints, and exposure to

evolution content. The first two aspects were cited as frequently as the latter. All three of the studies noted above used class time to explicitly acknowledge concerns about evolution conflicting with religious beliefs and concluded that this pedagogical approach is useful for engaging college students in the study of evolution.

At the level of high school biology instruction, Wiles and Alters (2011) measured how students' level of acceptance of evolution changed both immediately following a 6 week summer program and 1 year later using the Measure of Acceptance of the Theory of Evolution (MATE) instrument. The program was designed for gifted students who had completed their junior year in high school and it explicitly addressed a number of factors that may negatively impact students' acceptance of evolution, including non-scientific factors such as a perceived conflict between religious faith and evolution. This perceived conflict was not addressed as part of the course instruction on evolutionary science, but in an extracurricular seminar that presented the variety of religious traditions' views on evolution and faith, and in a forum with an invited theologian as a speaker who confirmed the compatibility of evolution with faith in the divine. Wiles and Alters (2011) note that despite the fact that religious factors have been shown to have an impact on high school students' attitudes toward evolution (Woods and Scharmann 2001), the extracurricular seminar and forum activities cited above are not appropriate for a science course. Students who participated in the summer program however, did show a significant increase in acceptance of evolution, immediately after the program and 1 year later, though the study did not differentiate the impact of individual factors. In a subsequent study Wiles (2014) analyzed open-ended questionnaires and interviews with this same population of students, who were now either entering college as freshman or had completed one or 2 years of college, to determine which factors the students considered important to their change in acceptance of evolution. He reported that regardless of their level of acceptance of evolution, the students often cited their religion as a factor influencing their decision.

Another study with high school students at a Christian school in Thailand investigated changes in students' positions on the relationship between evolution and creation and the reasons for changes in their position (Yasri and Mancy 2016). The class included both Christian and Buddhist students and their course on biological evolution lasted for 3 months. The course began with an introduction to the differences between science and religion with a focus on the different ways of learning about the world that science and religion provide. Teachers also emphasized, however, that they respected other views on the relationship between science and religion. The remainder of the course focused on science instruction about evolution. After the evolution instruction, students were surveyed about their initial position on the relationship between evolution and creation, whether or not their position had changed, and if so their new position and the reason for the change. Though there were significant differences in the particular position on evolution and creation that Christian versus Buddhist students chose prior to and after instruction on evolution, a large percentage of students (nearly 77%) underwent a change in position towards increasing acceptance of evolution. These students reported that the reason for their change was due to both changes in their understanding of the evidence for evolution and of ways of relating evolution and their religious beliefs.

These studies with high school students, as well as the three studies with college students cited above, highlight the value of evolution instruction that includes an acknowledgement of students' religious concerns about evolution and an introduction to the variety of possible relationships between science and religion. A remaining challenge is to equip public high school biology teachers in the US with classroom activities that accomplish this as part of regular biology classroom instruction on evolution, rather than depending on specialized extracurricular activities or programs that not all students may be able to access. We argue that including activities in the science classroom that address religious factors is appropriate if the these activities do not diminish in students' minds the consensus of the scientific community on the validity of evolution (the goal of many opposed to evolution who propose "teaching the controversy" in the science classroom (Scott 2004)) and if these activities do not promote a specific religious view (a violation of the separation of church and state). To this end, we have developed a "Cultural and Religious Sensitivity (CRS) Teaching Strategies Resource" intended to aid teachers in creating a positive learning experience for students encountering the topic of evolution by including an acknowledgement of students' religious or cultural concerns about evolution and an introduction to the variety of possible relationships between science and religion with a focus on the nature of science. These practices, and those described in the previous studies with high school students, fall within the framework of Religious Cultural Competence in Evolution Education (ReCCEE) described by Barnes and Brownell (2017) who recommended the use of the framework by secular college instructors when teaching evolution to religious college students. It is worth noting that the CRS makes no assumption about the particular worldview of the high school teacher using the resource and that it is designed to increase the comfort level of both teachers and students, regardless of whether

or not the teacher shares their students' worldview. The CRS places a focus on creating a classroom environment where individual worldviews are respected while encouraging a sound scientific understanding of evolution.

The CRS resource is part of an exploratory design-based study, the *Teaching Evolution through Human Examples* (TEtHE) project, which created four curriculum units for advanced placement (AP) biology classes that use human evolution case studies to teach core evolutionary principles outlined in the AP Biology learning objectives (Pobiner et al. 2018). While the focus of the overall project was AP biology classes, we think that the classroom activities described in the CRS are appropriate for general biology classes as well and the results reported here have implications for all high school evolution instruction. As noted in Pobiner et al. (2018), AP biology classrooms provide a "best case" learning context for the formative evaluation of the TEtHE curriculum mini-units and CRS because AP students are generally more motivated to learn and are more sufficiently aware of the impact of teaching materials on their own learning. We are currently exploring the impact of these materials in an introductory high school biology population.

Purpose

The purpose of this paper is to describe the "Cultural and Religious Sensitivity (CRS) Teaching Strategies Resource" and to report on the students' experience of this resource. Specifically, we describe the qualitative results of student focus groups that were designed to explore the extent to which the resource activities helped to create a supportive classroom environment that would encourage students to engage the topic of evolution, and more generally what benefits, if any, students derived from participating in these activities. For example, would participating in the activities alleviate any anxiety students might have about learning evolution? If so, this would indicate that the activities helped to create a supportive classroom environment. How would participation in the activities impact students' understanding of cultural concerns about evolution? If the activities helped students recognize that cultural concerns about evolution vary and that these concerns cannot be addressed by the scientific study of evolution, then this would indicate that the activities helped with an understanding of the nature of science. How would students feel about a discussion of the cultural controversy surrounding the topic of evolution taking place in a science classroom? The resource recommends activities that are different than those students expect to take place in a science classroom. For the resource to be judged successful to a large extent, it must address the likely variety in student and teacher comfort with this approach.

Quantitative measures of the success of the resource in terms of structure and function, from the perspective of both teachers and students, and the impact of the resource activities on students' understanding and acceptance of evolution are reported elsewhere (Pobiner et al. 2018). The qualitative data we provide here contribute to one of the main questions guiding the research and evaluation of the TEtHE project:

> *"To what extent can the project team develop a set of Cultural And Religious Sensitivity (CRS) resources that provide teachers with strategies that create a supportive classroom environment for the teaching of evolution and support an understanding of the nature of science?"*

While key points about the development and field-testing of the CRS resource, and quantitative measures of its impact on understanding and acceptance of evolution are summarized in this paper, readers are referred to Pobiner et al. (2018) for details about the design-based research approach of the TEtHE project including quantitative measures of the impact of the curriculum units and CRS resource on students' understanding and acceptance of evolution. Provided below are details about the CRS methodology, including a description of the CRS resource, field testing, focus groups and analysis of transcripts. Results from the analysis of audio transcripts of focus groups with students that experienced one of the CRS classroom activities, a summary of their teachers' evaluation of the activity, and a discussion of the implications for teaching evolution in public high school classrooms are described.

Methods

The CRS resource

Development process

As noted in Pobiner et al. (2018), the TEtHE project was conducted within a design-based research framework (Anderson and Shattuck 2012). The project advisory board meeting for the *Teaching Evolution through Human Examples* project determined the CRS resource structure, content and focus, and determined the criteria to guide the CRS resource development process (Table 1). These criteria were drawn from a literature review as well as the professional experiences of the project advisory board. The lead CRS author, Constance Bertka, developed a first draft of the resource and feedback from the advisory board led to revisions for a second draft of the resource. As part of this process the advisory board was specifically asked to evaluate whether or not all of the criteria were met in both the background material provided for the teachers and each classroom activity, and if needed, to recommend revisions to meet this goal.

Table 1 CRS resource criteria

Criterion	Description
Criterion 1	Acknowledges that diverse cultural viewpoints about the origin, diversity, and evolution of life have existed and continue to exist among human cultures and communities
Criterion 2	Respects students' and teachers' worldviews
Criterion 3	Encourages a supportive classroom environment with a focus on the goal of understanding the science of human evolution
Criterion 4	Aids in the management of conflict in the classroom rather than a specific resolution of the conflict
Criterion 5	Portrays the variety of possibilities for a relationship of science to religion beyond conflict
Criterion 6	Uses an understanding of the nature of science as a reference to illustrate the parameters within which science operates

This second draft was used in the National Field Test by seven teachers and was the version experienced by the students who participated in the focus groups. Teacher and student feedback were used to create a final version of the resource. The final resource is freely available from the *Smithsonian Institution Human Origins* Program's website.[1]

Resource content

The result of the development process was a resource that includes a variety of strategies, providing both background information for the teacher and activities to engage students in two 50–75 min directed classroom discussions. This approach recognizes that both the perceived need for these strategies, as well as the teacher's willingness to acknowledge religious and cultural controversies in the classroom, will vary. To inspire confidence in teachers who may be called on to respond to questions about religious and cultural controversies, Part One of the resource provides concise background information on the nature of science as pertinent to managing a conflict between science and religion; the range of creationists views; the variety of possible relationships between science and religion, including examples of how individuals accommodate evolution and religion; and the historical context and background on legal cases dealing with the teaching of evolution. For teachers seeking a proactive approach that acknowledges religious and cultural controversies and encourages a classroom exploration of their impact on the understanding of evolution, Part Two of the resource presents two classroom activities, each one consisting of three to four individual student exercises to engage students in directed classroom discussions. The two classroom activities use a procedural neutrality approach (Hermann 2008) in which information about the cultural controversy surrounding evolution and different points of view about this controversy are elicited from students and from resource materials. The teacher does not make a value judgment about these views, but does help students come to a correct understanding of the nature of science.

