A New Measure of Students' Perceived Conflict between Evolution and Religion (PCoRE) Is a Stronger Predictor of Evolution Acceptance than Understanding or Religiosity

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ABSTRACT

Evolution is controversial among students and religiosity, religious affiliation, understanding of evolution, and demographics are predictors of evolution acceptance. However, quantitative research has not explored the unique impact of student perceived conflict between their religion and evolution as a major factor influencing evolution acceptance. We developed an instrument with validity evidence called "Perceived Conflict between Evolution and Religion" (PCoRE). Using this measure, we find that, among students in 26 biology courses in 11 states, adding student perceived conflict between their religion and evolution to linear mixed models more than doubled the capacity of the models to predict evolution acceptance compared with models that only included religiosity, religious affiliation, understanding of evolution, and demographics. Student perceived conflict between evolution and their religion was the strongest predictor of evolution acceptance among all variables and mediated the impact of religiosity on evolution acceptance. These results build upon prior literature that suggests that reducing perceived conflict between students' religious beliefs and evolution can help raise evolution acceptance levels. Further, these results indicate that including measures of perceived conflict between religion and evolution in evolution acceptance studies in the future is important.

INTRODUCTION

Evolution is a foundational component of every level of biology education (American Association for the Advancement in Science [AAAS], 2011; Brownell *et al.*, 2014). However, many college biology students in the United States reject most of evolution that has taken place during the history of life on Earth and only accept that small microevolutionary changes have occurred in populations over short periods of time (Nadelson and Southerland, 2012; Sbeglia and Nehm, 2019; Barnes *et al.*, 2020a; for a review article, see Pobiner, 2016). Decades of research has examined the causes of this rejection of evolution among students (Lawson and Weser, 1990; Rutledge and Warden, 2000; Brem *et al.*, 2003; Sinatra *et al.*, 2003; Weisberg *et al.*, 2018), and religiosity and religious identification have been documented as key factors correlated with evolution rejection (Glaze, 2017; Dunk and Wiles, 2018; Barnes *et al.*, 2019). However, the psychological construct of *perceived conflict* between religious beliefs and evolution has been explored less and may be a more direct source of rejecting evolution than the more commonly studied construct of religiosity (Nehm and Schonfeld, 2007; Barnes *et al.*, 2017a, 2020a).

Rebecca Price, *Monitoring Editor*

Submitted Feb 2, 2021; Revised Jun 1, 2021; Accepted Jun 10, 2021

CBE Life Sci Educ September 1, 2021 20:ar42

DOI:10.1187/cbe.21-02-0024

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In this study, we created a new instrument to measure perceived conflict between a student's religion and evolution, including students' perceived conflict between evolution and their 1) belief in God,[1] 2) personal religious beliefs, 3) religious teachings, and 4) religious communities' beliefs. We provide validity evidence of the new instrument based on content and internal structure (American Educational Research Association, American Psychological Association, and National Council on Measurement in Education [AERA *et al.*], 2014) by analyzing prior qualitative literature and conducting Rasch analysis on response data collected from students in college introductory biology classes ($n = 2275$). We also examined process response validity through cognitive interviews with students and provide validity evidence based on relationships with other variables (AERA *et al.*, 2014), including concurrent validity (e.g., correlation with prior measures of similar constructs) and relationship with other important variables (e.g., acceptance of evolution). Specifically, we explored whether perceived conflict between students' religion and evolution can explain acceptance of evolution to a greater extent than religiosity, religious affiliation, and other factors associated with low evolution acceptance, such as a low understanding of evolution. Further, we explored whether the associations of religiosity and religious affiliation with lower evolution acceptance may be moderated and/or mediated by students' perceived conflict between their religions and evolution.

We assert that this shift in focus from religion as the source of rejection of evolution to perceived conflict with religion as the source of rejection can help instructors increase student acceptance of evolution. While a student's religious identity is unlikely to change, prior research illustrates that instructors can reduce their students' perceived conflict between religion and evolution while teaching evolution (Barnes and Brownell, 2017). We hope that this new instrument will help researchers explore how to reduce perceived conflict between students' religious beliefs and evolution and increase students' evolution acceptance.

BACKGROUND

College Biology Student Acceptance of Evolution Can Be Low

Evolution is different from many other core concepts taught in biology, because it can be controversial among students (AAAS, 2011; Barnes *et al.*, 2020a). Many college biology students do not think billions of years of macroevolutionary patterns are real and that humans share a common ancestor with the rest of life on Earth. For instance, it has been shown that 30% of introductory college biology students in the United States do not think that life on Earth shares a common ancestor (Barnes *et al.*, 2020a). Thus, evolution is different from topics such as photosynthesis and cellular respiration, because as students learn more about photosynthesis or cellular respiration, they are almost certain to believe what they are learning is true; however, with evolution, students may not become more accepting of evolution as they learn more about evolution (Sinatra *et al.*, 2003; Hermann, 2012).

Motivated reasoning and identity-protective cognition can explain the differential impacts of students' understanding of evolution on their acceptance of evolution compared with other topics such as photosynthesis and cellular respiration. Identity-protective cognition is a form of motivated reasoning and occurs when some one reasons toward a conclusion that is more aligned with their social identity rather than what is most accurate, because the more accurate information is a threat to their identity (Kahan *et al.*, 2007; Kahan, 2017). Students accept that photosynthesis and respiration are true as they learn it, because these topics present no threat to their identities. However, individuals can perceive a conflict between evolution and their religious identities, which may reduce the positive impact of understanding evolution on acceptance of evolution (Weisberg *et al.*, 2018) due to identity-protective cognition and motivated reasoning.

How Are Religiosity and Religious Affiliation Related to Acceptance of Evolution?

Religious affiliation refers to the religion with which a person identifies, such as Christianity or Hinduism, and religiosity refers to the strength of some one's religious identity (Cohen *et al.*, 2008). Students who affiliate with Christian religions and who score high on measures of religiosity tend to be less accepting of evolution (Glaze *et al.*, 2014; Rissler *et al.*, 2014; Dunk *et al.*, 2017; Barnes *et al.*, 2019). Similar patterns have been demonstrated for Muslim students (Barnes *et al.*, unpublished data; Jensen *et al.*, 2019). However, if rejection of evolution is a result of identity-protective cognition, then it is not religiosity or religious affiliation itself that is causing students' rejection of evolution, but it is actually the extent to which students perceive a conflict between their religious identities and evolution. In fact, a student can be highly religious and still accept evolution (Winslow *et al.*, 2011; Barnes *et al.*, 2017b, 2021; Barnes and Brownell, 2018), suggesting it is not religiosity itself that is the most direct construct related to low evolution acceptance.

Perceived Conflict between Evolution and Religion May Be a Major Explanatory Variable for Students' Evolution Acceptance

Perceived conflict between some one's religion and evolution is distinct from their religiosity and religious affiliation. For instance, some one can be a highly religious Buddhist who perceives no conflict between their religion and evolution or a moderately religious Christian who perceives a high amount of conflict between their religion and evolution. This conflict can originate from personal beliefs, from teachings of religious texts, from other religious individuals who interact with that person, or even from evolution instructors; the source of conflict is likely to be different for each person. For instance, students could perceive high conflict between religion and evolution within their religious communities, but low conflict between their own personal religious beliefs and evolution.

Perceived conflict between religion and evolution has been reported in qualitative research studies with students, and these studies suggest a significant impact of students' perceived conflict on their evolution acceptance. Multiple studies have documented the specific conflicts that students perceive between

[1]We recognize that, for polytheistic religions, the term "gods" would be more accurate than "God" to describe deities, but because the majority of religious students in the United States belong to a monotheistic religion, we used the term "God" in our study and in this article. We encourage the readers to think of this term as inclusive of any religion's higher power(s).

their religions and evolution; students discuss how they perceive a conflict with their belief in God and evolution (Winslow *et al.*, 2011; Barnes *et al.*, 2017a), and they highlight specific religious beliefs about the creation of the universe and timeline of creation that they perceive to be in conflict with evolution (Winslow *et al.*, 2011; Barnes *et al.*, 2017a, 2020c). Students have also reported how their evolution acceptance is impacted by perceived conflict with evolution among their religious communities and the teachings of their religions in houses of worship and religious texts (Barnes *et al.*, 2020c). Conversely, studies have shown that students can be religious and experience no conflict between evolution and their personal religious beliefs or religious communities (Barnes *et al.*, 2017b), and students who reported lowering their perceived conflict between their religions and evolution also reported increasing their acceptance of evolution (Winslow *et al.*, 2011). But despite the evidence from qualitative research that perceived conflict between religion and evolution may be a major factor impacting student evolution acceptance, quantitative studies on evolution acceptance rarely measure students' perceived conflict between their religions and evolution (for exceptions, see Nehm and Schonfeld, 2007; Barnes *et al.*, 2020a), but instead measure religiosity or religious affiliation (Glaze and Goldston, 2015; Dunk *et al.*, 2017; Barnes *et al.*, 2019).

There Are Gaps in the Current Literature on Students' Perceived Conflict between Their Religions and Evolution

Due to the lack of quantitative research on students' perceived conflict between religion and evolution, there are gaps in our knowledge of this variable and its relation to students' evolution acceptance levels. We do not know the average levels of students' perceived conflict between their religions and evolution, whether these levels differ depending on students' religious affiliations, and to what extent perceived conflict between religion and evolution can account for lower levels of evolution acceptance among students. Finally, we do not know the extent to which specific conflicts in different domains of a student's religious life (personal religious beliefs, belief in God, religious teachings, and within a religious community) may differentially predict students' evolution acceptance levels.

RESEARCH QUESTIONS

1. To what extent does average perceived conflict between religion and evolution vary across students with different religious affiliations?
2. To what extent does students' perceived conflict between their religions and evolution predict their evolution acceptance levels more than other commonly measured variables related to evolution acceptance?
   a. Do certain domains of perceived conflict predict evolution acceptance more than other domains of conflict?
3. To what extent does perceived conflict between religion and evolution mediate and/or moderate the relationship between evolution acceptance and religiosity?

METHODS

These data were gathered as part of a larger study examining the impact of Religious Cultural Competence in Evolution Education (Barnes and Brownell, 2017) on undergraduate biology students' evolution acceptance and their perceived conflict between religion and evolution. We recruited instructors via the Society for the Advancement of Biology Education Research Listserv, a network Listserv of community college instructors in California, and through personal connections with community college instructors in Arizona. We also used the directories of biology faculty from institutions in which there are large-enrollment introductory biology courses to identify and contact instructors. We asked instructors if they would be willing to send out a link to a Qualtrics survey to the students in their class and offer a small amount of extra credit for completing the survey. All activities were approved by Arizona State University's Institutional Review Board protocol 8191.

We collected data from students across 26 biology courses that were offered in 11 states (Arizona, Utah, Texas, New York, Alabama, Minnesota, North Carolina, South Carolina, Florida, California, and Oklahoma) at the beginning of the semester before they learned evolution. Courses were introductory biology courses for majors and nonmajors. The survey was open for ~1–2 weeks for each data collection to give students enough time to complete it. The survey questions used in analyses as well as the order in which the questions were presented to students can be found in the Supplemental Material.

Positionality

We acknowledge that our research team's identities influence and potentially bias our research. Our team's religious identifications include agnostic, atheist, Christian, and no religious identification. We bring our disciplinary expertise to this work as discipline-based education researchers in biology education, a psychometrician, and instructors and students in undergraduate biology courses.

Measures

Previously Developed Measures. To measure acceptance of evolution, we used the previously published Inventory of Student Evolution Acceptance (I-SEA), which includes 24 statements with which students agree or disagree on a five-point scale. The I-SEA measures acceptance of microevolution (e.g., "natural selection is a reasonable explanation that describes the ways in which groups of organisms have changed over time"), acceptance of macroevolution (e.g., "I think that new species arise from ancestral species"), and acceptance of human evolution (e.g., "like other organisms, the human species is a result of evolution from an ancestral group"; Nadelson and Southerland, 2012). We chose to use the I-SEA instead of other published instruments such as the Measure of Acceptance of the Theory of Evolution or the Generalized Acceptance of Evolution Evaluation (Rutledge and Warden, 1999; Smith *et al.*, 2016), because the I-SEA is the only instrument that disaggregates student acceptance of microevolution, macroevolution, and human evolution, each of which has been shown to be a different construct (Nadelson and Southerland, 2012; Sbeglia and Nehm, 2019). Further, the I-SEA does not have other limitations of other acceptance of evolution measurement tools (Barnes *et al.*, 2019; Sbeglia and Nehm, 2019).

To measure religiosity, we used four items from a previously published instrument used in the psychology of religion to measure student religiosity (Cohen *et al.*, 2008). The

items measure the intrinsic strength of one's religious identity (e.g., "I consider myself a religious person") and participation in religious activities (e.g., "I attend religious services regularly") and are similar to other common measures used both in studies of religion (Dingemans and Van Ingen, 2015; Ecklund *et al.*, 2018) and studies of evolution acceptance (Rissler *et al.*, 2014; Dunk *et al.*, 2017). The instrument consisted of four items with which the students agree or disagree on a five-point scale. A higher number on the scale indicates higher religiosity.

We asked students to self-identify from the following list of religious affiliations: agnostic, atheist, Buddhist, Christian–Catholic, Christian–The Church of Jesus Christ of Latter-day Saints, Christian–Protestant, Christian–Other, Christian–nondenominational, Hindu, Jewish, Muslim, nothing in particular, other faith, and decline to state. Students who chose a religious affiliation other than agnostic, atheist, nothing in particular, and decline to state were presented with our novel perceived conflict between religion and evolution measure described in further detail below in the *Development and Validation of the Perceived Conflict between Religion and Evolution (PCoRE) Measure* section.

We collected information to use as control variables in our analyses, including understanding of evolution, age, gender, race/ethnicity, and parent educational levels, because these variables are often related to acceptance of evolution (Bailey *et al.*, 2011; Baker, 2013; Rissler *et al.*, 2014; Sbeglia and Nehm, 2018). To measure students' evolution understanding, we used two subscales on the Evolutionary Attitudes and Literacy Survey (EALS; Hawley *et al.* 2010). We used the two subscales (14 items) from the instrument that measure "evolutionary knowledge" (e.g., "In most populations, more offspring are born than can survive") and "evolutionary misconceptions" (e.g., "Evolution is a linear progression from primitive to advanced species"). Students were asked to decide whether each item was true or false or whether they did not know enough to answer based on their evolution understanding. We chose to use the EALS to measure evolution understanding, because it has been used in other evolution education studies (Short and Hawley, 2015; Dunk *et al.*, 2017) and has shown evidence of reliability and validity among college students (Hawley *et al.*, 2010) and the items do not appear to conflate evolution acceptance with evolution understanding, which is a criticism of other evolution understanding measures (Glaze and Goldston, 2015; Smith and Siegel, 2016; Barnes *et al.*, 2019). We asked students to self-identify from the following list of racial/ethnic identities: 1) American Indian, Native American, or Alaskan Native; 2) Asian; 3) Black/African American; 4) Native Hawaiian or Other Pacific Islander; 5) Hispanic; 6) White; 7) other not listed; and (8) prefer not to answer. Students were instructed that they could check more than one box if they held multiple identities, and those students who did choose more than one box were categorized as multiracial. We also asked students to report gender, age, and parents' highest level of education to control for potentially confounding demographic factors related to evolution education outcomes (Dunk *et al.*, 2017; Sbeglia and Nehm, 2018; Barnes *et al.*, 2019, 2020b). All survey questions analyzed, in the order they were presented to students, are in the Supplemental Material.

Development and Validation of the Perceived Conflict between Religion and Evolution (PCoRE) Measure

We previously developed and published a unidimensional perceived conflict instrument that consisted of only four items (Barnes *et al.*, 2020a), but in this study, we created a novel multidimensional instrument that contains 20 items to improve upon the prior instrument. We expected the new 20 items to fall on four dimensions of conflict: perceived conflict between 1) one's belief in God and evolution, 2) one's personal religious beliefs and evolution, 3) the teachings of one's religion and evolution, and 4) one's religious community and evolution. We chose the four dimensions of conflict based on prior literature and interviews with students that indicated there are differences in perceived conflict across these different dimensions of one's religious life (Winslow *et al.*, 2011; Barnes *et al.*, 2017a, 2020c; Barnes and Brownell, 2018; Truong *et al.*, 2018). For instance, students may perceive broadly that they cannot believe in God and accept evolution (e.g., that one has to be an atheist to accept evolution), or they may perceive that more specific religious beliefs (e.g., humans were created by God separately from other animals) conflict with accepting evolution. Students may also perceive that specific religious teachings (e.g., that the Earth was created in seven literal days) conflict with evolution or that their religious communities do not accept evolution.

Our previous measure also did not specify whether students' perceived conflict was with microevolution, macroevolution, human evolution, and/or the common ancestry of life. Prior work shows that students typically perceive less conflict with nonhuman microevolution than human macroevolution (Nadelson and Southerland, 2012; Sbeglia and Nehm, 2019; Barnes *et al.*, 2020c). Thus, we created five items for each of the four dimensions of conflict that inquire about perceived conflict at different scales or contexts of evolution, including microevolution of nonhumans, microevolution of humans, macroevolution of nonhumans, macroevolution of humans, and the common ancestry of life. Because items on the perceived conflict instrument were constructed to measure conflict between one's personal religion and evolution, we did not present this instrument to students who were not affiliated with any religion or did not disclose their religious affiliations.

The prior literature on perceived conflict between religion and evolution was our primary source of *content validity* for this measure (AERA *et al.*, 2014) and guided the generation of items for the instrument. See Table 1 for a complete list of items in the final instrument.

To provide evidence of *response process validity* (AERA *et al.*, 2014), we conducted cognitive interviews (Willis, 2004; García, 2011; Castillo-Díaz and Padilla, 2013) with 10 undergraduate biology students who explained to the interviewer their thought processes as they answered each question on the survey. This helped us confirm that students were answering the questions based on their perceived conflict between religion and evolution and not an extraneous construct.

To provide evidence for validity based on the *internal structure* (AERA *et al.*, 2014) of the measure, we used Rasch dimensionality analyses. We followed the approach described by Sbeglia and Nehm (2018). We fit three polytomous partial-credit models: a unidimensional model with all 20 items (*irtmodel = PCM* in *TAM*), a two-dimensional model with

TABLE 1. Perceived conflict between religion and evolution survey items on the four dimensions of conflict[a]

Perceived conflict between belief in God and evolution (PCgod)	Perceived conflict b/w personal religious beliefs and evolution (PCbelief)	Perceived conflict b/w teachings of religion and evolution (PCteachings)	Perceived conflict b/w religious community's beliefs and evolution (PCcommunity)
My belief in God makes it harder to believe that all of life on Earth evolved from ancient microscopic life.	My personal religious beliefs make it harder to believe that all of life on Earth evolved from ancient microscopic life.	The teachings of my religion contradict that all of life on Earth evolved from ancient microscopic life.	My religious community does not believe that all of life on Earth evolved from ancient microscopic life.
My belief in God makes it harder to believe that humans evolved from ancient ape ancestors.	My personal religious beliefs make it harder to believe that humans evolved from ancient ape ancestors.	The teachings of my religion contradict that humans evolved from ancient ape ancestors.	My religious community does not believe that humans evolved from ancient ape ancestors.
My belief in God makes it harder to believe that nonhuman life evolved from previous different species.	My personal religious beliefs make it harder to believe that nonhuman life evolved from previous different species.	The teachings of my religion contradict that nonhuman life evolved from previous different species.	My religious community does not believe that nonhuman life evolved from previous different species.
My belief in God makes it harder to believe that humans have changed over time due to evolution.	My personal religious beliefs make it harder to believe that humans have changed over time due to evolution.	The teachings of my religion contradict that humans have changed over time due to evolution.	My religious community does not believe that humans have changed over time due to evolution.
My belief in God makes it harder to believe that nonhuman life has changed over time due to evolution.	My personal religious beliefs make it harder to believe that nonhuman life has changed over time due to evolution.	The teachings of my religion contradict that nonhuman life has changed over time due to evolution.	My religious community does not believe that nonhuman life has changed over time due to evolution.

[a]Students chose options on a five-point Likert scale from "strongly disagree" to "strongly agree." PCteachings and PCcommunity items were not predictive of evolution acceptance in our final models after controlling for other variables.

10 items in each dimension (dimension 1 = PCgod + PCbelief, dimension 2 = PCcommunity + PCteachings; *irtmodel = PCM2* in *TAM*), and a four-dimensional model with five items in each dimension (dimension 1 = PCgod, dimension 2 = PCbelief, dimension 3 = PCcommunity, dimension 4 = PCteachings; *irtmodel = PCM2* in *TAM*; Table 1). The multidimensional models used a multidimensional random coefficients multinomial logit formulation. We compared the fit of these three models using likelihood ratio tests. We also used the Rasch residuals approach by conducting a principal component analysis of the residuals of the unidimensional Rasch model. If the data fit the unidimensional model, the model residuals are expected to be small and without structure, as indicated by a low eigenvalue of the first contrast, that is an eigenvalue less than 2 (Boone, 2016; Sbeglia and Nehm, 2018). A correlation matrix between all items on the perceived conflict scale can be found in Supplemental Figure 1. Results from the Rasch analysis show the four-dimensional model was the best-fitting model (see Wright map for this model in Supplemental Figure 2). We confirmed that there was no further dimensionality by examining the eigenvalues of the residuals of the four unidimensional models, each corresponding to one of the four dimensions in the four-dimensional model (see more details in the *Results* section).