CRS Activity #1 CRS Activity #1, *"Directed Discussions-Why study evolution?"* is designed to be used at the start of the instruction on evolutionary theory, in communities where the teacher is aware that students may have routinely encountered mostly negative or mistaken notions of evolutionary theory, especially as it applies to human evolution. The activity might also be useful at the first signs of unexpected negativity in any classroom. It is designed to help students recognize that they are not being asked to accept evolution or change their personal beliefs, but to understand evolution from a scientific perspective. Exercise 1 of the activity is a homework assignment "What Do You Know about Evolution?" In this exercise students are asked to provide short answers to three questions:

1. Summarize the theory of evolution in three sentences or less.
2. Are you aware of explanations for the variety of life (including animals, plants, microbes, and other forms of life found on Earth today) other than the theory of evolution, that are important to you or someone you know? If so, list one or two such explanations along with a one- or two-sentence description of each.
3. Some people are concerned about studying the theory of evolution. List one or two concerns that you are aware of that others, or you, may have about studying evolution.

Students share their answers to the questions in this assignment with each other in small group discussions and directed class discussions that are aimed at identifying common responses to the last two of the three questions. The questions are designed to provide the teacher with insight into what the students already know about evolution, including misconceptions, and to provide students with an opportunity to list concerns that they are aware of in regards to studying evolutionary theory. As the small groups record their common responses to these questions, and share them with the entire class, the teacher is encouraged to keep a public record of responses. However, the only responses that should be critiqued by the teacher are those that refer to the nature of science, and then preferably only after completing

[1] https://humanorigins.si.edu/education/teaching-evolution-through-human-examples.

Exercise 2 which explicitly explores this topic. Misconceptions about the science of evolutionary theory that are recorded from these discussions may be addressed later, as appropriate, with references to the evolution content instruction. The goal of CRS Activity #1, and in particular Exercise 1, is to allow students to begin their study of evolution with the recognition that their personal worldviews are acknowledged and respected. The teacher is advised to be nonjudgmental about student responses but help students understand that in class they will be working together to understand the theory of evolution from a scientific perspective and that the next exercise will help make this clear.

In Exercise 2, "Ways of Knowing," students are provided a figure that has three overlapping spheres representing three different "ways of knowing," personal experience, tradition, and science- and they are instructed to answer the following question:

When people think about the world, they often draw on more than one kind of knowledge. The figure suggests three common ways of knowing. How does science as a way of knowing differ from the other ways of knowing listed in the figure?

Remaining in their small groups, students are asked to first write their own answer to the question, then to again share their answers with others in their group and identify common responses to report out to the entire class. The question is intended as a catalyst for a discussion about the nature of science. The teacher keeps a public record of key phrases from the groups' responses and then provides students with a description of the nature of science provided in the background material found in Part One of the CRS resource (nature of science description summarized from NGSS Lead States 2013). Key points from this description emphasize that science, understood as both a process for learning about the natural world as well as the knowledge about the natural world gained through this process, is a "way of knowing" with a characteristic set of assumptions. These assumptions include the idea that the natural world is understandable, but absolute truth is unobtainable because new observations can lead to new ideas. That said, the process of science overall is more often an exercise in continually refining ideas than outright refuting them. One outcome of this process is a scientific theory: a comprehensive explanation of some aspect of nature that is supported by a vast body of observations and experimentation. Scientific explanations must be predictive of new observations and therefore testable. Science, by definition, is limited to explaining the natural world through natural causes. In this exercise the teacher guides the class in comparing the group responses to the provided description. The goal is to critique the students' understanding of the nature of science without elevating one way of knowing over another.

Exercise 3, "Relating Science to Other Ways of Knowing," explores possible relationships between science, or specifically evolution, and religious or cultural beliefs, providing students with an introduction to the variety of ways individuals manage this intersection. In this exercise, students work in small groups to classify five statements by organizations (religious and secular) or individuals into three possible ways of relating science and religion: conflict, separation, or interaction. While these statements allow students to recognize the possibility of a non-conflict relation between evolution and religious worldviews, no one religious worldview is promoted over another. Students are provided with examples of both religious people who accept evolution and examples of those who reject evolution, and the reasoning behind their position. Teachers are asked to summarize the main point of the activity, that more than one approach to relating science and religious beliefs exists, and that two of these approaches see a positive role for both science and religion to play in understanding the world.

At the end of class students leave with a homework assignment, Exercise 4, "Evolution as a Tool to Understand and Address Human Biological Challenges," that introduces them to the idea that evolutionary theory is an explanatory tool that biologists use to solve problems and make testable hypotheses. In Exercise 4 students are provided short summaries of research studies that address Tibetans' adaption to altitude, the search for drugs to treat malaria, and the evolution of human skin color. The summaries identify for the students the research question scientists are trying to answer and the students are asked to list the type of data the scientists are collecting to answer the question. The exercise does not assume that students have any understanding of evolutionary theory, but is intended to introduce them to the idea of data collection as a precursor to scientific explanation using evolutionary theory. CRS Activity #1 is modeled in part after classroom exercises described by Scharmann (2005).

CRS Activity #2 Not all teachers may feel it is necessary to begin their instruction on evolution with an activity to acknowledge students' concerns. CRS Activity #2, *"A Historical Role Play- How do people think about evolutionary theory?"* was developed for teachers working in communities in which they believe anti-evolutionism is either nonexistent or a minority viewpoint. This activity is designed to be completed at the end of the instruction on evolution and to reinforce that instruction. CRS Activity #2 offers an opportunity for students to review and use learned concepts about evolution, increase their

Table 2 Historical Characters

Character	Reaction to Darwin's 1859 publication of *On the Origin of Species*
Charles Darwin	Author of publication and proponent of evolution. Paired with *William Thomson*
William Thomson	Physicist who is opposed to evolution. Paired with *Charles Darwin*
Thomas Henry Huxley	Biologist who is a proponent of evolution. Paired with *Samuel Wilberforce*
Samuel Wilberforce	Bishop of Oxford who is opposed to evolution. Paired with *Thomas Henry Huxley*
Leonard Smith	Pigeon breeder, a fictional character reflective of time period, proponent of evolution. Paired with *Eliza Wilkins*
Eliza Wilkins	Housemaid, a fictional character reflective of time period, proponent of evolution but has mistaken notions about the theory. Paired with *Leonard Smith*
Asa Gray	Botanist who is a proponent of evolution. Paired with *Admiral Robert FitzRoy*
Admiral Robert FitzRoy	Ship captain of the *Beagle* who is opposed to evolution. Paired with *Asa Gray*

insights about the nature of science, and increase their understanding of the cultural controversy that surrounds the study of evolution. One of the main objectives is to help students recognize the differences between historical concerns about evolutionary theory that were rooted in religious and cultural worldviews and those concerns that were rooted in a scientific understanding reasonable for that time period. Students use their knowledge of the nature of science and modern evolutionary theory to consider responses to these historical concerns. Teachers are reminded to review key points from the discussion of the nature of science provided in the CRS background material (noted above in reference to Activity #1) with their students if necessary. This activity is in part a revision of a classroom exercise previously designed by Solomon et al. (1993).

In Exercise 1, begun as a homework assignment and then discussed in groups in class, students are assigned one of eight historical characters (see Table 2) and given a brief biographical description of their character along with two or three questions about their character's reaction to the 1859 publication of Charles Darwin's *On the Origin of Species by Means of Natural Selection*. When students return to class, they view a short video about Charles Darwin that provides insight into the cultural context of Darwin's time. After the video, all students assigned the same character work together as a group to agree on how their character would reply to these questions using information from the biographical sketch. For example, the students who were assigned Thomas Henry Huxley, a biologist, draft answers in the character's voice to two questions:

1. What evidence do you have to support the view that humans are related to animals?
2. Does Darwin's theory disprove the existence of God?

Meanwhile, students assigned Samuel Wilberforce, the Bishop of Oxford, draft answers to the questions:

1. Why do you oppose the theory of evolution proposed by Darwin?
2. How do you explain the range of animals and plants that are alive today?

In Exercise 2 the character groups are paired so that each group contains one individual who was supportive of the theory of evolution in 1859 and one who either objected to the idea or had mistaken notions about the theory (see Table 2). The nuances of the characters' support of, or concern about, the theory of evolution are presented in the biographical character sketches the students are assigned. Not all of the characters chosen to represent proponents of evolution accepted all aspects of the theory as presented by Darwin. Most importantly, those characters chosen to represent opposition to the theory of evolution highlight both scientific and religious concerns about the theory at the time of its publication.

Students work together in their paired groups to consider how the proponent of evolution in each pair might have responded to his or her colleague or peer. They draft both a historical and modern-day response to concerns about evolution highlighted by one of their characters. All the paired groups are provided with a series of questions to guide their responses:

1. Which character is a proponent of evolution? Or if both are proponents, which has an understanding of evolution closest to that of Darwin's?
2. Given the opposing character's specific objection(s) or misconception(s) about the theory, should the response include reference to the nature of science? For example, should the responses discuss the type of questions that science is able to explore? Why or why not?
3. If the opposing character's objection(s) depend on a nineteenth-century understanding of nature, what type of new evidence would the proponent of evolution need to answer the objection(s) or misconception(s)?
4. What insights from a modern understanding of evolutionary theory or earth history would help the

Table 3 Summary of teacher, school and focus group characteristics

Teacher #	Years of experience	Confidence teaching evolution	School	CRS activity	Class size	Focus group size	Timing of focus group
10	3	High	Private suburban	1	9 9	11 combined classes	Evening same day as CRS
11	8	High	Public suburban	1	21 19 23	9 – –	1 day after CRS
3	12	High	Public suburban	1	20	8	7 days after CRS
14	3	High	Public suburban	2	13 18	13 18	Directly after CRS

proponent of evolution respond to the character's objection(s) or misconception(s)?

The paired groups then take turns introducing their characters to the entire class, describing the concern or misunderstanding one of their characters expressed, and outlining possible historical and modern day responses to those concerns. Students are asked to separate religious and cultural concerns from scientific concerns. The teacher is encouraged to remind students that the goal is to be able to recognize and classify these different historical viewpoints but not to stage a debate between historical characters. The exercise should help students recognize that the theory of evolution meets one of the criteria of a robust scientific theory: it continues to be the best natural explanation of observations of nature even in light of new discoveries. Students should also recognize that cultural and religious responses to evolution varied in the past, just as they do today. Exercise 3, the final exercise for CRS Activity #2 is the "Relating Science to Other Ways of Knowing" exercise that explores possible relations between science, or specifically evolution, and religious or cultural beliefs. In contrast to CRS Activity #1 in which this exercise is completed in class, here it is assigned for homework.