To provide evidence of *concurrent validity* (AERA *et al.*, 2014), we administered the new perceived conflict survey and our previously published perceived conflict survey (Barnes *et al.*, 2020a) to 494 students in introductory biology classes in Florida, Texas, and Oklahoma. We ran bivariate correlations between each of the four items from the previous survey and the summed score of the corresponding five-item expanded scale of the new survey. All measures were moderately correlated (r = 0.55–0.65) indicating that these novel instruments have a level of concurrent validity with the previous instrument's items, but also measure something unique that is not measured by the previous instrument.

Other *validity evidence based on relations to other variables* (AERA *et al.*, 2014) of the novel instrument is illustrated throughout the rest of our analyses; we explore the contribution of students' perceived conflict between their religions and evolution to students' evolution acceptance beyond other variables shown to be related to evolution acceptance (religiosity, religious denomination, understanding of evolution, age, race/ethnicity, gender, and parent educational levels).

Analyses

We used R v. 3.6.2 for all analyses (R Core Team, 2020). We used the R package TAM for all the Rasch modeling (Bates *et al.*, 2015; Robitzsch *et al.*, 2020). We used the R packages nlme, lme4, and MuMIn for linear mixed models and to calculate corrected Akaike information criterion (AICc) values and conditional R^2 values (Bartoń, 2019; Pinheiro *et al.*, 2019). We used the package mediation in R for the mediation analyses (Tingley *et al.*, 2014).

Rasch Models

We used Rasch models to analyze and score the dichotomous and Likert-scale responses (Linacre and Wright, 1993; Boone, 2016). Rasch models are statistical models that are members of item response theory (e.g., Hambleton *et al.*, 1991), a modern paradigm for design, analysis, and scoring of instruments measuring people's latent psychological traits. Using Rasch models to analyze and score Likert scales can overcome several limitations of the traditional method of simply converting Likert-scale responses to numbers, that is, converting a five-point Likert scale to values from 0 to 4 and analyzing these numbers with

statistical procedures. First, the traditional method assumes that the psychological distance between any two adjacent responses on the Likert scale is equal. However, that might not be the case for a five-point "strongly disagree" to "strongly agree" scale. The psychological distance between "agree" to "strongly agree" might be smaller than that between "neither agree nor disagree" to "agree" (Boone, 2016). The Rasch models account for varying psychological distances between adjacent responses and yield equal-interval measures, also known as logit scale measures. Second, different items within a scale might differ in how agreeable they are (Boone, 2016). For example, in evolution acceptance scales, items about microevolution acceptance might be more agreeable than items about human evolution acceptance. Unlike the traditional Likert scaling method that assigns the same numbered scale to all items indiscriminately, Rasch models also account for the variable "agreeabilities" across items with its parameters of the statistical model. Finally, Rasch models calibrate item difficulties, that is, the "agreeability" of an item, and "person ability," that is, the measure of the latent trait, on the same linear scale (Stachl and Baranger, 2020). Hence a series of Rasch analyses can be done to examine the characteristics of the measurement instrument to assist with understanding the instrument and making potential improvements. The person ability measures are equal-interval logit scale measures and can be subsequently used in parametric statistical analyses.

For the I-SEA scale, we ran three unidimensional Rasch models with items pertaining to acceptance of microevolution, macroevolution, and human evolution to convert the Likert-scale responses to equal-interval logit scale measures. We also converted religiosity Likert-scale responses and evolution understanding dichotomous responses into equal-interval logit scale measures by running a separate unidimensional Rasch model for each. We modified the Likert-scale coding to start at zero, as required by the TAM package for all Likert scales. Again, we ran polytomous partial-credit Rasch models and used a weighted maximum-likelihood estimation in TAM to calculate theta values, that is, person abilities. These person ability measures were used as the measures of acceptance of microevolution, macroevolution, human evolution, religiosity, and evolution understanding in the rest of the analyses (see Supplemental Figures 3–7 for all Wright maps). We examined the eigenvalues of the residuals for each of these Rasch models to ensure that a unidimensional model is suitable for the data.

For all of our Rasch models, we assessed item fit by examining weighted mean-squares infit and outfit statistics computed using the *msq.itemfit* function based on weighted likelihood estimates. Finally, we checked for item reliability using the expected a posteriori/plausible value reliability index (EAP/PV) and for person reliability using the weighted likelihood estimation (WLE) person separation index, which estimates whether items of similar difficulty would generate a similar order of person abilities.

Linear Mixed Models

Because of the nested nature of our data, that is, several students within a class were surveyed, we used linear mixed models with class as a random effect with varying intercepts for our analyses. We dummy coded all categorical variables for all the analyses with the following reference levels: gender: woman; race/ethnicity: White; religious affiliation: Non-Catholic Christian; parent education: less than high school. A full demographic table of study participants is provided in Supplemental Table 1.

To compare the Rasch measures from the four different dimensions of the perceived conflict scale, we used delta dimensional alignment (Schwartz, 2012; Castellano *et al.*, 2016) and a weighted maximum-likelihood estimation to calculate the theta values, that is, person ability. These person ability measures were used as measures of students' perceived conflict between evolution and their 1) belief in God, 2) personal religious beliefs, 3) religious teachings, and 4) beliefs of their religious communities.

Assessing whether Average Perceived Conflict between One's Religion and Evolution Varies across Religious Affiliations. We ran four linear mixed models with our four perceived conflict measures as the outcome variables and religious affiliation as the predictor. For these models, we controlled for all demographic variables, that is, age, gender, race/ethnicity, and parent education, and took the nested nature of the data into account by including class as a random effect. Next, we calculated estimated marginal means and did pairwise comparisons with the p values adjusted for multiple testing using the Tukey method to determine significant differences between groups.

Evaluating whether Students' Perceived Conflict between Their Religions and Evolution Account for Their Evolution Acceptance Levels to a Greater Extent Than Religiosity, Religious Affiliation, and Evolution Understanding. We compared two sets of linear mixed models with microevolution, macroevolution, and human evolution acceptance I-SEA scores as outcome variables, respectively:

1. Models with religiosity, religious affiliation, evolution understanding, gender, race/ethnicity, age, and parent education as predictors. These models serves as the baseline models.
2. Models with all the predictors listed above plus all four perceived conflict measures as predictors.

We used the class surveyed as a random effect in all the models (see correlation matrix between all predictor variables in Supplemental Figure 8).

We compared model fit between the two models above for each outcome variable using two approaches:

1. Using an information theoretic approach to compare the Akaike information criterion (AIC) values of the two kinds of models. Lower AIC values indicate better model fit.
2. Comparing the conditional R^2 (i.e., coefficient of determination) values of both kinds of models using the function *r.squaredGLMM* from the R package MuMIn (Bartoń, 2019). Conditional R^2 is the variance explained by the model including both fixed and random effects (Nakagawa *et al.*, 2017). A higher conditional R^2 value indicates that the model explains a greater proportion of variance in the data.

Assessing whether Perceived Conflict between Religion and Evolution Mediate and/or Moderate the Relationship between Evolution Acceptance and Religiosity. Perceived conflict between religion and evolution could affect the

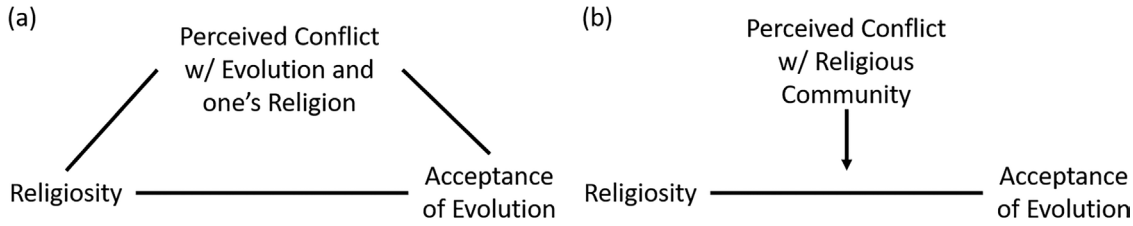

FIGURE 1. Mediation (a) and moderation (b) models for the relationships between religiosity, evolution acceptance (macroevolution and human evolution), and perceived conflict between evolution and one's religion (belief in God, religious beliefs, religious teachings, and among their religious community).

relationship between evolution acceptance and religiosity in two main ways, which are not mutually exclusive:

1. It could moderate the relationship between religiosity and evolution acceptance, that is, the relationship between religiosity and evolution acceptance may be different at different levels of perceived conflict. Specifically, at lower levels of perceived conflict, we may not observe a relationship between religiosity and evolution acceptance.
2. It could mediate the relationship between religiosity and evolution acceptance, that is, religiosity could affect evolution acceptance indirectly through perceived conflict.

We examined the moderation effect by adding an interaction between religiosity and each of the four perceived conflict measures in four separate models for each evolution acceptance measure to the linear mixed models described in the previous section.

We used a regression model–based approach for our mediation analyses following the methods developed by Imai *et al.* (2010). The advantage of this approach for mediations is that it allows us to take the nested nature of our data into account by incorporating linear mixed models. We ran four sets of mediation models with each of the four perceived conflict measures as the mediator. The outcome variables were macroevolution and human evolution acceptance. Because microevolution acceptance was not found to be negatively associated with religiosity in our linear mixed models, we did not run mediation models for microevolution acceptance.

In the mediation package, to estimate the mediation effect, one has to run two models, the "mediator model" with the mediator as the outcome and all the covariates as predictors and the "outcome model" with the mediator and covariates as predictors. Next, we use the *mediate* function and input these two models to calculate the estimated average mediation effect, in our case, the association of religiosity with evolution acceptance that can be attributed to differences in perceived conflict reported by students with different levels of religiosity. The *mediate* function also estimates the average direct effects of a predictor on a response variable, in our case, the association of perceived conflict with evolution acceptance. Figure 1 illustrates the models we tested.

In our case, the "mediator model" was a linear mixed model with one of the four perceived conflict measures as the outcome and religiosity, religious affiliation (Non-Catholic Christian, Catholic, Jewish, Muslim, Hindu, and Buddhist), evolution understanding, race/ethnicity, age, gender, and parent education as predictors. Our "outcome model" was a linear mixed model with evolution acceptance as the outcome and a perceived conflict measure between evolution and religion, religiosity, religious affiliation, evolution understanding, race/ethnicity, age, gender, and parent education as predictors. We had two outcome models for each of the four perceived conflict measures and one each for macroevolution and human evolution acceptance, for a total of eight models. Applying the *mediate* function, we calculated the average mediation effects and the average direct effects using 1000 quasi-Bayesian Monte Carlo simulations to calculate confidence intervals and statistical significance of the mediation. The data and R script used for analyses are available in the Supplemental Material. We refer the readers to Imai *et al.* (2010) for a detailed description of this mediation method (Imai *et al.*, 2010).

RESULTS

Population

A total of 3807 students completed the survey. Of these students, 1199 (31.5%) students did not specify any religious affiliation (they chose atheist, agnostic, nothing in particular, or decline to state), so they did not answer the questions in the perceived conflict instrument, because this instrument is focused on personal religious beliefs. In the remaining data set of 2608 students who specified a religious affiliation, less than 2% of data were missing, so we did not impute any data following prior recommendations (Meade and Craig, 2012). After removing students with missing data, our data set contained data for 2567 students that we used for the Rasch analyses. For the linear mixed models, we also removed data from students who declined to state their demographics, picked the option "other faith" for religious affiliation, or picked "nonbinary" or "other" for gender. So, our final data set consisted of 2275 students for linear mixed models.

Of these 2275 students, 1119 (49%) were non-Catholic Christian (mostly Protestant and nondenominational Christians), 885 (39%) were Catholic Christians, 57 (3%) were Jewish, 100 (4%) were Muslim, 65 (3%) were Hindu, and 49 (2%) were Buddhist. Two hundred and thirteen (9%) were Black/African American; 465 (20%) were Hispanic; 209 (9%) were Asian; 1133 (50%) were White; 57 (3%) were Native American, Pacific Islander, or another race/ethnicity; and 198 (9%) students clicked more than one box for race/ethnicity, and these students were categorized as multiracial.

Rasch Models

Dimensionality of the Perceived Conflict Scale. The four-dimensional model had the highest log-likelihood and lowest AIC

values, indicating that it is the best-fitting model (log likelihood = –10,201, AIC = 20,581.7 compared with log likelihood = –10,555 and AIC = 21,275.9 for the two-dimensional model and log likelihood of –11,681 and AIC = 23,523.9 for the unidimensional model). The eigenvalue of the first contrast was 4.82 for the unidimensional model, suggesting that the unidimensional model was not a good fit to the data. The eigenvalues of the first contrast for the four unidimensional models, each corresponding to one of the dimensions of our four-dimensional model, were all lower than 1. This confirms that the four-dimensional model is appropriate for the data and no further dimensions are needed.

Fit Statistics for All the Rasch Models: Four-Dimensional Perceived Conflict Model, Unidimensional Religiosity Model, Microevolution, Macroevolution, and Human Evolution Acceptance Models, and Evolution Understanding Model. The first eigenvalues of residuals of the religiosity model, the three evolution acceptance models, and the evolution understanding model were less than 2, indicating that the data were unidimensional, and a unidimensional model was appropriate. Weighted mean-squares item fit statistics (WMNSQ, equal to infit MNSQ) for all our Rasch models were largely within the acceptable range (i.e., 0.7–1.3 logits). WMNSQ values lay between 0.9 and 1.2 for perceived conflict, 0.9 and 1.2 for religiosity, 0.97 and 1.1 for microevolution, 0.8 and 1.3 for macroevolution, 0.9 and 1.5 for human evolution, and 0.9 and 1.1 for evolution understanding. For all our models measuring psychological attitudinal constructs, the reliability measures had an acceptable value, that is, were greater than 0.7. The evolution understanding model had a lower reliability, but this is acceptable for tests measuring content knowledge of a domain (see, e.g., Carlson *et al.*, 2010, pp. 136–138). The EAP/PV reliability index, a measure of item reliability, was 0.82 for religiosity, 0.84 for microevolution, 0.85 for macroevolution, and 0.91 for human evolution, but it was only 0.56 for evolution understanding. EAP/PV values for the perceived conflict with belief in God, religious beliefs, religious teachings, and religious community dimensions of the perceived conflict scale were 0.94, 0.94, 0.93, and 0.92, respectively. Person reliabilities as estimated by WLE person separation index, which estimates whether a similar order of person abilities would be generated by items of similar difficulty, were 0.74 for religiosity, 0.78 for microevolution, 0.84 for macroevolution, and 0.89 for human evolution, but only 0.51 for the evolution understanding model. WLE separation index values for the perceived conflict with belief in God, religious beliefs, religious teachings, and religious community dimensions of the perceived conflict scale were 0.87, 0.89, 0.87, and 0.89, respectively. See Supplemental Tables 2 and 3 for fit statistics for all Rasch models.

Finding 1: Non-Catholic Christian and Muslim Students Show the Highest Levels of Perceived Conflict between Evolution and Religion

Perceived conflict levels on all four measures were highest for non-Catholic Christian students, followed by Muslim students, for perceived conflict with belief in God and personal religious beliefs, and Catholic students for perceived conflict with religious teachings and religious community. None of the perceived conflict measures for Muslim students were significantly different from non-Catholic Christian students (all $p > 0.6$). Generally, Jewish, Buddhist, and Hindu students had lower perceived conflict measures than non-Catholic Christian, Muslim, and Catholic students. However, levels of perceived conflict with religious teachings for Jewish students were not significantly different from non-Catholic Christian, Muslim, and Catholic students. There was wide variation in the levels of perceived conflict within their religious community for Jewish students, such that they were not significantly different from Catholic, Muslim, and Hindu students (Figure 2). See Supplemental Table 4 for estimated marginal means and standard errors.

Finding 2: Perceived Conflict between Religion and Evolution Predicts Evolution Acceptance More Than Religiosity, Religious Affiliation, Evolution Understanding Levels, and Demographics

Models that included perceived conflict measures as predictors had much lower AIC values compared with models that did not include them, indicating significantly better model fit (Table 2). Moreover, conditional R^2 values for the models that included perceived conflict measures as predictors were much greater than the models that did not include these measures (Table 2). This means that adding perceived conflict measures significantly improved the model and the resulting model explained a greater proportion of the variation in evolution acceptance. Moreover, perceived conflict with students' belief in God had the largest and most negative slope compared with all other predictor variables for predicting acceptance of microevolution (–0.45 ± 0.05 SE), macroevolution (–0.48 ± 0.04 SE), and human evolution (–0.64 ± 0.05 SE; see Table 3 for full regression model output). Perceived conflict with students' religious beliefs also had a large negative slope for predicting acceptance of microevolution (–0.34 ± 0.05 SE), macroevolution (–0.28 ± 0.04 SE), and human evolution (–0.45 ± 0.05 SE). Perceived conflict with students' religious communities and perceived conflict with religious teachings did not have a significant negative effect on evolution acceptance. Contrary to expectations, perceived conflict with students' religious communities had a small statistically significant positive slope for predicting microevolution acceptance (0.11 ± 0.04 SE) and perceived conflict with religious beliefs had a small positive slope for predicting human evolution acceptance (0.08 ± 0.04 SE; Table 3). These positive slopes are due to correlations between these perceived conflict measures and the perceived conflict with God and perceived conflict with religious beliefs measures. This was confirmed by running models that did not include any of the other perceived conflict measures and evaluating the slopes, which were negative in these models.

Finding 3: When Students Perceive Less Conflict between Evolution and Their Belief in God, Their Religiosity Is a Weaker Predictor of Their Evolution Acceptance

For macroevolution acceptance, there was a significant interaction between religiosity and perceived conflict with one's belief in God and evolution (estimate ± SE = –0.056 ± 0.022, $p = 0.009$), but not for any of the other three perceived conflict measures (all $p > 0.09$). For human evolution acceptance, again there was a significant interaction between religiosity and perceived conflict with one's belief in God and evolution (estimate ± SE = –0.062 ± 0.025, $p = 0.015$). This implies that the slope

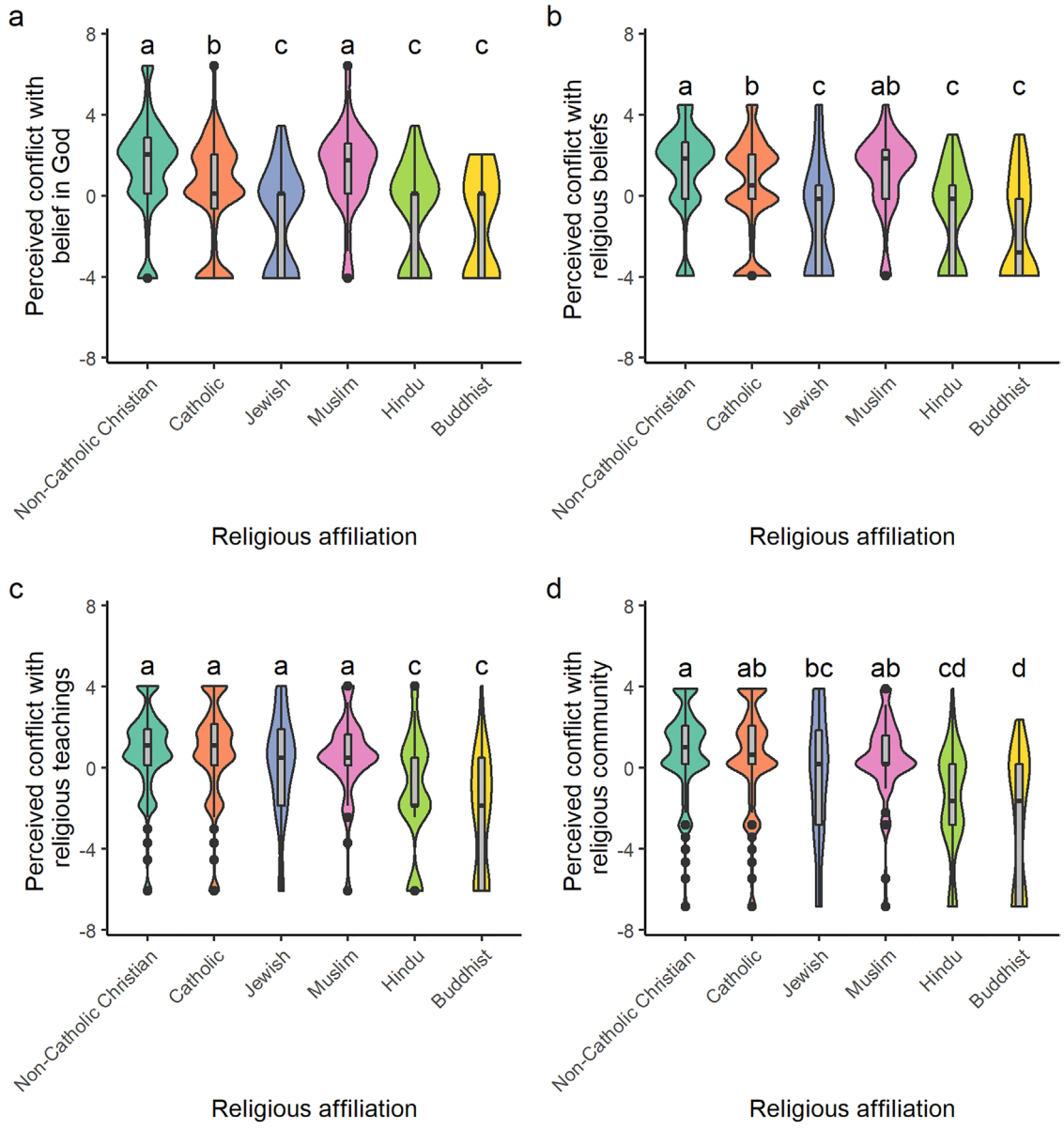

FIGURE 2. Student perceived conflict between evolution and (a) belief in God, (b) personal religious beliefs, (c) religious teachings, and (d) beliefs of religious community by religious affiliations. All perceived conflict measures were estimated using Rasch models and are on a logit scale. The shape of the violin shows the distribution of the data (where the violin is thicker, there are more data points); gray bar in the middle of the violin indicates the interquartile range, black line in the middle of the bar indicates the median, and black lines stretched out from the bar indicate first/third quartile ± 1.5 interquartile range. The same letter on top of the violins indicate that groups are similar, and different letters indicate that they are statistically different based on post hoc Tukey comparisons.