CRS Activity #2 assumes that the students have previously explored a scientific understanding of evolutionary theory as they are asked to draw upon that understanding to complete the exercises. This activity is designed to help students understand the cultural controversy surrounding evolution while demonstrating characteristics of a successful scientific theory, its ability to both predict future observations and withstand rigorous testing. If class time permits, students who had begun their instruction on evolution with Activity #1 would also benefit from completing their evolution instruction with Activity #2.

Field test

During the 2013–2014 school year, 218 students of seven different teachers field tested one of the two CRS activities. These students were drawn from the larger pool of 304 students of 10 teachers who participated in the TEtHE project testing one of the four curriculum units for advanced placement (AP) biology classes. The recruitment strategies used to invite these teachers to participate in the larger study are described elsewhere (Pobiner et al. 2018), but it is worth noting here that many of the teachers who responded to the recruitment were typically well-respected, experienced teachers, all of whom already taught AP Biology. The teachers who volunteered to test one of two CRS activities were free to choose which of the two activities they would use in their classroom.

Five focus groups were conducted with students of four of these teachers. These four teachers were observed using the CRS activities in order to document their fidelity to the lesson exercises. Three of these teachers used the CRS activity with more than one class of students. Each of the four teachers described their confidence in teaching evolution as "high" before their participation in the TEtHE project, and all had faced sensitive issues with the topic of evolution in their classrooms in the past. The teachers all taught in suburban schools, three of which were public and one private (see Table 3). We include below a summary of these teachers' responses to a survey question about their experience using one of the CRS classroom activities.

The results of survey data collected from advisory board members, all seven teachers who field tested the CRS, and 120 returned student surveys in which they rated the degree to which the CRS learning materials aligned to the criteria/core strategies and the degree to which the materials were useable/feasible are reported elsewhere (Pobiner et al. 2018). Also reported in Pobiner et al. (2018) is the impact of the CRS activities on student understanding and acceptance of evolution from

pre-curriculum to post-curriculum assessments. These results are referred to in the discussion section of this paper.

Focus groups

To gain insight into the students' perspectives of the CRS activity; their experience of the activity, the extent to which the activity helped to create a supportive classroom environment and what benefits if any the students derived from participating in the activity; we chose to conduct focus groups. The choice of focus groups, rather than individual student interviews, was based on the advantage of focus groups for general topics where fostering talk among the participants through a structured interview is beneficial for revealing multiple perspectives (Bogdan and Biklen 1998, 2016). Participating in a group discussion can help the students both express and recognize their own views (Bogdan and Biklen 1998, 2016). We felt this interaction between students would give us the most insight into the potential impact of the CRS resource and whether or not the approach it supports warrants further research. While focus group interviews may introduce the risk of losing data if a student is concerned about speaking in front of their peers, speaking individually to a researcher with whom the student has no familiarity may also be uncomfortable. Students in our group interviews were encouraged to express dissenting views if they held them and in general were reflective about how their views compared to others in the group. With the exception of one of the focus groups that contained too many students for an ideal experience and only half of the participants expressed an opinion, the other four groups had much higher participation rates with 64–88% of the students expressing an opinion.

Student participation in the focus group was voluntary. Given the design-based research nature of this project, which involved a collaborative partnership between researchers and practitioners, we relied on the teachers to invite students to participate in the focus groups (Pobiner et al. 2018; Anderson and Shattuck 2012). Teachers were asked to recruit seven to ten students for the focus group and to allot 1 h of time for the group discussion. They were encouraged to assemble as diverse a group of students as possible in terms of cultural background, gender and academic performance. All of the focus groups were conducted by the lead author. See Table 3 for a summary of teacher, school and focus group characteristics.

In most cases teachers were able to schedule the focus group meeting the same day, or 1 day after, the students experienced the CRS activity, however one group meeting took place a week later. Two of the three focus groups conducted with students who had experienced CRS Activity #1 had a productive number of student participants, 5 to 10 (Krueger and Casey, 2015), one group was slightly larger, 11 participants, and all three group sessions lasted 1 h. However due to scheduling difficulties, the two focus groups conducted with students who had experienced CRS Activity #2 took place immediately after the activity as part of the regularly scheduled class time, and were therefore of a much shorter duration (25 min) and included the entire class as participants.

Both of the CRS activities highlight cultural concerns about evolution. The focus group questions were designed to elicit responses from the students that could be used to explore how the students experienced the CRS activities and to evaluate the structure and function of the CRS activities to guide future revisions of the resource. The facilitator explained to the students that their thoughts and comments on the classroom activity would be very helpful to the CRS resource team as they considered future development of the activity. The students were assured that there were no wrong answers, that different points of view were welcome, and that participation was voluntary. All focus groups were audio recorded and transcribed verbatim with the students' permission and understanding that their responses would remain anonymous. Following an ice-breaker question in which all students were invited to introduce themselves by first name and identify their favorite animal, the facilitator briefly reviewed with the students an outline of the CRS activity they had experienced. Following this review, seven additional questions were posed to the students (see Table 4). The questions were open ended by design, encouraged the students to think back to their classroom experience with the activity and were sequenced from general to more specific as is standard for focus group questions (Krueger and Casey 2015). The students were assured that time would be reserved towards the end of the discussion for them to ask any questions they might have for the CRS resource team. Follow up questions to clarify students' responses or to ask participants for specific examples were also used as needed.

Analysis of transcripts

In analyzing the focus group transcripts, the goal was to inductively identify common themes expressed in relation to the students' experience of one of the two CRS activities. Three of the focus groups conducted were with students who had experienced the CRS Activity #1 *"Why Study Evolution?"* and two of the focus groups were conducted with students who had experienced the *"Historical Role Play"* CRS Activity #2. Transcripts of focus groups with students who had experienced the "*Why Study Evolution?"* activity were coded by the lead author independently from those who had experienced the "*Historical Role Play"* activity and findings for both activities

Table 4 Focus group questions

Number	Question
1.	Think back to when your teacher first told you that you would be participating [in a classroom discussion about *"Why Study Evolution?"*] or [in class in a *"Historical Role Play"* about evolution]. What were your first thoughts about this?
2.	How did the classroom feel to you as you and your classmates worked together on the [*"Why Study Evolution?"*] or [*"Historical Role Play"*] activities? Was it relaxed; tense; or something in-between?
3.	Question for *"Why Study Evolution"*—Think about your understanding of evolution and human origins. Tell us one way in which participating in these activities impacted your own understanding? Question for *"Historical Role Play"*—Tell us one way in which these activities impacted your own understanding of the reasons why people react to the theory of evolution differently.
4.	If you could invite a friend to class to participate in these activities, would you? If yes, what would you say to them in the invitation? If no, why not?
5.	Tell us one aspect of these activities that you really liked. Tell us one aspect of these activities that needs improvement or "really has to go".
6.	Is there anything else about the activities you would like us to know?
7.	Are there any questions you have for us?

are presented below. However, the findings presented for the "*Historical Role Play*" activity are tentative due to the difficulty with the number (two classes of one teacher), size and timing of the focus groups. We present them here only to be seen as generally supportive of the goals of the CRS resource.

The coding process described by Bogdan and Biklen (1998, 2016) was followed. As a first step in the coding process, all transcripts for the focus groups associated with the same CRS activity were reviewed twice during a long single period. Then the transcripts of each of the focus groups were analyzed independently from other focus groups associated with the same activity to identify patterns in the data. An inductive approach was taken to coding, moving from specific codes to defining more general themes. This process began with initial coding using the constant comparative method to identify numerous codes for responses to each question (Krueger and Casey 2015). Focused coding was applied to these initial codes to combine, eliminate, or subdivide codes for each question of each of the individual focus groups. This process resulted in a total of 58 codes identified for focus group responses associated with the *"Why Study Evolution?"* activity, and 24 codes identified for the focus group responses associated with the *"Historical Role Play"* activity. For each code the number of instances of students' responses captured by the code, as well as the code assigned to each student respondent, was recorded.

The codes for each question were then analyzed across all focus groups who experienced the same CRS activity to identify repeating ideas for each focus group question for each activity. These repeating ideas may have been expressed by different students in the same focus group, or by different students across the focus groups. These repeating ideas were used to identify common themes for each CRS activity; that is, themes that connected repeating ideas across all questions for all of the focus groups associated with the activity. To check for consistency of coding the lead author coded the material twice with several weeks passing between coding efforts and achieved approximately the same results (Schreier 2012). In response to reviewers' comments, coding was reviewed again a third time. In this review, rather than subdividing codes into repeating ideas, we recorded the overall instances of each theme, the focus group questions from which the instances were derived, the number of instances per focus group and the percentage of students in a given focus group who expressed an instance of the theme (see Tables 5, 6). Theme descriptions were further refined in this process but overall interpretations remained the same.

Results

The intent of offering two different class activities in the CRS resource was to allow teachers to choose between activities based on their perception of whether or not the topic of evolution was a sensitive or troubling topic for the majority of students in their class. The final version of the CRS resource includes an acceptance of evolution survey that teachers can distribute to students before beginning their instruction on evolution to help teachers determine which activity might be most appropriate for their classroom. However, the teachers who participated in this study volunteered to test one of the two CRS activities; they were free to choose which activity they preferred to test and were not asked to justify their reasoning. Judging from the responses of students in the focus groups of the five classes who participated, all contained students who expressed finding the topic worrisome.

Listed below are the common themes identified for the focus groups conducted with students from the three classes who experienced CRS Activity #1, and focus groups conducted with students from the two classes who experienced CRS Activity #2. For each theme identified, Tables 5, 6 detail the frequency of instances for the theme, the number of instances per teacher and the percentage of students in each focus group that expressed an instance of the theme.