of the relationship between religiosity and evolution acceptance is more negative at higher levels of perceived conflict with evolution and one's belief in God, that is, when perceived conflict between belief in God and evolution is higher, religiosity has a stronger negative effect on evolution acceptance (Figure 3). In contrast, at lower levels of perceived conflict with students' belief in God, the relationship between religiosity and evolution acceptance is weaker. There was also a significant interaction between religiosity and perceived conflict with evolution among one's religious community for human evolution acceptance (estimate ± SE = –0.053 ± 0.027, p = 0.047). However, there was no significant interaction between religiosity and the remaining two perceived conflict measures for human evolution acceptance, that is, perceived conflict between evolution and religious teachings and personal religious beliefs. This suggests that the relationship between religiosity and evolution acceptance is similar at different levels of perceived conflict between evolution and one's personal religious beliefs, religious teachings, and beliefs of one's religious community (see Supplemental Tables 5–7 for full regression output and Supplemental Figure 9 for scatter plots of evolution acceptance measures against religiosity measures broken down by students' perceived

TABLE 2. Conditional R^2 and AICc values for linear mixed models of evolution acceptance that included perceived conflict measures as predictors compared with models that did not[a]

	Conditional R^2			AICc value		
	Microevolution	Macroevolution	Human evolution	Microevolution	Macroevolution	Human evolution
Models without any perceived conflict measures	0.12	0.14	0.20	8236.50	7505.31	8509.00
Models with only perceived conflict with belief in God	0.28	0.35	0.46	7772.61	6855.32	7624.73
Models with only perceived conflict with personal religious beliefs	0.26	0.33	0.44	7812.26	6950.32	7715.66
Models with only perceived conflict with religious community	0.14	0.18	0.25	8188.72	7391.48	8352.57
Models with only perceived conflict with religious teachings	0.15	0.18	0.25	8150.33	7403.50	8371.55
Models with all perceived conflict measures	0.30	0.37	0.48	7723.17	6807.28	7529.87

[a]Higher R^2 and lower AICc values indicate that the models with perceived conflict measures best fit the data. Both models included course as a varying intercept random effect, and religiosity, religious affiliation, evolution understanding, race/ethnicity, age, gender, and parent education as predictors.

conflict between evolution and religion). There was no significant interaction between religiosity and any of the perceived conflict measures for microevolution acceptance.

Finding 4: Perceived Conflict between Belief in God and Evolution Mediated the Relationship between Religiosity and Evolution Acceptance

Our mediation analyses showed that a large proportion of the difference between evolution acceptance of high-religiosity students and low-religiosity students was associated with differences in their perceived conflict between their belief in God and evolution (67% for macroevolution acceptance and 52% for human evolution acceptance; Table 4). The average mediation effect of perceived conflict with belief in God was –0.16 for macroevolution and –0.23 for human evolution acceptance (all $p < 0.001$). Similarly, a large proportion of the difference in evolution acceptance between students with high and low religiosity levels was associated with differences in the perceived conflict between students' religious beliefs and evolution (56% for macroevolution acceptance and 45% for human evolution acceptance). The average mediation effect of perceived conflict with personal religious beliefs was –0.14 for macroevolution and –0.19 for human evolution acceptance (all $p < 0.001$). On the other hand, perceived conflict with evolution among one's religious community and perceived conflict with the teachings of one's religion were not significant mediators of the relationship between religiosity and macro- or human evolution acceptance (Supplemental Table 8). For mediation path models showing coefficients before and after adding perceived conflict with belief in God to models predicting macroevolution and human evolution models, see Figure 4. The mediation path models for all mediation analyses of macroevolution and human evolution can be found in Supplemental Figure 9. These results show that highly religious students perceive higher conflict between their belief in God and their personal religious beliefs and evolution leading to lower levels of evolution acceptance.

DISCUSSION

In this paper, we developed PCoRE, a novel instrument that measures students' perceived conflict between religion and evolution. This measure includes students' perceived conflict between evolution and their 1) belief in God, 2) personal religious beliefs, 3) religious teachings, and 4) religious communities' beliefs. Content validity evidence was gathered based on prior qualitative literature, and Rasch dimensionality analysis confirmed that a four-factor solution resulted in the best model fit statistics, providing internal structure validity evidence for the new instrument (AERA *et al.*, 2014). Correlations with prior measures of perceived conflict provided concurrent validity evidence. Further, we gathered process response validity evidence through cognitive interviews with students and validity based on relationships with other important variables such as acceptance of evolution (AERA *et al.*, 2014).

In the prior literature, the strongest predictors of students' evolution acceptance have included religiosity, religious affiliation, and understanding of evolution (Glaze *et al.*, 2014; Dunk *et al.*, 2017; Barnes *et al.*, 2019). In this study, we found that, even after controlling for these variables, perceived conflict between evolution and a student's 1) belief in God and 2) personal religious beliefs were the strongest predictors of evolution

TABLE 3. Parameter estimates from linear mixed models for evolution acceptance among college students with all four perceived conflict measures as predictors[a]

	Microevolution acceptance			Macroevolution acceptance			Human evolution acceptance		
	Value	SE	*p* value	Value	SE	*p* value	Value	SE	*p* value
(Intercept)	0.10	0.15	0.507	−0.05	0.12	0.698	−0.34	0.14	0.017
Religiosity	**0.14**	**0.03**	**<0.001**	**−0.07**	**0.02**	**0.006**	**−0.19**	**0.03**	**<0.001**
Evolution understanding	**0.32**	**0.03**	**<0.001**	**0.14**	**0.02**	**<0.001**	**0.18**	**0.03**	**<0.001**
Perceived conflict with evolution measures									
Perceived conflict with belief in God	**−0.45**	**0.05**	**<0.001**	**−0.48**	**0.04**	**<0.001**	**−0.64**	**0.05**	**<0.001**
Perceive conflict with religious beliefs	**−0.34**	**0.05**	**<0.001**	**−0.28**	**0.04**	**<0.001**	**−0.45**	**0.05**	**<0.001**
Perceived conflict within religious community	**0.11**	**0.04**	**0.005**	−0.04	0.03	0.214	−0.06	0.04	0.099
Perceived conflict with religious teachings	−0.05	0.04	0.200	0.05	0.03	0.119	**0.08**	**0.04**	**0.042**
Religious affiliation (ref: non-Catholic Christian)									
Catholic	0.01	0.07	0.927	**0.20**	**0.05**	**<0.001**	**0.36**	**0.06**	**<0.001**
Jewish	0.10	0.19	0.587	**0.37**	**0.15**	**0.015**	**0.47**	**0.18**	**0.008**
Muslim	−0.08	0.15	0.599	0.02	0.12	0.899	−0.05	0.14	0.723
Hindu	−0.29	0.21	0.171	−0.04	0.17	0.803	0.21	0.20	0.300
Buddhist	0.37	0.21	0.083	−0.06	0.17	0.720	0.37	0.20	0.073
Race/ethnicity (ref: White)									
Asian	−0.13	0.13	0.313	0.17	0.10	0.098	−0.19	0.12	0.112
Black	−0.18	0.10	0.078	0.03	0.08	0.723	−0.10	0.10	0.292
Latinx	−0.13	0.08	0.123	−0.05	0.07	0.476	**−0.24**	**0.08**	**0.003**
Multiracial	0.03	0.10	0.743	0.08	0.08	0.356	−0.05	0.10	0.631
Other	−0.21	0.19	0.267	−0.26	0.15	0.088	−0.27	0.18	0.129
Age	0.01	0.03	0.697	**0.05**	**0.02**	**0.037**	**0.06**	**0.03**	**0.042**
Male	**−0.13**	**0.06**	**0.038**	0.02	0.05	0.650	0.10	0.06	0.080
Parent education (ref: <high school)									
High school	−0.13	0.16	0.410	−0.08	0.13	0.531	0.22	0.15	0.136
Some college	−0.09	0.15	0.546	−0.04	0.13	0.736	0.17	0.15	0.263
Associate's degree	−0.05	0.17	0.785	−0.08	0.14	0.580	0.12	0.16	0.439
Bachelor's degree	0.02	0.15	0.866	−0.12	0.12	0.301	0.13	0.14	0.373
Master's degree	−0.12	0.15	0.427	−0.13	0.12	0.300	0.18	0.14	0.210
>Master's degree	−0.12	0.16	0.445	−0.02	0.13	0.858	0.26	0.15	0.090
Model log likelihood		−3834.25			−3376.30			−3737.60	
Model AIC		7722.50			6806.60			7529.20	
Random effects variance		0.07			0.03			0.00008	
Residual variance		1.30			1.07			1.25	

[a]Bolded numbers indicate $p < 0.05$.

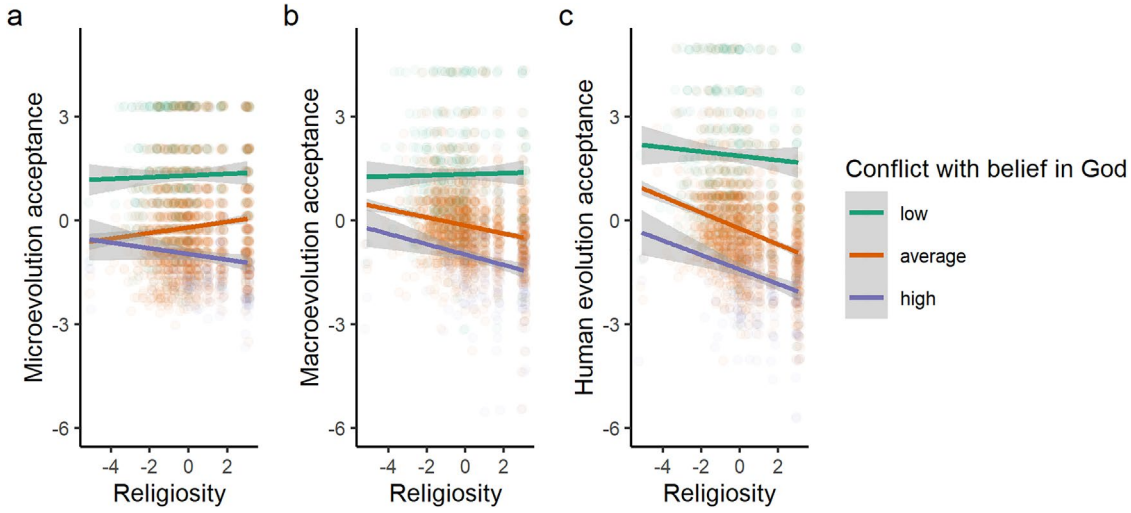

FIGURE 3. Scatter plots of evolution acceptance measures against religiosity measures with overlaid ordinary least squares (OLS) regression lines broken down by students' perceived conflict between evolution and belief in God: (a) microevolution acceptance, (b) macroevolution acceptance, and (c) human evolution acceptance. The points were jittered for clarity, and darker points indicate multiple overlapping points. Jittering involves adding a small amount of random noise to the data points to be able to visualize them better and is useful when a large data set might have a large number of overlapping points.

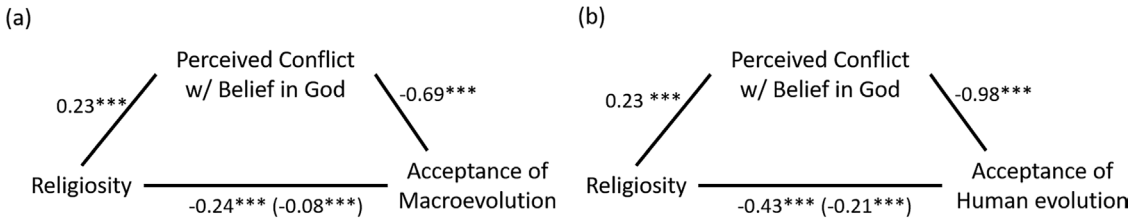

FIGURE 4. Mediation models illustrating the mediation effect of perceived conflict between evolution and belief in God on the relationship between religiosity and (a) acceptance of macroevolution and (b) acceptance of human evolution. Coefficients within the parenthesis are the reduced coefficients after adding perceived conflict with belief in God to models.

acceptance. We also found that perceived conflict with evolution among students' religious communities or within their religious teachings were not significant predictors of students' evolution acceptance after accounting for perceived conflict with evolution and students' belief in God or personal religious beliefs. This study builds on prior literature that suggests that reducing students' perceived conflict between evolution and their personal religious beliefs may increase their acceptance of

TABLE 4. Results from the mediation analyses using 1000 quasi-Bayesian Monte Carlo simulations to calculate confidence intervals and statistical significance[a]

	Macroevolution acceptance			Human evolution acceptance		
	Estimate	95% CI lower	95% CI upper	Estimate	95% CI lower	95% CI upper
Mediator:	Perceived conflict between evolution and one's belief in God					
Mediation effect	–0.16	–0.19	–0.13	–0.23	–0.27	–0.18
Direct effect	–0.08	–0.13	–0.03	–0.21	–0.26	–0.15
Total effect	–0.24	–0.29	–0.19	–0.43	–0.50	–0.36
Proportion mediated	0.67	0.54	0.84	0.52	0.44	0.61
Mediator:	Perceived conflict between evolution and one's personal religious beliefs					
Mediation effect	–0.14	–0.16	–0.11	–0.19	–0.23	–0.15
Direct effect	–0.11	–0.16	–0.06	–0.24	–0.29	–0.19
Total effect	–0.24	–0.29	–0.19	–0.44	–0.50	–0.37
Proportion mediated	0.56	0.45	0.72	0.45	0.37	0.53

[a]Mediation effect indicates the amount of the association of religiosity with evolution acceptance that is mediated by one's perceived conflict between evolution and one's belief in God. Direct effect indicates the amount of the association of religiosity with evolution acceptance not related to perceived conflict. Proportion mediated shows the proportion of total association of religiosity with evolution acceptance that can be attributed to perceived conflict. CI, confidence interval.

evolution (Brem *et al.*, 2003; Winslow *et al.*, 2011; Southerland and Scharmann, 2013; Barnes *et al.*, 2017a). Further, it implies that specifically reducing students' perceived conflict between believing in God and evolution may be the most impactful practice for increasing student acceptance of evolution. Importantly, to our knowledge, this study provides the first multifactor quantitative measure of perceived conflict between evolution and religion that has been tested and can be implemented in future evolution education studies.

In this study, we also found that Muslim students and Christian students who were not Catholic had the highest perceived conflict with their belief in God and evolution, which suggests that these students could benefit the most from reducing their perceived conflict. Non-Catholic Christian students are approximately one-quarter of introductory undergraduate biology students (Barnes *et al.*, 2020b), suggesting that reducing perceived conflict among this group could impact a sizable proportion of undergraduate biology students and their acceptance of evolution. These results corroborate past studies demonstrating that Muslim individuals may experience high perceived conflict with their religions and evolution (Dagher and BouJaoude, 1997; BouJaoude *et al.*, 2011; Deniz *et al.*, 2008; Yousuf *et al.*, 2011; Asghar, 2013; Athanasiou and Papadopoulou, 2015; Yok *et al.*, 2015; Stears *et al.*, 2016; Rachmatullah *et al.*, 2018; Unsworth and Voas, 2018; Barnes *et al.*, under review). Future studies could use the PCoRE instrument to explore ways to reduce perceived conflict among Muslim students.

In past studies, researchers have found that it is common for students to think that someone has to be an atheist in order to fully accept evolution (Winslow *et al.*, 2011; Barnes *et al.*, 2020a); in the current study, we found that students' perceived conflict between evolution and their belief in God was the single strongest predictor of their evolution acceptance. Thus, a misconception that accepting evolution requires atheism could be a deciding factor for many students to not accept evolution. A way that evolution instructors may be able to reduce students' perceived conflict between evolution and belief in God is to discuss that evolution is not necessarily atheistic and that students do not have to reject a belief in God in order to accept evolution. Biologists and science education researchers have written extensively about the conflation of evolution acceptance with atheism (Smith, 1994; Miller, 1999; Meadows *et al.*, 2000; Scott, 2005; Collins, 2006; Reiss, 2009; Gould, 2011; Southerland and Scharmann, 2013; Tolman *et al.*, 2020). In our past study, we reported that almost half of college biology students think that in order to accept evolution they would have to be atheists, highlighting the prevalence of this misconception (Barnes *et al.*, 2020a). So, if perceived conflict between belief in God and evolution is the strongest predictor for evolution acceptance, it is not surprising that evolution acceptance levels among students are low. In the prior study, although the perception that one has to be an atheist to accept evolution was common among both religious and nonreligious students, it was only among the highly religious students that this perception was related to lower evolution acceptance, lower comfort in learning evolution, and higher perceived conflict between religion and evolution (Barnes *et al.*, 2020a). We advocate for instructors to describe evolution as agnostic with respect to the existence of God, owing the origin of the term to the evolutionary scientist Thomas Henry Huxley,[2] who invented it to describe the most scientific view of matters such as the existence of deities, which are outside the abilities of scientific practices to explore (Huxley and Huxley, 1900).

These data illustrate that it is not the extent to which a student is religious or the religion with which they affiliate that will predict their evolution acceptance the most, which may help moderate instructor perceptions about how they can impact student evolution acceptance levels. Biology instructors are likely reluctant to try to change a student's religious beliefs, and studies have documented that student religiosity and religious affiliation are unlikely to change over a college biology degree (Kimball *et al.*, 2009). It may be encouraging for evolution educators to see that these variables are not the most predictive factors for students' evolution acceptance. However, several studies thus far have shown that it *is* possible to reduce students' perceived conflict between their religious beliefs and evolution over a college biology degree (Winslow *et al.*, 2011) or even during one module of evolution instruction (Barnes *et al.*, 2017a, 2020c; Truong *et al.*, 2018). For instance, by providing students with examples of religious scientists who accept evolution, teaching the bounded nature of science, and making students aware of the spectrum of viewpoints on the relationship between religion and evolution, instructors were able to reduce the number of students who perceived conflict between religion and evolution by half (Barnes *et al.*, 2017a). These strategies can be considered culturally competent for religious students in that they help biology instructors better communicate evolution to religious students while being respectful of their identities.

Novel Perceived Conflict Instrument: Recommendations for Future Use

Our novel instrument for measuring perceived conflict between students' religions and evolution could be used in classes and/or in future studies examining students' evolution acceptance. Given that students' perceived conflict between evolution and their 1) belief in God and 2) other personal religious beliefs were the two strongest predictors of evolution acceptance among many other well-studied variables, future studies examining student evolution acceptance will be stronger if they include these measures. Indeed, perceived conflict more than doubled the amount of variation explained in students' evolution acceptance when added to our models. However, perceived conflict with evolution and 1) religious teachings and 2) the students' religious communities did not predict evolution acceptance in our regression models after controlling for other variables. Thus, instructors and researchers could administer a shortened version of our perceived conflict instrument that includes only the two dimensions of perceived conflict that best predicted student evolution acceptance: 1) perceived conflict with evolution and belief in God and 2) perceived conflict with evolution and personal religious beliefs (Table 1).

Another recently published instrument, the "Scales of Evolutionary Conflict Measure" (SECM), measures student "perceptions of evolutionary conflict" (Sbeglia and Nehm, 2020). In

[2]We acknowledge that Thomas Huxley is a problematic figure who expressed racist views with respect to human evolution. However, this does not discredit his invention of the term "agnostic."

contrast to our instrument, this instrument was built to measure broader perceptions of potential conflict with evolution that are not specific to conflict between religion and evolution (Sbeglia and Nehm, 2020). Example items on the SECM include: "evolutionary ideas are at odds or in conflict with my culture/values/beliefs," "evolutionary ideas are at odds or in conflict with my family's culture/values/beliefs," and "evolutionary ideas are at odds or in conflict with my community's culture/values/beliefs" (strongly disagree–strongly agree). Further, some items on this measure appear to measure evolution acceptance directly (e.g., "evolutionary ideas are at odds with my beliefs").

Uniquely, our new instrument specifically targeted perceived conflict with religion, because prior qualitative literature clearly indicated that conflict with religion is most important for evolution acceptance (Jackson *et al.*, 1995; Dagher and BouJaoude, 1997; Goldston and Kyzer, 2009; Winslow *et al.*, 2011). The specificity of this measure allows researchers to identify when the source of conflict is religion and to quantify its association with different levels of evolution acceptance as opposed to other sources of conflict that may exist. Thus, we posit that the instrument that we have developed is most appropriate to use when investigating 1) conflict between students' religion and evolution, 2) how to reduce perceived conflict with religion and evolution, and 3) how perceived conflict with religion may relate to students' evolution acceptance levels. Another advantage of our measure is that it uniquely includes the different contexts of evolution with which students may perceive more or less conflict (micro- and macroevolution of non-humans, micro- and macroevolution of humans, and the common ancestry of life on Earth; Sbeglia and Nehm, 2019). Prior evolution educational measures have been critiqued for not specifying the context of evolution, because students tend to have different levels of perceived conflict and acceptance depending on the context of evolution (Nadelson and Southerland, 2012; Sbeglia and Nehm, 2019).

Limitations and Future Research

We collected data from 26 undergraduate biology courses in 11 states, but these results may not be generalizable beyond this sample. However, we collected a large enough sample in enough states that the results should be relevant to the science education community in the United States. Further, these data were collected at a single time point, and thus all results are correlational and do not determine causation between variables. The results suggest that reducing perceived conflict between religion and evolution may increase student acceptance of evolution, but intervention studies in which students' acceptance of evolution is measured before and after reducing students' perceived conflict are necessary to confirm this.