Table 5 Frequency of instances for CRS Activity# 1 focus group themes, and their distribution among classes and students in focus groups

Theme #	Theme description	Number of instances	Focus group questions from which instances derive	Instances per teacher	Percentage of students in focus group expressing instance (%)
1	Encouraged respectful classroom discussion and reduced tension around the topic of evolution	32	2, 4,5, 6	(10) 3 (11) 10 (3) 19	(10) 18 (11) 56 (3) 63
2	Increased awareness of the possibility of non-conflict between evolution and religious beliefs	19	3, 4, 5, 6	(10) 7 (11) 6 (3) 6	(10) 27 (11) 44 (3) 63
3	Encouraged reflection on own views and interest in others' views	29	1, 3, 4, 5, 6	(10) 10 (11) 9 (3) 10	(10) 55 (11) 44 (3) 63
4	Students questioned the appropriateness of the activity	7	1, 2, 5	(10) 2 (11) 1 (3) 4	(10) 9 (11) 11 (3) 25

Table 6 Frequency of instances for CRS Activity# 2 group themes, and their distribution among classes and students in focus groups

Theme #	Theme description	Number of instances	Focus group questions from which instances derive	Instances per teacher	Percentage of students in focus group expressing instance (%)
1	Activity was positively anticipated	11	1, 2	14-1 5 14-2 6	14-1 31 14-2 28
2	Encouraged an understanding of the cultural context of modern and historical views about evolution	12	3, 4, 5, 6	14-1 5 14-2 7	14-1 38 14-2 28
3	Students recognized that this activity could make some people uncomfortable	5	1, 2, 4	14-1 5 14-2 0	14-1 23 14-2 0

Common themes for CRS Activity #1

1. Encouraged respectful classroom discussion and reduced tension around the topic of evolution

Students of all three teachers referred to the positive rapport that already existed in their classroom among students and between students and their teacher. However, in the focus group of teacher 11 and 3 there was also surprise expressed that this congenial atmosphere could remain when the topic of evolution was raised, especially as students recalled previous classroom experiences with the topic.

In classroom 11 one student remarked:

"It made like a good learning environment with no one fighting and everyone like 'oh yeah, I hadn't thought of that!'." (11B5)

The student's peers responded with an affirmation of this description of the classroom environment and a comparison to a previous classroom experience:

"Everyone was pretty respectful of other's opinions and let them finish what they had to say before they went off about what they thought". (11B6)

"It was definitely different because in certain classes like social studies classes there's always like a debate about religion. There's always like one person yelling at someone else about it. It definitely wasn't like that." (11B1)

A similar discussion emerged in the focus group of teacher 3, where students expressed surprise at the relaxed atmosphere in the classroom and appreciation of the discussions that took place:

"We were a lot more relaxed than I expected." (3B3)

"Zero to very little yelling." (3B2)

"I just value how we can really just sit down and talk about this openly without having to get into some kind of huge debate or argument." (3A1)

This last student's comment also inspired another student to recall a previous negative classroom experience:

> *"This is adding on to what she said. But in my last class, we had, it wasn't supposed to start out on a debate on this, …it was about the ethics of testing for genetic disorders… and we probably got three minutes in before it devolved into just a rampant debate between evolutionists and creationists…" (3B1).*

Among the students of all three teachers who participated in the focus groups, there was a general awareness that evolution is a controversial topic and could be an uncomfortable classroom discussion. Students suggested the CRS activity was useful for reducing tension and, if not a concern for them personally, might ease the concerns of religious friends or family.

Students of teacher 3 spoke about the usefulness of beginning instruction on evolution with the exercises in the CRS activity. Student 3B2 is an example:

> *"I really liked the first thing we did, the three questions [exercise 1]. I thought it was like a good opener, like, it sort of eased the tension I think… I think it was like, let's get this out of the way, yes there are other ideas, but we kind of have to learn this anyways." (3B2)*

The first exercise is designed to provide an opportunity for students to note other cultural ideas about the diversity of life and specific concerns about studying evolution. Nowhere in the focus group conversation does the student quoted above, 3B2, reveal their own cultural or religious concerns, but they are certainly aware that these exist for some people and applaud the value of acknowledging those concerns upfront. Following this student's remark another student, who elsewhere in the conversation does identify themselves as religious, also spoke favorably about exercises 1 and 2 and was appreciative of the opportunity to share beliefs with their peers:

> *"I really enjoyed the first two, what do you know about evolution and ways of knowing diagram because I felt like those two are really nice opening things and it led to a lot of really interesting class discussions where we just shared things that we believed and we talked…" (3A3)*

When students were asked a final time if there was anything else they would like us to know about the activity this same student spoke on a more personal level about the value of the activity's approach, taking the time to introduce the topic of evolution with an acknowledgement of cultural concerns:

> *"I really liked how the lessons eased you into evolution, the idea of it, because some people aren't open to learning it, so it's kind of helping you not to have to be bombarded…"(3A3)*

Students were also reflective about who in their personal sphere might benefit from participating in the activity and why. In the focus group of teacher 11 one student, who does not reveal whether or not they are religious themselves, notes the value of the activity for religious friends:

> *"I think I would, personally, invite my friends because I have, not all of my friends, but some of my friends are more religious and I know that some of them have always struggled with the concept of evolution. And I would really want to invite them to the class so that they could see that there is the ability to coexist or to even be together with the two topics." (11B2)*

This student recognized the discomfort that the topic of evolution can raise for their religious friends and suggested the activity could help these friends see a possibility for the coexistence of evolution and their religious beliefs thereby alleviating their struggle with evolution. Following this student's comment, a classmate, who elsewhere describes himself as "very religious", remarked:

> *"Yeah, I mean I would invite someone [to class]. I can't think of a reason why not. …it might clear some things up for anybody that might be in the same boat as [student 11B2] was talking about." (11B5)*

Students who openly identified as religious were included in the 56% of students in the focus group of teacher 11, and the 63% of students in the focus group of teacher 3, who expressed an instance of Theme 1. The percentage of students expressing this theme in the focus group of teacher 10 was less, 18%. Of the three teachers who used CRS Activity #1, the students of teacher 10 had the highest pre-curriculum acceptance of evolution as measured with the Generalized Acceptance of EvolutioN Evaluation instrument (GAENE, a 16 item Likert-scale instrument used to assess student acceptance of evolution, Smith et al. 2016) (Pobiner et al. 2018). While not identifying as religious themselves, but previously noting that some of their family members are conflicted about evolution because of their religiosity, one student of teacher 10 noted the value of the activity's approach for introducing the topic of evolution:

> *"It's cool that it's presented like a discussion, it's not presented like it's trying to convince you of everything, that's why I would invite someone who's a creationist to this, because I wouldn't say, 'oh come*

learn about evolution'. I'd say 'we're talking about evolution and how it relates to other ways of thinking and how it relates to religion and how people deal with that, we're going to talk about it, and come say what you think, we're not going to try to convince you." (10A3)

This student highlighted the value of a respectful discussion, one that avoids targeting any personal belief, as the starting point for a study of evolution.

2. Increased awareness of the possibility of non-conflict between evolution and religious beliefs

Students were curious about the relationship between evolution and religion and many commented on the possibility of non-conflict between the two and the role the activity played in helping them recognize this possibility. All three teachers had students who expressed this sentiment. A student of teacher 10 who introduced herself by noting her religious upbringing stated:

"…today when we were talking about the different ways of thinking, the conflict/separation/integration, it made it more clear for me because it's not like there's one way…it's not one or the other, there's many grey areas in between, it's not that you either believe in evolution or religion, and it kind of comforted me to think that it's okay to believe both…" (10A2)

Other students in this teacher's class also noted with interest, rather than a personal connection, the possibility of believing both. For example in response to the above student, one classmate immediately replied:

"I think it's kind of what you said, a mix between religion and science…I think it's interesting that you can believe what you believe in and still believe in the science, it's not one or the other" (10A1)

As was the case for theme 1, the percentage of students in the focus group of teacher 10 who expressed an instance of theme 2 was only 27%, compared to 44% and 63% for the students in the focus groups of teachers 11 and 3. The classes of teachers 11 and 3 had pre-curriculum GAENE scores that were lower than the class of teacher 10. Student 10A2, and one other student of teacher 10, are the only students in this focus group who described themselves as religious. The other self-described religious student noted that they belonged to a very liberal tradition where a conflict between science and religion was not an issue and a topic they had previously explored in religious education.

For students of teacher 11 the recognition of non-conflict between evolution and religion was described in more personal terms. One religious student explained:

"I'd say they [the exercises] made me a little more aware. Because I'm also very religious and it just made me more aware of my own beliefs and how they can coexist. So I guess, more interaction than conflict, or like one has to overcome or dominate the other one." (COB5)

To which their peer replied:

"I'd just say that I'm pretty religious too…I was raised in a very narrow minded household about evolution…I was always raised to think that there was conflict, but really I've realized that there isn't as much conflict as you'd think." (COB4)

Students of teacher 3 had the lowest pre-curriculum GAENE scores of all three teachers. Students of this teacher who described themselves as religious also spoke about the recognition of options for relating evolution and religion beyond conflict in more personal terms as well. Student 3A2 is one example:

"I like the ways of knowing diagram and the relating science to other ways of knowing just because it showed me other ways of thinking. I didn't have to just choose one or the other…" (3A2)

Student 3A4 also expressed appreciation that the statements in exercise three included examples that illustrated the possibility of a non-conflict relationship between evolution and religious belief, relieving them of the burden to choose one or the other.

"Coming into this, I've always thought creationism is over here and evolution is over there and you can't bring them together, no way. …There's part(s) of evolution that I do believe are true now… (3A4).

With the possibility of a non-conflict relation between evolution and religion realized, this student was able to reconsider the validity of evolution.

3. Encouraged reflection on own views and interest in others' views

Many of the instances recorded for theme two, as well as theme one, are a reminder that most students, like the public at large, assumed that conflict was the best description of the relationship between evolution and religious beliefs. The instances that describe theme three, in contrast, point to the general curiosity that students displayed about other peoples' cultural or religious views

on evolution (where these other people could be fellow classmates, family members or anyone who held a view about evolution different then their own), or they indicate thoughtful reflection by the students about their own views.