This perceived conflict scale was developed to be inclusive of any religious identity, but we acknowledge that Christians dominated our sample. We encourage future validation of this scale in populations that have larger percentages of Muslim, Jewish, Hindu, and Buddhist students. We also acknowledge that religious identity can be contextual and that our sample from the United States may be different from a sample of religious individuals from other countries.

Another limitation is that we used the partial credit model (PCM) instead of the generalized partial credit model (GPCM) that estimates variable discrimination parameters and could have improved model fit. We chose to use the PCM following the convention of Rasch analysis in this particular field of inquiry (e.g., Boone, 2016; Sbeglia and Nehm, 2018). Besides the theoretical benefits of invariant comparison and sufficiency, adopting a Rasch model also facilitates the use of an array of practical tools as parts of the Rasch analysis.

CONCLUSION

In this study, we developed PCoRE, a new measure of perceived conflict between religion and evolution. We found that the extent to which students perceive evolution being in conflict with their belief in God and religious beliefs represented the strongest predictors of evolution acceptance independent of students' religiosity, religious denomination, understanding of evolution, and demographics. This implies that, in order to increase students' acceptance of evolution, the most impactful practice may be to reduce students' perceived conflict between evolution and their belief in God and their other religious beliefs. We present a new instrument to measure students' perceived conflict between their religions and evolution as a tool for researchers and educators to include in their future studies and classes. Future intervention studies could target students' perceived conflict with evolution and their belief in God and religious beliefs to confirm that reducing this conflict will increase student acceptance of evolution.

ACKNOWLEDGMENTS

We would like to thank the instructors of the courses included in this study who were willing to send our survey to their students and the students who completed the survey. We thank ASU's Biology Education Research Lab for helpful feedback about this project, and specifically Rachel Scott. This project was supported by National Science Foundation grants IUSE 1818659 and 1712188 as well as a Faculty Creative Research and Activity grant from Middle Tennessee State University.

REFERENCES

Asghar, A. (2013). Canadian and Pakistani Muslim teachers' perceptions of evolutionary science and evolution education. *Evolution: Education and Outreach*, *6*(1), 10. https://doi.org/10.1186/1936-6434-6-10

American Association for the Advancement in Science. (2011). *Vision and change in undergraduate biology education: A call to action*. Washington, DC.

American Educational Research Association, American Psychological Association, National Council on Measurement in Education. (2014). *The standards for educational and psychological testing*. Washington, DC: American Educational Research Association.

Athanasiou, K., & Papadopoulou, P. (2015). Evolution theory teaching and learning: What conclusions can we get from comparisons of teachers' and students' conceptual ecologies in Greece and Turkey? *Eurasia Journal of Mathematics, Science & Technology Education*, *11*(4), 841–853.

Bailey, G., Han, J., Wright, D., & Graves, J. L. (2011). Religiously expressed fatalism and the perceived need for science and scientific process to empower agency. *International Journal Science in Society*, *2*(3), 55–88.

Baker, J. O. (2013). Acceptance of evolution and support for teaching creationism in public schools: The conditional impact of educational attainment. *Journal for the Scientific Study of Religion*, *52*(1), 216–228. https://doi.org/10.1111/jssr.12007

Barnes, M. E., & Brownell, S. E. (2017). A call to use cultural competence when teaching evolution to religious college students: Introducing Religious Cultural Competence in Evolution Education (ReCCEE). *CBE—Life Sciences Education*, *16*(4), es4. https://doi.org/10.1187/cbe.17-04-0062

Barnes, M. E., & Brownell, S. E. (2018). Experiences and practices of evolution instructors at Christian universities that can inform culturally competent evolution education. *Science Education*, *102*(1), 36–59. https://doi.org/10.1002/sce.21317

Barnes, M. E., Dunlop, H. M., Holt, E. A., Zheng, Y., & Brownell, S. E. (2019). Different evolution acceptance instruments lead to different research findings. *Evolution: Education and Outreach*, *12*(1), 4. https://doi.org/10.1186/s12052-019-0096-z

Barnes, M. E., Dunlop, H. M., Sinatra, G. M., Hendrix, T. M., Zheng, Y., & Brownell, S. E. (2020a). "Accepting evolution means you can't believe in God": Atheistic perceptions of evolution among college biology students. *CBE—Life Sciences Education*, *19*(2), ar21. https://doi.org/10.1187/cbe.19-05-0106

Barnes, M. E., Elser, J., & Brownell, S. E. (2017a). Impact of a short evolution module on students' perceived conflict between religion and evolution. *American Biology Teacher*, *79*(2), 104–111. https://doi.org/10.1525/abt.2017.79.2.104

Barnes, M. E., Supriya, K., Dunlop, H. M., Hendrix, T. M., Sinatra, G. M., & Brownell, S. E. (2020b). Relationships between the religious backgrounds and evolution acceptance of Black and Hispanic biology students. *CBE—Life Sciences Education*, *19*(4), ar59. https://doi.org/10.1187/cbe.19-10-0197

Barnes, M. E., Truong, J. M., & Brownell, S. E. (2017b). Experiences of Judeo-Christian students in undergraduate biology. *CBE—Life Sciences Education*, *16*(1), ar15. https://doi.org/10.1187/cbe.16-04-0153

Barnes, M. E., Werner, R., & Brownell, S. E. (2020c). Differential impacts of religious cultural competence on students' perceived conflict with evolution at an evangelical university. *American Biology Teacher*, *82*(2), 93–101. https://doi.org/10.1525/abt.2020.82.2.93

Barnes, M. E., Maas, S. A., Roberts, J. A., & Brownell, S. E. (2021). Christianity as a concealable stigmatized identity (CSI) among biology graduate students. *CBE—Life Sciences Education*, *20*(1), ar9. https://doi.org/10.1187/cbe.20-09-0213

Bartoń, K. (2019). *MuMIn: Multi-model inference (R Package Version 1.43.15)*. Retrieved May 5, 2020, from https://CRAN.R-project.org/package=MuMIn

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. doi: 10.18637/jss.v067.i01

Boone, W. J. (2016). Rasch analysis for instrument development: Why, when, and how? *CBE—Life Sciences Education*, *15*(4), rm4. https://doi.org/10.1187/cbe.16-04-0148

BouJaoude, S., Wiles, J. R., Asghar, A., & Alters, B. (2011). Muslim Egyptian and Lebanese students' conceptions of biological evolution. *Science & Education*, *20*(9), 895–915.

Brem, S. K., Ranney, M., & Schindel, J. (2003). Perceived consequences of evolution: College students perceive negative personal and social impact in evolutionary theory. *Science Education*, *87*(2), 181–206. https://doi.org/10.1002/sce.10105

Brownell, S. E., Freeman, S., Wenderoth, M. P., & Crowe, A. J. (2014). BioCore Guide: A tool for interpreting the core concepts of *Vision and Change* for biology majors. *CBE—Life Sciences Education*, *13*(2), 200–211. https://doi.org/10.1187/cbe.13-12-0233

Carlson, M., Oehrtman, M., & Engelke, N. (2010). The Precalculus Concept Assessment: A tool for assessing students' reasoning abilities and understandings. *Cognition and Instruction*, *28*(2), 113–145. https://doi.org/10.1080/07370001003676587

Castellano, K. E., Duckor, B., Wihardini, D., Telléz, K., & Wilson, M. (2016). Assessing academic language in an elementary mathematics teacher licensure exam. *Teacher Education Quarterly*, *43*(1), 3–27.

Castillo-Díaz, M., & Padilla, J.-L. (2013). How cognitive interviewing can provide validity evidence of the response processes to scale items. *Social Indicators Research*, *114*(3), 963–975.

Cohen, A. B., Shariff, A. F., & Hill, P. C. (2008). The accessibility of religious beliefs. *Journal of Research in Personality*, *42*(6), 1408–1417. https://doi.org/10.1016/j.jrp.2008.06.001

Collins, F. S. (2006). *The language of God: A scientist presents evidence for belief*. New York NY: Simon and Schuster.

Dagher, Z. R., & BouJaoude, S. (1997). Scientific views and religious beliefs of college students: The case of biological evolution. *Journal of Research in Science Teaching*, *34*(5), 429–445.

Deniz, H., Donnelly, L. A., & Yilmaz, I. (2008). Exploring the factors related to acceptance of evolutionary theory among Turkish preservice biology teachers: Toward a more informative conceptual ecology for biological evolution. *Journal of Research in Science Teaching*, *45*(4), 420–443. https://doi.org/10.1002/tea.20223

Dingemans, E., & Van Ingen, E. (2015). Does religion breed trust? A cross-national study of the effects of religious involvement, religious faith, and religious context on social trust. *Journal for the Scientific Study of Religion*, *54*(4), 739–755.

Dunk, R. D. P., Petto, A. J., Wiles, J. R., & Campbell, B. C. (2017). A multifactorial analysis of acceptance of evolution. *Evolution: Education and Outreach*, *10*, 4. https://doi.org/10.1186/s12052-017-0068-0

Dunk, R. D. P., & Wiles, J. R. (2018). Changes in acceptance of evolution and associated factors during a year of introductory biology: The shifting impacts of biology knowledge, politics, religion, demographics, and understandings of the nature of science. *Retrieved from BioRxiv 280479 [biology]*. https://doi.org/10.1101/280479

Ecklund, E. H., Scheitle, C. P., & Peifer, J. (2018). The religiosity of academic scientists in the United Kingdom: Assessing the role of discipline and department status. *Journal for the Scientific Study of Religion*, *57*(4), 743–757. https://doi.org/10.1111/jssr.12552

García, A. A. (2011). Cognitive interviews to test and refine questionnaires. *Public Health Nursing*, *28*(5), 444–450. https://doi.org/10.1111/j.1525-1446.2010.00938.x

Glaze, A. L. (2017, April). Divided we fall: The evolution controversy as a driver for rethinking science education. American Education Research Association held at San Antonio, TX.

Glaze, A. L., & Goldston, M. J. (2015). U.S. science teaching and learning of evolution: A critical review of the literature 2000–2014. *Science Education*, *99*(3), 500–518. https://doi.org/10.1002/sce.21158

Glaze, A. L., Goldston, M. J., & Dantzler, J. (2014). Evolution in the southeastern USA: Factors influencing acceptance and rejection in pre-service science teachers. *International Journal of Science and Mathematics Education*, *13*(6), 1189–1209.

Goldston, M. J. D., & Kyzer, P. (2009). Teaching evolution: Narratives with a view from three southern biology teachers in the USA. *Journal of Research in Science Teaching*, *46*(7), 762–790.

Gould, S. J. (2011). *Rocks of ages: Science and religion in the fullness of life*. New York, NY: Random House.

Hambleton, R. K., Swaminathan, H., & Rogers, H. J. (1991). *Fundamentals of item response theory*. London: Sage.