A self-identified religious student in the focus group of teacher 11 remarked:

> *"It was interesting, it just kind of brought you to think about what your views on evolution are because I'm pretty devoutly religious. It was interesting to think about like, how my beliefs can mesh with evolution and I could still believe in science." (11B4)*

Earlier in the discussion this student noted that they were interested in studying evolution because "you should know it well enough to know what you are disregarding or accepting." The activity helped create a space for the student to consider what their own view on the relationship between evolution and their religious belief might be and to consider new possibilities for that relationship.

Several students described their own view in the context of the influence of their family. This student, in the focus group of teacher 3, contrasts their experience with that of another classmate's:

> *"I go to the same church as [classmate], but I'd say my experience is different. My family, they've been teaching evolution along with Catholic beliefs…the extreme controversy hasn't really affected me as much, because I've been taught both, and been able to choose both." (3A3)*

This student attributes their ability to choose "both" to the impact of their family teaching evolution and Catholic beliefs. Another student in the focus group then volunteered:

> *"I'm Catholic as well, but my dad…he's not very religious…I sort of believe a little of both, I believe that evolution got us to where we are, but I don't believe that there wasn't something that caused it to start." (3B2)*

In previous remarks this student had contrasted the difference between their mother's and their father's views on evolution. In reflecting on their own view, the student described the middle ground they had chosen.

Student 3A4, quoted above under theme two in terms of their changing ideas about the relation between evolution and creationism, had also admitted that "I was gonna participate [in study of evolution] for my grades sake, but not tell my mom," who the student said was opposed to evolution "because of her religious beliefs." This student also described another family member, a cousin, as "a biologist who is firmly believing that its evolution, creationism isn't a part at all." In thinking about who they might invite to participate in the activity this student replied:

> *"I would probably actually invite my cousin… I would like her to come in and see and just listen and understand there's multiple sides to the story and what people believe. I don't know what she was taught to believe… I thought it was a really nice class to just expose you to other peoples' beliefs and to show you that they can co-exist, and that's what I though, especially with the science relating to, or evolution relating to ways of knowing, I really liked that and I think that would really help, if I did bring my cousin." (3A4)*

The activity inspired the student to reflect on her own views, and those of her family members, especially a cousin who the student felt should be exposed to other people's beliefs.

The students' interest in other peoples' views included those of their classmates. This student, who self identified as religious, repeatedly noted throughout the group discussion their interest in the other students' views:

> *"I liked questions two and three [exercise 1], primarily because I just like hearing other peoples' thought, and just hearing what they have to say about evolution or creationism or whatever it is because I just find it really interesting." (3A1)*

This student may have been repeatedly the most exuberant in the focus group of teacher 3 in terms of expressing appreciation for a discussion of varying cultural views about evolution, but in general the participation of all the students in this focus group discussion was very high, with at least 88% of the students offering remarks. Most of the students in this focus group self-identified as religious. As a class, the students of teacher 3 had the lowest pre-curriculum GAENE scores of the three classes that experienced the activity, but most of the students in the focus group seemed welcoming of the opportunity to have participated in discussions about evolution and religious beliefs.

Two of the students in the focus group of teacher 10, the highest pre-curriculum GAENE score class of all three classes, and the focus group where only two students self-identified as religious, found a particular revelation about others' views interesting:

> *"What I really took away from the conversation, or what I was really surprised by, are there are places that evolution needs to be handled so lightly…*

When I came in here I just felt like the vast majority of America believed that some form of evolution did occur." (10B1)

This student was surprised to learn that cultural concerns about evolution existed at all and after their remark a classmate also responded:

"I was only exposed to evolution, so I'd never actually met someone who really believed in creation." (10A4)

The student in this focus group who had noted that they belonged to a very liberal religious tradition where a conflict between science and religion was not an issue, and a topic they had previously explored in religious education, responded to their peers' remarks with a justification of the activity:

"For me, I really didn't feel impacted by today's class but that's mostly because everything we've covered so far I have covered, but it just sort of reinstalls the fact that this is the basis, this is where you start, you need to know that not everyone believes it and there are opposing theories and some people strongly believe in those, and you have to start with that sort of level of knowledge." (10A3)

The student felt it was important for their classmates to be aware of the range of views on the topic of evolution.

Later in this discussion student 10B1 offered a reason why they would invite their friends who accept evolution to participate in the activity, despite an earlier misgiving that the friends might be "insensitive" to a creationists view:

"Maybe I would invite them [friends who do accept evolution] to give them more perspective that there are people who don't believe in evolution." (10B1)

Two other classmates responded with similar reasoning:

"I would bring my friends for that reason, so like, if you came, I guess, this class sort of, makes you more sensitive about people who don't believe in evolution." (10B3)

"I kind of agree with what they (10B3) said, …it would help with sensitivity, and it would provide just a little more insight, to people at either end of the spectrum, not because it's just evolution or creationism…it's good to just be aware, and the exercises help build awareness, that there are more than just one or two views on the subject." (10A2)

As the students in this focus group reflected on their own views, and those of friends who shared their views, they described the activity as an experience that could increase sensitivity and reasoned that this might be particularly helpful for individuals on either "end of the spectrum" who believed a choice had to be made between evolution and creation.

None of the students in the focus group of teacher 3 expressed surprise that some people did not accept evolution, but one student in the focus group of teacher 11 also found it interesting that someone might be opposed to evolution based on their religious beliefs:

"I thought it was interesting because I'm kind of the opposite. I'm not very religious, I wasn't raised in a religious household or anything, but I thought it was interesting like how there are people who find evolution offensive because of religion and they think there's a conflict. I just never really thought about it before." (11B1)

Participating in the activity exposed this student to perspectives they were not aware of and had not previously considered, an exercise they found interesting. One other classmate also expressed a similar interest in learning more about an extreme view they felt was held by some religious people, but not their religious classmates:

"It might be fun to see their [creationist] side of the story. Like why they [evolution and religion] couldn't coexist or why they don't want to look at it and things like that. Because I feel like, at least in the class that I was in, we didn't have anybody that was like that. So it would be nice to see someone else for a first hand account of what it's like and where they are coming from." (11B5)

This student was specifically interested in learning more about a view with which they had no firsthand experience.

4. Students questioned the appropriateness of the activity

This theme had the least number of instances but appeared in all three focus groups; it was voiced by one student each of teachers 10 and 11, and two students of teacher 3. While not a majority opinion, it is an important reminder that the CRS activity is an unusual one for a science classroom and may not be welcomed by all students.

The student of teacher 10 who voiced this theme never described their own religiosity, but during the focus group discussion they did express surprise that "the vast

majority of Americans do not accept evolution" and noted that "all of my friends believe evolution." Early on in the discussion this student expressed surprise that the first exercise opened the possibility of a reference to religion:

> *"One thing that just shocked me in the homework questions about why study evolution [exercise 1], it felt like there was kind of this idea, I felt like it kept trying to reference religion, but it was almost skirting around it,…all the questions were kind of hinting at religion without ever saying it…" (10B1)*

Later in the discussion the student refers to a previous experience in another school learning about evolution and explicitly states their preference for restricting the biology classroom discussion to science:

> *"I think their approach [in previous school], they didn't look at religion at all, I kind of preferred that because, I just feel like, this is a biology class, this isn't religion class or something, in biology class we're going to learn the scientific point of view of evolution, so for me, that's just what I feel, that since this is a science class we learn the science." (10B1)*

For this student the activity introduced the possibility of a discussion that, in their opinion, was not appropriate for the science classroom. It is probably safe to assume that for this student evolution did not present any challenge to personally held beliefs and no acknowledgement of personal concerns was necessary for them to comfortably engage in learning about evolution. In fact one of the student's final comments in the focus group was that they "would like evolution spoken about more authoritatively."

The student who expressed this theme in the focus group of teacher 11 also gives us no hint of their personal religiosity and is succinct in their reasoning:

> *"I would focus more on science because it is a science class. Maybe just acknowledge that there are different points of view about evolution, but right now this is just what we know. This is the science that we've proven and that we have a theory about and show that and learn it." (11B3)*

The student does not see the value of a prolonged discussion that ventures beyond the science of evolution.

The objections raised by one student in the focus group of teacher 3 questions the appropriateness of the activity from another perspective, namely that the activity might entail more personal sharing then a student is comfortable with:

> *"I was comfortable sharing my views within our group because we got to choose where we sat, so I was comfortable with the people in my group, but I still, I don't think its anybody else's business what I think about evolution, or, you know from my home or from my religion, it's nobody else's business about what my religion is, so when you ask those questions about religion…, everyone's responding from what they are, and that wasn't something I wanted to share with the class, so I thought that was an uncomfortable question to ask you to share with the class." (3A5)*

We do not know from the focus group discussion whether this student considers themselves more or less religious than their classmates, but the student reiterates their opposition to any discussion of religion alongside evolution:

> *"I didn't like exercise 3 [relating ways of knowing], I think it should have been gotten rid of completely because I think religion should have been left out of it, altogether left out, because instead of looking at different explanations, we should have just learned evolution." (3A5)*

After this comment another classmate responded offering a reason why the exercise might be useful:

> *"I get where they're coming from with how they should be separate [religion and evolution] but at the same time, you're going to be dealing with both, so it was kind of nice to like learn about how to handle that through a simple worksheet instead of being thrown out into the real world where you have to then deal with it either way." (3A4)*

The religious classmate who offered this defense of the exercise had previously described her appreciation of this exercise because it offered her possibilities for a non-conflict relation between evolution and religion. The classmate who objected to the exercise replied:

> *"I just don't think it's the school's job to help us with that, that's all" (3A5)*

The reality displayed by this exchange is that while the exercises were viewed as helpful by one student, another student viewed them as inappropriate, but these students must share the same classroom. While a second student of teacher 3 also felt that only evolution should be taught in the science classroom, this was a minority expressed opinion in all three focus groups.

Teachers' evaluation of CRS Activity #1

Teachers were asked to respond in writing to two survey questions about the CRS-whether or not they would use the activity they field tested in the future, and to tell us anything else they would like us to know about their

experience using the activity. All three teachers who used Activity #1 responded that they would use the activity in the future, but teacher 3 indicated they would "modify it to work as an embedded theme in multiple units, not all at once." While we recommend that the activity be completed prior to any instruction on evolution in classes where the teacher is aware that students are troubled by the topic, we also note in directions to teachers that alternatively the activity could be used at the first appearance of student discomfort or resistance. Understandably, teachers may well find that particular exercises in the activity are more useful for their classroom situation than others and use discretion as to when to introduce those exercises.

Teacher 11 expressed frustration with the time constraints in an AP classroom:

> *"For my time, there was too much to do. I liked the activities, but in AP time is always of the essence and this took me many class periods.*

Two class periods were required for the teacher to complete the activity, which amounted to over 70 min of class time.

Teacher 10 also committed more than one class period to the activity but described a new appreciation for the value of taking this time:

> *"This was the first time I have taken class time to address the question, 'Why Study Evolution?' In years past, I took for granted that everyone would be on board and if they were not there was not much I could do about it. I appreciate the way this structured lesson helped me slow down and acknowledge that certain people have doubts about the evidence for evolution. Those doubts should not have to be muffled. There is space for such dialogue, without diminishing the significance of evolution to the study of biology."*

We recognize that teachers will vary in their decision about taking class time to proactively address cultural concerns about evolution, whether out of a wariness about these types of discussion in the classroom, or because of time constraints. This recognition was the reason for creating a resource that provided not only classroom activities, but also background information for teachers to help them respond to students concerns if the students independently voiced those concerns.

Common themes for CRS Activity #2

CRS Activity #2 was field tested by the same teacher (14) with two different classes. All of the students in each class were invited to participate in the focus group sessions and these sessions were scheduled during regular class time. This resulted in 13 students participating in focus group 14-1 and 18 students participating in focus group 14-2, more than the ideal 8 to 11 students that participated in the focus group sessions for CRS Activity #1. The two focus group sessions for CRS Activity #2 were each only 25 min long. These factors are a challenge for facilitating a rich conversation with participation by the majority of students; for the focus group with 18 students, only 50% participated in the discussion. Despite the shorter time and large number of participants, the focus group with 13 students had a participation rate within the range of the CRS Activity #1 focus groups, 69%. As noted previously, because of the challenges presented by number, size and timing of the focus groups for Activity #2, the findings presented here are tentative. We present them here only to be seen as generally supportive of the goals of the CRS resource.

The students of teacher 14 had the same pre-curriculum GAENE score as the students of teacher 10, the students with the highest pre–curriculum GAENE score of all the classes that participated in a focus group for CRS Activity #1 (Pobiner et al. 2018). Only one student of teacher 14, in focus group 14-1, identified themselves as religious during the discussion. None of the students in focus group 14-2 identified themselves this way, but one student did note that all of them "have different beliefs."

1. Activity was positively anticipated

Before coming to class to participate in CRS Activity #2, students had been assigned a historical character. Their teacher invited them to attend the next class dressed in the costume of their assigned character and told them they would receive extra credit for doing so. Students welcomed the novelty of a historical role play in a science classroom and several expressed excitement about the activity:

> *"When I found out that we were acting I was really excited because I think that kind of stuff is really fun. And I thought it was a unique and interesting assignment, just because its something you don't usually do, act in a biology class or dress up." (14-2A2)*

This student expressed an appreciation for the chance to play a character. Likewise, a student in the other class noted the added value of learning in this fashion rather than just "reading off the paper":

> *I thought it was exciting because I'm more of an interactive learner, I like [both] visuals and doing stuff, and that's what it was like." (14-1A2)*

Students in both classes assumed that participating in the activity meant class would be fun and perhaps less rigorous then usual:

> *"I thought it would be fun because like [classmate] said, no notes, its kind of easy going and also I wanted [a part] in the play…" (14-1A2)*

This positive anticipation was also expressed by students in class 14-2:

> *"I thought that at first it was going to be fun because obviously if your dressing [up] its not going to be as hard. You didn't just say we are going to be writing a paper or something. So I guess my first thought [about it] was positive." (14-2B1)*

While these students expressed looking forward to the activity because of its unique nature in comparison to their previous classroom experiences, one student in class 14-2 described a scholarly interest:

> *"I was looking forward to it because I thought it would give me a good kind of backdrop as to what was going on during Darwin's time." (14-2A1)*

This student anticipated the historical insight the activity would provide.

When students spoke about their expectations of the activity, in both classes there was a mention of the possibility of a debate:

> *"I was kind of excited because that way I [would get to] argue, and I love debate." (14-1B2)*

For this student the possibility of a debate was something to look forward to but, for the one student in the group who had identified as religious, the possibility of a debate was expressed as a reason for concern:

> *"I was a little concerned at first because I knew a little bit of background about this debate, and I knew it would have a lot of religion in it, and I'm religious myself, so I was a little worried about people bashing my views, but it didn't really get to that, so I was happy." (14-1B1)*

While the description of the activity provided for the teacher, and the instructions to students for the exercises, do not describe the activity as a debate, both students and the teacher used this term to discuss the activity. The "debate" scenario these students envisioned is not supported by the design of the exercises and, as the above student noted, never occurred. The activity is purposely designed to *avoid* a student debate and teachers are encouraged to clarify this point when beginning the exercises. That said, this student's comment during the focus group served as a reminder that while many students might approach the activity with positive anticipation, this may not be the case for all students.

2. Encouraged an understanding of the cultural context of modern and historical views about evolution

Students in both focus groups of teacher 14 expressed having a general awareness of famous historical debates about evolution. Participating in the exercises led students to think explicitly about how the characters' backgrounds might have influenced their views on Darwin's theory. For students in focus group 14-1 the discussion centered on modern day opinions about evolution, including how they might be related to religious beliefs. In response to the question "Tell us one way in which these activities impacted your own understanding of the reasons why people react to the theory of evolution differently," the first student to reply stated:

> *"I just know that previously before I came here, I'd gone to a private school, and they don't teach evolutionary theory in private school, so I could see where religious people, because [they] don't have exposure to [evolution], have different understandings and beliefs. Seeing the different role plays of the historical figures from a religious aspect and a scientific aspect, you could see both [views]. You could see how in their eyes [a religious person] they might see something [that] they haven't been exposed to" (14-1A3)*

The historical role play reminded this student of their experience in a previous school where evolution was not taught. We can assume from the context of the student's remarks that this was because of a perceived conflict with religious beliefs. The student found, in the examples of the historical characters, insight into the views of a religious person who has never explored evolution from a scientific perspective. One of the student's classmates then responded:

> *"Well this is sort of interesting to me, because as a child I was sort of a blank slate, no one swayed my opinion…I learned about it [evolution] myself… seeing how other people were brought up and how their opinions were formed, it [brought] clarity as to how people could see things." (14-1B2)*

The activity also brought this student to think about their own experience with the topic of evolution and reflect on why their "opinion" might be different, namely because of their families approach to learning about evolution. They recognized that a different cultural context could result in a different opinion about the topic. This observation was confirmed by another student's remarks:

"It [the activity] helped me realize that the background that people come from really makes a difference because the way these people [historical characters] were raised and what they went to school for kind of had an effect on how they felt about the theory of evolution." (14-1A5)

This awareness of the impact of cultural context on an individual's views about evolution arose in the conversation again when students were asked to think about inviting someone to participate in the activity:

"I think for some people this could be really enlightening, especially what [classmate, (14-1A5)] said. What they were saying…different careers and upbringings can influence your opinion and that, [the activity] might lead people to understand each other better, and then same with [classmate], maybe respect each other more…seeing it from another viewpoint." (14-1A2)

In this example the student both recognized the impact of cultural context on views about evolution and suggested that this recognition might help people both understand the other's view better and, in agreement with another student, lead to greater respect between individuals.

The discussion that took place in focus group 14-2 was more reflective about historical arguments in favor of, or opposed to, evolution rather than modern day views:

"It was cool that we were able to see that it was not just religion that conflicted with evolution, it was also other science…like Lord Kelvin and his mathematical equations." (14-2B5)

The exercise included Lord Kelvin as an example of a religious scientist who was opposed to evolution, not because of his religious beliefs, but because the immense time required for evolution to occur was not compatible with his calculation of the age of the earth. In this case the cultural context that needs to be accounted for is the best science of the day and the student appreciated this fact. In response to this observation another student remarked:

"I think there's some logical points and people could draw some conclusions against [evolution]. However, I think I can see past those …[given the] modern era with new evidence. But I still think that a lot of the reasons why people didn't agree with it [were] very sound at the time for their own understanding." (14-2B2)

This student, while acknowledging that some of the initial opposition to evolution made sense in light of the science of the time, also made the connection that new evidence supported the theory. Just as students in focus group 14-1 saw value in increasing understanding about different modern day views of evolution, these students saw value in increasing understanding about the historical views. For example, in thinking about a reason for inviting someone to participate in this activity one student said:

"I think it would help someone to really understand the arguments that were made [about evolution]. Maybe I would invite them to get a better understanding." (14-2A1)

The common factor in understanding both modern and historical views that this activity brought to light for the students was cultural context, whether that be an individual's schooling or family background, or the type of scientific understanding available to the individual.

3. Students recognized that this activity could make some people uncomfortable

As described in the context of theme 1, some students anticipated a debate and for the student who identified as religious in focus group 14-1 this possibility caused reason for concern. While the exercises did not lead to heated debates, the students were aware that modern cultural concerns about evolution exist and they wondered if the exercises might be uncomfortable for individuals who shared the historical characters' religious concerns. This was expressed particularly by students in focus group 14-1 when they were asked whether or not they would invite someone to class to participate in the role play activity:

"[I would not invite someone] because some people are very sensitive about their religious beliefs." (14-1B3)

When asked to elaborate the student responded:

"This lesson in particular doesn't really have anything that would be considered too offensive to people of almost any different religious background, but it could cause people to look at things differently and it is good to expose them in this way, but not everybody is going to accept the different forms of exposure…" (14-1B3)

The student who had identified as religious would consider inviting someone to class, but only in a particular instance:

> *"I also think that if I were to invite a friend, I'd be sure that they had some level of respect and tact because we've been in class all semester and we're actually pretty good friends and we respect each other, but if I were to bring in somebody from the outside, even though this is from a historical context, the debate[s] are kind of still going [on] sadly, and people have opinions that they want to voice, and even though you're trying to keep a role play peoples' opinions come out, and if they're in conflict and they don't respect each other, it briefly turns into a heated argument, and its not great…" (14-1B1)*

This concern was not expressed at all by students of the teacher's other class who participated in focus group 14-2, but there was also no student in this class who had explicitly identified themselves as being religious. This activity was designed for classrooms where the teacher believes that the majority of students are not opposed to learning about evolution because of cultural or religious concerns, and the activity is intended to be used after the students have completed their instruction on evolution. The students' comments about the potential impact of the activity on religious peers is a reminder of the importance of creating a classroom environment that is respectful of all student views, including those in the minority.