Hawley, P. H., Short, S. D., McCune, L. A., Osman, M. R., & Little, T. D. (2010). What's the matter with Kansas? The development and confirmation of the Evolutionary Attitudes and Literacy Survey (EALS). *Evolution: Education and Outreach*, *4*(1), 117–132. https://doi.org/10.1007/s12052-010-0294-1

Hermann, R. S. (2012). Cognitive apartheid: On the manner in which high school students understand evolution without believing in evolution. *Evolution: Education and Outreach*, *5*(4), 619–628. https://doi.org/10.1007/s12052-012-0446-6

Huxley, T. H., & Huxley, L. (1900). *Life and letters of Thomas Henry Huxley* (Vol. 1). London: Macmillan.

Imai, K., Keele, L., & Tingley, D. (2010). A general approach to causal mediation analysis. *Psychological Methods*, *15*(4), 309.

Jackson, D. F., Doster, E. C., Meadows, L., & Wood, T. (1995). Hearts and minds in the science classroom: The education of a confirmed evolutionist. *Journal of Research in Science Teaching*, *32*(6), 585–611.

Jensen, J. L., Manwaring, K. F., Gill, R. A., Sudweeks, R. S., Davies, R. S., Olsen, J. A., … & Bybee, S. M. (2019). Religious Affiliation and Religiosity and Their Impact on Scientific Beliefs in the United States. *BioScience*, *67*(4), 292–304. https://doi.org/10.1093/biosci/biz014

Kahan, D. M. (2017, May 24). *Misconceptions, misinformation, and the logic of identity-protective cognition* (Cultural Cognition Project Working Paper Series No. 164, Yale Law School, Public Law Research Paper No. 605, Yale Law & Economics Research Paper No. 575*)*. https://doi.org/10.2139/ssrn.2973067

Kahan, D. M., Braman, D., Gastil, J., Slovic, P., & Mertz, C. K. (2007). Culture and identity-protective cognition: Explaining the white-male effect in risk perception. *Journal of Empirical Legal Studies*, *4*(3), 465–505. https://doi.org/10.1111/j.1740-1461.2007.00097.x

Kimball, M. S., Mitchell, C. M., Thornton, A. D., & Young-Demarco, L. C. (2009). *Empirics on the origins of preferences: The case of college major and religiosity* (Working paper no. 15182). Cambridge, MA: National Bureau of Economic Research. Retrieved May 5, 2020, from www.nber.org/papers/w15182

Lawson, A. E., & Weser, J. (1990). The rejection of nonscientific beliefs about life: Effects of instruction and reasoning skills. *Journal of Research in Science Teaching*, *27*(6), 589–606. https://doi.org/10.1002/tea.3660270608

Linacre, J. M., & Wright, B. D. (1993). *A user's guide to BIGSTEPS: Rasch-model computer program*. San Diego, CA: Mesa Press.

Meade, A. W., & Craig, S. B. (2012). Identifying careless responses in survey data. *Psychological Methods*, *17*(3), 437.

Meadows, L., Doster, E., & Jackson, D. F. (2000). Managing the conflict between evolution & religion. *American Biology Teacher*, *62*(2), 102–107. https://doi.org/10.2307/4450848

Miller, K. R. (1999). *Finding Darwin's God: A scientist's search for common ground between god and evolution*. New York, NY: Harper-Collins.

Nadelson, L. S., & Southerland, S. (2012). A more fine-grained measure of students' acceptance of evolution: Development of the Inventory of Student Evolution Acceptance—SEA. *International Journal of Science Education*, *34*(11), 1637–1666. https://doi.org/10.1080/09500693.2012.702235

Nakagawa, S., Johnson, P. C., & Schielzeth, H. (2017). The coefficient of determination R^2 and intra-class correlation coefficient from generalized linear mixed-effects models revisited and expanded. *Journal of the Royal Society Interface*, *14*(134), 20170213.

Nehm, R. H., & Schonfeld, I. S. (2007). Does increasing biology teacher knowledge of evolution and the nature of science lead to greater preference for the teaching of evolution in schools? *Journal of Science Teacher Education*, *18*(5), 699–723.

Pobiner, B. (2016). Accepting, understanding, teaching, and learning (human) evolution: Obstacles and opportunities. *American Journal of Physical Anthropology*, *159*, 232–274.

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., Heisterkamp, S., & Van Willigen, B. & R Core Team. (2019). *Package 'nlme.' Linear and nonlinear mixed effects models (Version 3)*. Retrieved July 5, 2019, from https://CRAN.R-project.org/package=nlme

Rachmatullah, A., Nehm, R. H., Roshayanti, F., & Ha, M. (2018). Evolution education in Indonesia: Pre-service biology teachers' knowledge, reasoning models, and acceptance of evolution. In *Evolution education around the globe* (pp. 335–355). New York, NY: Springer.

R Core Team. (2020). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/

Reiss, M. J. (2009). The relationship between evolutionary biology and religion. *Evolution*, *63*(7), 1934–1941. https://doi.org/10.1111/j.1558-5646.2009.00714.x

Rissler, L. J., Duncan, S. I., & Caruso, N. M. (2014). The relative importance of religion and education on university students' views of evolution in the Deep South and state science standards across the United States. *Evolution: Education and Outreach*, *7*(1), 24. https://doi.org/10.1186/s12052-014-0024-1

Robitzsch, A., Kiefer, T., & Wu, M. (2020). *TAM: Test analysis modules (R Package Version 3.3, 9–35)*. Retrieved February 12, 2020, from https://CRAN.R-project.org/package=TAM

Rutledge, M. L., & Warden, M. A. (1999). The development and validation of the Measure of Acceptance of the Theory of Evolution instrument. *School Science and Mathematics*, *99*(1), 13–18. https://doi.org/10.1111/j.1949-8594.1999.tb17441.x

Rutledge, M. L., & Warden, M. A. (2000). Evolutionary theory, the nature of science & high school biology teachers: Critical relationships. *American Biology Teacher*, *62*(1), 23–31. https://doi.org/10.1662/0002-7685(2000)062[0023:ETTNOS]2.0.CO;2

Sbeglia, G. C., & Nehm, R. H. (2018). Measuring evolution acceptance using the GAENE: Influences of gender, race, degree-plan, and instruction. *Evolution: Education and Outreach*, *11*(1), 18. https://doi.org/10.1186/s12052-018-0091-9

Sbeglia, G. C., & Nehm, R. H. (2019). Do you see what I-SEA? A Rasch analysis of the psychometric properties of the Inventory of Student Evolution Acceptance. *Science Education*, *103*(2), 287–316. https://doi.org/10.1002/sce.21494

Sbeglia, G. C., & Nehm, R. H. (2020). Illuminating the complexities of conflict with evolution: Validation of the scales of evolutionary conflict measure (SECM). *Evolution: Education and Outreach*, *13*(1), 23. https://doi.org/10.1186/s12052-020-00137-5

Schwartz, R. A. (2012). *The development and psychometric modeling of an embedded assessment for a data modeling and statistical reasoning learning progression* (PhD thesis). University of California, Berkeley.

Scott, E. C. (2005). *Evolution vs. creationism: An introduction*. Berkeley: University of California Press.

Short, S. D., & Hawley, P. H. (2015). The effects of evolution education: Examining attitudes toward and knowledge of evolution in college courses. *Evolutionary Psychology*, *13*(1). https://doi.org/10.1177/147470491501300105

Sinatra, G. M., Southerland, S. A., McConaughy, F., & Demastes, J. W. (2003). Intentions and beliefs in students' understanding and acceptance of biological evolution. *Journal of Research in Science Teaching*, *40*(5), 510–528. https://doi.org/10.1002/tea.10087

Smith, M. U. (1994). Counterpoint: Belief, understanding, and the teaching of evolution. *Journal of Research in Science Teaching*, *31*(5), 591–597. https://doi.org/10.1002/tea.3660310512

Smith, M. U., & Siegel, H. (2016). On the relationship between belief and acceptance of evolution as goals of evolution education twelve years later. *Science & Education*, 1–24. https://doi.org/10.1007/s11191-016-9836-4

Smith, M. U., Snyder, S. W., & Devereaux, R. S. (2016). The GAENE—Generalized Acceptance of Evolution Evaluation: Development of a new measure of evolution acceptance. *Journal of Research in Science Teaching*, *53*(9), 1289–1315. https://doi.org/10.1002/tea.21328

Southerland, S. A., & Scharmann, L. C. (2013). Acknowledging the religious beliefs students bring into the science classroom: Using the bounded nature of science. *Theory into Practice*, *52*(1), 59–65. https://doi.org/10.1080/07351690.2013.743778

Stachl, C. N., & Baranger, A. M. (2020). Sense of belonging within the graduate community of a research-focused STEM department: Quantitative assessment using a visual narrative and item response theory. *PLoS ONE*, *15*(5), e0233431.

Stears, M., Clément, P., James, A., & Dempster, E. (2016). Creationist and evolutionist views of South African teachers with different religious affiliations. *South African Journal of Science*, *112*(5–6), 1–10.

Tingley, D., Yamamoto, T., Hirose, K., Keele, L., & Imai, K. (2014). mediation: R package for causal mediation analysis. *Journal of Statistical Software*, *59*(5), 1–38. Retrieved May 5, 2020, from www.jstatsoft.org/v59/i05

Tolman, E. R., Ferguson, D. G., Mann, M., Cordero, A. M., & Jensen, J. L. (2020). Reconciling evolution: Evidence from a biology and theology course. *Evolution: Education and Outreach*, *13*(1), 1–8.

Truong, J. M., Barnes, M. E., & Brownell, S. E. (2018). Can six minutes of culturally competent evolution education reduce students' level of perceived conflict between evolution and religion? *American Biology Teacher*, *80*(2), 106–115. https://doi.org/10.1525/abt.2018.80.2.106

Unsworth, A., & Voas, D. (2018). Attitudes to evolution among Christians, Muslims and the non-religious in Britain: Differential effects of religious and educational factors. *Public Understanding of Science*, *27*(1), 76–93.

Weisberg, D. S., Landrum, A. R., Metz, S. E., & Weisberg, M. (2018). No missing link: Knowledge predicts acceptance of evolution in the United States. *BioScience*, *68*(3), 212–222.

Willis, G. B. (2004). *Cognitive interviewing: A tool for improving questionnaire design*. New York, NY: Sage.

Winslow, M. W., Staver, J. R., & Scharmann, L. C. (2011). Evolution and personal religious belief: Christian university biology-related majors' search for reconciliation. *Journal of Research in Science Teaching*, *48*(9), 1026–1049. https://doi.org/10.1002/tea.20417

Yousuf, A., bin Daud, M. A., & Nadeem, A. (2011). Awareness and acceptance of evolution and evolutionary medicine among medical students in Pakistan. *Evolution: Education and Outreach*, *4*(4), 580–588. https://doi.org/10.1007/s12052-011-0376-8

Yok, M. C. K., Clément, P., Leong, L. K., Shing, C. L., & Ragem, P. A. (2015). Preliminary results on Malaysian teachers' conception of evolution. *Procedia-Social and Behavioral Sciences*, *167*, 250–255.