Teachers' evaluation of CRS Activity #2

Only teacher 14 field-tested Activity #2. This teacher also reported that they would use the activity in the future and offered a suggestion for revision:

> *"I think this activity was near perfect, but I would like to see more perspectives of scientists [in exercise 3]. Although scientist perspectives were presented in the role play, there were none presented in the examination of the interplay between religion and science. I would like to see some modern day perspectives of scientists that are atheists, but also of some that are religious."*

The final version of the resource now available online includes this revision. We have added statements from three individual scientists that illustrate different approaches to the relationship between science and religion and include both religious and non-religious scientists.

Discussion

Study limitations

Noted below are several limitations of this study including the variation in timing and length of focus groups, the limited diversity of student and teacher populations, and the variation in fidelity to CRS activity lesson plans. As previously noted the timing and length of the focus groups varied. While three of the focus groups met for an hour, two only met for 25 min. Students of two teachers met the same day as the instruction occurred, either immediately after the class or later in the evening, students of one teacher met the following afternoon, and students of one teacher met for the discussion 7 days after experiencing the CRS activity. Each session began with a reminder that the focus of discussion would be the CRS activity the class had experienced and the exercises pertinent to each activity were reviewed with the students to help them recall the experience. Not surprisingly, the group that needed to be redirected the most in terms of reflecting on questions in light of the CRS activity, rather than the evolution curriculum unit they experienced, was the class whose focus group occurred 1 week after they had completed CRS Activity #1. That said, in general students from this class vividly remembered the CRS activity which perhaps speaks to the novelty of this approach in a high school science classroom. It is also not surprising that the number of instances recorded for each of the themes identified for Activity #2 is lower than that identified for Activity #1, given that the focus groups with students who experienced Activity #2 were of a much shorter time period.

It remains to be seen how the CRS activities would be experienced by more diverse student populations and by teachers less confident with the subject of evolution. All of the students from the focus groups in this study were advanced placement biology students in suburban school communities. The majority of students from these classrooms were Caucasian with fewer Asian, Hispanic, and African American students (see Pobiner et al. 2018). The four teachers of these students varied in their years of experience teaching evolution, yet all described themselves as "very confident" teaching evolution. These teachers were not reluctant to teach evolution, nor did their students express a reluctance to work to understand the subject material. However, it is noteworthy that even in these ideal learning environments, students expressed concerns about the subject matter in relation to their own personal religious beliefs or the religious beliefs of their friends and family, and all of the teachers reported having to face sensitive issues with the subject in the past.

The lead author observed the field test teachers using the CRS activities in order to document their fidelity to the lesson exercises. In evaluating the students' experience of the activities from the focus group data it is also important to note that the three teachers who field tested CRS Activity #1 varied in their fidelity to the lesson exercises. One teacher chose to begin the activity with the "Ways of Knowing" exercise rather than small group discussions of the homework assignment "What Do You Know about Evolution?" Another began immediately correcting misunderstandings about evolution that were revealed by this homework assignment. The teachers also varied in whether or not they asked students to discuss their answer to the question posed in the "Ways of Knowing" exercise in their small groups, and only two critiqued answers in terms of a correct understanding of the nature of science. The teacher who omitted this step, however, had spent time discussing the nature of science in response to misunderstandings about evolution that had been revealed by the first exercise. While all the teachers had students complete the third exercise "Relating Science to Other Ways of Knowing," only two classes worked in small groups to complete the exercise, but all teachers used a class discussion to share student answers.

CRS Activity #2 was field tested with two different classes by the same teacher. Students of both classes arrived to class expecting that they were going to be participating in a "debate", though the exercises are not described this way in the CRS resource. The teacher varied at which point in the lesson students viewed the video about Charles Darwin: one class followed the lesson plan, which suggests the video be shown at the beginning of class, and the other class viewed the video after character group interviews. The students were also assigned an additional reading for the "Relating Science to Other Ways of Knowing" exercise.

It is to be expected that teachers, especially experienced ones, will modify lesson materials to meet the needs and time constraints of their classes. Some of the observed departures from lesson fidelity in this study are more concerning than others. For example, while the order of exercises one or two in CRS Activity #1 may be flexible, immediately correcting misconceptions about evolution might lessen students' appreciation of the invitation to express their concerns. Likewise for CRS Activity #2, changing when in the exercises students view the video may be inconsequential, but leaving students with the idea that they would be participating in a debate could increase anxiety about the subject material. These field test observations of teachers were used to revise the final CRS resource specifically in order to alert future teachers who use the resource to these concerns.

Only four of the seven teachers who field tested the CRS activities were observed using the activities. However, despite the uncertainty in the fidelity to lesson plan of the three unobserved teachers and the documented departures from lesson plans of the four observed teachers, 81% of the students surveyed about the usability of the materials in reference to the criteria guiding their development (Table 1) judged the materials as "Just Right" (Pobiner et al. 2018). These results are encouraging in terms of the possibility of creating a supportive environment in the science classroom using the CRS activities, even if fidelity to lesson exercises is variable.

Finally, as is true with any study undertaken by interviewing individuals or groups, we note that social desirability could have biased the students' responses to focus group questions. However, we are encouraged by the discourse that took place between students and their seemingly willingness to express a variety of perspectives, sometimes agreeing and other times disagreeing with their classmates' comments. As is appropriate for an exploratory design-based study, the results from the TEtHE project, including these focus group results, will be used to inform more rigorous future work.

Impact of the CRS resource teaching strategies

One of the questions guiding the research and evaluation of the TEtHE project (Pobiner et al. 2018) was "To what extent can the project team develop a set of Cultural And Religious Sensitivity (CRS) resources that provide teachers with strategies that create a supportive classroom environment for the teaching of evolution and support an understanding of the nature of science?" Two of the themes identified from the focus groups of students who experienced CRS Activity #1, theme #1, "Encouraged respectful classroom discussion and reduced tension around the topic of evolution" and theme #2, "Increased awareness of the possibility of non-conflict between evolution and religious beliefs," are explicitly supportive of criteria 2 and 5 used to develop the CRS (Table 1). Specific quotes from these students, considered as a whole, are generally supportive of all of the criteria used to develop the CRS (Table 1). As described in reference to specific themes, students noted several benefits from participating in CRS Activity #1, either for themselves, or (they assumed) for others. These included easing the tension of religious students around the topic of evolution, interesting and non-confrontational class discussions, the respect shown for other's opinions, an appreciation of the discussion of ways of knowing, recognizing that evolution could coexist with personal religious beliefs, and an increased sensitivity concerning others' views

about evolution and religion. All three teachers of these students reported that they would use the exercises again with the most experienced two teachers noting the caveats of time constraints or possibly modifying the exercises to be used throughout their instruction on evolution. The least experienced teacher noted how the exercises could be used to acknowledge concerns "without diminishing the significance of evolution to the study of biology."

CRS Activity #2 was designed for those classrooms where the teacher does not believe cultural concerns about evolution are personally important to their students. Rather than exercises designed to ease students concerns about learning evolution, it instead offers an opportunity for students to review and use learned concepts about evolution and the nature of science, while increasing their understanding of the cultural controversy that can surround the study of evolution. However, this is accomplished in a context that is supportive of the overall criteria guiding the development of the CRS. One of the themes identified from the focus groups of students who experienced CRS Activity #2, theme #2, "Encouraged an understanding of the cultural context of modern and historical views about evolution," and specific quotes from these students, are also supportive of the criteria used to develop the CRS. As described in reference to this theme, students noted several benefits from participating in CRS Activity #2, either for themselves or (they assumed) for others. These included participating in a unique and interesting assignment, an appreciation of the importance of new evidence to the support of evolutionary theory, gaining an understanding of how people came to their view of evolution, and increasing respect for others. The teacher who field tested this activity also reported that they would use it again and offered suggestions for adding material to expose students to the variation in scientists' personal approach to relating science and religion.

The CRS development criteria have much in common with the practices described by Barnes and Brownell's (2017) framework for Religious Cultural Competence in Evolution Education (ReCCEE). This framework identifies successful practices reported in previous studies for addressing evolution and religion in a college classroom, namely acknowledge, explore, teach the nature of science, outline the spectrum of viewpoints, provide role models and highlight potential compatibility (see Table 2, Barnes and Brownell 2017). The "explore" practice explicitly recommends that students be encouraged to explore their personal views on evolution and religion. The CRS development criteria did not specifically include a call for students to do this, but theme #3 identified for CRS Activity #1, "Encouraged reflection on own views and interest in others' views" illustrates that completing the exercises for this activity also supported this practice.

Students who contributed to the focus group discussions largely noted benefits of participating in the CRS activities and the themes identified from the focus groups suggest that the CRS development criteria were met. We are confident that the resource can provide teachers with strategies to create a supportive classroom environment and support an understanding of the nature of science. However, one of the themes identified for each of the CRS activities indicated that students either did not themselves experience the activity positively or were concerned that other students may have a negative experience.

For CRS Activity #1 this was theme #4, "Students questioned the appropriateness of the activity." This theme had the lowest frequency of incidences and was expressed by the least number of students in all the focus groups, for two of the focus groups just one student and in the remaining focus group two students. We do not know for certain whether or not these students were themselves religious, but the focus group in which two different students raised this concern was from the class with the lowest pre-curriculum GAENE score. One of these students described the exercises as uncomfortable because they did not want to share their own religious orientation with the class. The two other students spoke of a preference for only science being taught in a science class. While the majority of students in all of these focus groups participated in the focus group discussion we do not know if those who largely remained silent also held minority views. This theme is a reminder that while science educators are grappling with how to effectively communicate evolution to students who perceive a conflict with their religious beliefs some of these students might prefer "just learning the science." Other students, perhaps regardless of their own religious views, may have little patience for discussions that include cultural controversies about evolution in the science classroom. The final version of CRS Activity #1, available online, was revised to remind teachers to be sensitive to both of these possibilities, assuring students that no one is required to share personal religious views and that the CRS exercises are an introductory activity and most of the student's instruction time will be spent on learning evolution.

For the focus group students who experienced Activity #2, only the religious student who was initially worried about a debate taking place spoke in terms of the activity personally making them uncomfortable, but three different students raised this concern in reference to how people with a religious view similar to those of historical characters opposed to evolution might experience the activity. The students raise an important point and while

this activity is intended for classrooms where the teacher does not expect that students are opposed to evolution, the final version of the CRS also reminds teachers using this activity to insist on respect for all student worldviews and to recognize that this activity could be personally challenging for students in their classroom with a minority religious worldview.

As reported by Pobiner et al. (2018), another one of the research questions of the Teaching Evolution through Human Examples (TEtHE) design based study was "To what extent does the use of the curriculum units alone, and the curriculum units used in conjunction with the CRS activities affect student understanding of evolutionary concepts and their acceptance of evolution?" While there were no statistical differences in acceptance of evolution among students of teachers who used either of the CRS activities and those that did not, students of teachers who used one of the CRS activities generally showed larger increases in understanding of evolution than those whose teachers did not use one of the CRS activities (Pobiner et al. 2018). At minimum including these activities in the classroom did no harm in terms of students' understanding of evolution and the possibility remains that the larger increases in understanding may be attributable in part to an increase in student's comfort learning about evolution. To explore this possibility a more rigorously designed study than the exploratory TEtHE design-based study is required. However, we believe that both the quantitative and qualitative results from the field testing of the CRS are encouraging and suggest that the resource can provide useful teaching strategies that—when used with content instruction on evolution—can have a positive impact on student learning of evolution.

Acknowledging students' concerns as a pedagogical approach for teaching evolution to high school students

Our study is distinct from previous studies with high school students that included quantitative or qualitative measures of the impact of acknowledgement as a pedagogical approach (Wiles and Alters 2011; Wiles 2014; Yasri and Mancy 2016) in that we have designed and field tested materials to be used with public or private AP high school students in the US during regular biology classroom instruction on evolution, rather than using materials and approaches that depend on specialized extracurricular activities. The intended audience for the TEtHE project was AP students and their teachers, but with adjustments for reading level we think that the classroom activities described in the CRS are appropriate for general biology classes as well; we are currently exploring the impact of these materials in an introductory high school biology population. Like previous work with LDS college students (Manwaring et al. 2015), our qualitative results presented here, and the quantitative results presented in Pobiner et al. (2018), are supportive of an acknowledgement of students' concerns about evolution paving the way for students' increased understanding of evolution. Woods and Scharmann (2001) have argued that acknowledging high school students' worldviews, specifically using small-group peer discussion as advocated in the CRS exercises, can be an important step in helping students progress toward a scientific understanding of evolution. Given that the CRS is designed for public high schools it cannot be focused on acknowledging the stance of a single religion, like the exercises in the Manwaring et al. (2015) study, but must acknowledge a range of religious worldviews. We believe exercise 1 "What Do You Know About Evolution" and exercise 3 "Relating Science to Other Ways of Knowing" of CRS Activity #1 promote this broader recognition.

Studies with college students in a public university (Barnes et al. 2017; Troung et al. 2018) demonstrated that an acknowledgement approach that includes a discussion of the variety of ways of relating evolution and religion, an explanation of the nature of science and the presentation of religious scientist role models contribute to students' awareness of the possibilities for a non-conflict approach between evolution and religion—an awareness which supports their study of the science of evolutionary theory. Many of the students in our focus groups who experienced CRS Activity #1 indicated that the CRS exercises produced the same outcome. However, the CRS exercise "Relating Science to Other Ways of Knowing" as field tested did not include any example statements from scientists, with or without religious worldviews. At the recommendation of one of the field test teachers this exercise now includes examples of statements from scientists who hold religious worldviews as well as a statement from one scientist who does not. We would argue that it would be inappropriate in a public high school classroom to risk promoting one religious view over another by inviting a religious scientist to discuss their particular reconciliation of religion and evolution, as was done at the college level in the studies by Barnes et al. (2017) and Troung et al. (2018). Wiles and Alters (2011) invited a theologian to speak to high school students about the compatibility of evolution with faith in the divine, but did so in an extracurricular seminar, noting that they felt this activity was not appropriate for the science classroom. While we appreciate the focus of these previous studies on reducing the perceived conflict of religious belief with evolution and the added value of providing role models to highlight this possibility, in a US public high school classroom caution must be exercised to not inadvertently promote one religious worldview over another. The CRS resource, like these previous studies, uses the bounded

nature of science as a tool for helping students manage any conflict they perceive between their religious beliefs and evolution (Southerland and Scharmann 2013) and includes examples of this approach being used by those with religious worldviews in the "Relating Science to Other Ways of Knowing" exercise. However, this exercise also includes examples of those taking a conflict approach to evolution and religious belief. It is worth noting that recent work by researchers studying climate change literacy confirm the benefits of acknowledging a diversity of viewpoints through public dialogue that encourages a mutually respectful discussion (McNeal et al. 2014).

The results presented for CRS Activity #2 are tentative in nature, but we can note that while this activity was not designed to specifically help students with religious worldviews comfortably study evolution, one of the themes identified for this activity "Encouraged an understanding of the cultural context of modern and historical views about evolution" included instances of students describing the activity as useful for increasing respect between individuals with different views about evolution. These insights may serve students outside of the classroom as well.

It is noteworthy that for previous studies, as well as our own, the total amount of class time committed to these exercises was somewhat minimal: for this study and two of the previous studies, about 75 min (Manwaring et al. 2015; Yasri and Mancy 2016), for two other studies a total of 120 to 140 min (Wiles and Alters 2011; Barnes et al. 2017) and for the most recently published study, only 6 min (Troung et al. 2018). The case can be made that for a minimal expenditure of class time the acknowledgement of students concerns about evolution, the approach advocated in this study and previous studies, can increase the likelihood of instruction on evolution leading to an increased understanding of evolution, and while not the case in this study but shown in previous studies, an increased acceptance of evolution. Furthermore, this approach need not be limited to college classrooms, private high schools, or extracurricular seminars offered outside of regular biology classroom instruction on evolution.

Conclusions

Many students are aware of the religious and cultural concerns surrounding the teaching of evolution, whether or not they personally share these concerns. The majority response from students who participated in the focus groups was appreciation for the opportunity to have a respectful discussion that acknowledges these concerns. For some students the CRS (Cultural and Religious Sensitivity Teaching Strategies Resource) activities introduced them to the possibility of a non-conflict relation between evolution and religion; for others it helped them gain insight into views they did not necessarily share. Both of these experiences can be conducive to decreasing tension around the topic of evolution and helping to create a non-threatening classroom environment; some students explicitly expressed that the activities were a comforting way to begin their study of evolution. That said, a minority of students expressed frustration at a discussion about religious and cultural concerns taking place in the science classroom or concern that increasing awareness of the variety of possibilities for relating science and religion might be unwelcomed by some students. We conclude that for most, but not all students, acknowledging religious and cultural concerns about evolution is an effective classroom strategy for creating a supportive classroom environment to learn about evolution. While the CRS activities are a useful approach for creating a positive classroom environment in which students know that their worldviews will be respected, their successful implementation depends on sensitivity not only to the range of worldviews students may bring to the classroom but also their comfort in participating in the exercises.

Though the CRS resource was developed as part of an exploratory design-based study, both quantitative and qualitative results to date for this resource, as well as previous work by others, indicate that acknowledgement of religious and cultural concerns along with a focus on the nature of science and the variety of ways of relating evolution and religion, is a promising pedagogical approach to teaching evolution and one that merits further research. The TEtHE exploratory study is the first study to document both the quantitative and qualitative results of acknowledging religious and cultural concerns about studying evolution in US public and private AP high school biology classrooms during regular classroom instruction on evolution. Future work will focus on testing the approach taken in the CRS resource with high school general introductory biology classes rather than AP biology classes. In particular, the resource will be tested in the southeastern US where religious and cultural concerns about the teaching of evolution are prevalent and in a diversity of school settings by teachers with various levels of experience and confidence teaching evolution. This future work will include a more rigorous experimental design to explore the impact of the CRS on both the understanding and acceptance of evolution by high school students using either human or non-human examples to learn evolutionary concepts.

Abbreviations
CRS: Cultural and Religious Sensitivity Teaching Strategies Resource; LDS: The Church of Jesus Christ of Latter-day Saints; TEtHE: Teaching Evolution through Human Examples.

Authors' contributions
All authors made substantial contributions to the conception and design of the CRS resource. The focus group format was drafted by CMB and critically reviewed by BP. The analysis and interpretation of focus group transcripts was undertaken by CMB. PB also contributed to the design of the focus group analyses. The manuscript was drafted by CMB and critically reviewed by BP and PB. CMB took the lead on manuscript revisions in response to reviewers' comments and suggestions. All authors read and approved the final manuscript.

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Competing interests
The authors declare that they have no competing interests.

Availability of data and materials
The qualitative data reported are from transcripts of focus groups that were coded to identify repeating ideas and themes. The frequency of instances used to identify themes are listed in Tables 5, 6 of the manuscript. The raw transcripts from the classes of just four teachers are not being made publically available in order to protect the identity of the students.

Consent for publication
Not applicable

Ethics approval and consent to participate
All teacher participants were provided with a passive informed consent form, acceptance of which was taken as consent. All student participants were provided with a passive informed consent form for their parents as most were under the age of 18. Parents could sign and return the form to their child's teacher if they did not want to participate. All student participants were identified with a student code and data was de-identified immediately upon collection. All procedures were reviewed and approved by the Smithsonian Institution's Institutional Review Board (Approval Number HS13057, approved September 13, 2013).

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