

Exploring Patterns of Evolution Understanding, Religiosity, and Evolution Acceptance in  
Undergraduate Biology Students in the United States

By

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## **ABSTRACT**

Despite evolution's foundational position in the biological sciences, it remains controversial among students learning biology. Some of the most consistent factors associated with student evolution acceptance are how much someone grasps evolution conceptually (which is typically referred to as understanding), and the extent to which they identify as religious (which is called religiosity) but there are very few studies exploring how the relationship between understanding and acceptance can be impacted by student religiosity levels. Further, students show different levels of acceptance of evolution depending on whether it is microevolution, macroevolution, or human evolution, but few studies explore how evolution understanding is related to acceptance in these three different areas. In this study, we surveyed introductory college biology students from a wide range of geographical contexts in the United States to explore the relationship between their understanding and acceptance of evolution and how religiosity impacts that relationship. We also explored how these relationships change based on acceptance of microevolution, macroevolution, and human evolution. Among incoming college students in introductory biology classes in the United States, understanding of evolution was positively related to acceptance of microevolution, macroevolution, and human evolution, but this relationship was weaker for highly religious students. There was a moderated relationship between evolution acceptance and evolution understanding by student religiosity levels. Students who scored high on religiosity showed a weaker relationship between their evolution understanding and acceptance of macroevolution/human evolution compared to those who scored lower on religiosity.

Further, highly religious students also showed no relationship between their understanding of evolution and acceptance of the common ancestry of life on Earth.

These results indicate that understanding of evolution is not the only factor that educators need to consider if they are to convey the importance and veracity of evolutionary theory to their students.

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## INTRODUCTION

Despite evolution's standing as a core concept in biology (American Association for the Advancement of Science, 2011; Brownell et al., 2014), it remains controversial in American society (Brenan, 2019) and among college students (Barnes, Supriya, et al., 2020), leading to relatively low levels of evolution acceptance in both populations. Evolution acceptance, defined here as the extent to which one perceives evolutionary theory and claims as scientifically valid (Barnes et al., 2024) is a complex and multifaceted phenomenon that is associated with a variety of academic, social, and psychological factors. Some of the most widely studied factors are understanding of evolution, defined as how much someone conceptually grasps evolution (Akyol, Tekkaya, & Sungur, 2012; Smith & Siegel, 2004), and religion variables such as religiosity (Dunk et al., 2017; Jensen et al., 2019), religious affiliation (Jensen et al., 2019), and perceived conflict between religion and evolution (Barnes, Supriya, et al., 2021). Despite the extensive research that has explored the relationship between evolution understanding and evolution acceptance and the relationship between religiosity and evolution acceptance, a notable gap persists in the literature. Specifically, previous studies have not delved into the nuanced interrelations between evolution understanding, religiosity, and evolution acceptance together, particularly in the context of American undergraduate biology students. Thus, this thesis aims to fill this gap by examining how religiosity may moderate the relationship between evolution understanding and evolution acceptance. In other words, does the relationship between evolution understanding and evolution acceptance depend on how religious students are? Shedding light on these intricacies will enhance our understanding of how religious

undergraduate biology students—which include future teachers, doctors, and scientists—may or may not be utilizing their understanding of evolution to form their decision to accept or reject this fundamental theory in the field of biology.

## **POSITIONALITY**

Given that this research seeks to identify students' knowledge and how this said knowledge may impact their acceptance of its validity, this may bring up the question, "What is knowledge?". The answer to that question is not straight forward because knowledge can come in different forms. Scientific knowledge, for example, is based in empiricism and rationalism. However, there are other methods of knowing, for example: intuition, which relies on emotions or instincts, and authority, which relies on trust and accepting new ideas from others (Jhangiani et al., 2019). In conducting this study, one goal was to uncover the nuanced relationship between individuals' understanding and acceptance of the theory of evolution, a cornerstone of scientific knowledge. I acknowledge that this approach may take on a more positivist perspective of knowing. In other words, it assumes that knowledge must be supported via measurable observations or experiments (Waliaula, 2022) which juxtaposes a post-positivist perspective that emphasizes the inherent bias in all scientific inquiry and the value in qualitative methods (Ruth, 2023). While it's important to acknowledge the limitations of any singular perspective, it's also pertinent to recognize that the theory of evolution, including its core tenants such as natural selection, speciation, and the common ancestry of life on Earth, is supported by a wealth of observational and experimental evidence and represents some of the closest approximations to certainty that science offers. Thus, I associate an acceptance

of evolution with a recognition of well-supported scientific knowledge, understanding that scientific knowledge evolves with the accumulation of evidence.

## **BACKGROUND**

### **Literature Review**

To better understand the previous research that has explored the specific relationships between evolution understanding and evolution acceptance and between religious views and evolution acceptance, a systematic literature review was performed. To search for relevant publications on the two relationships, various combinations of search terms were entered to maximize the number of relevant publications found (**box 1**). No other filters (e.g. publication date) besides the search terms were applied. Searches yielded ten results per page, and the author continued checking each result until three consecutive pages yielded no relevant publications to add to the review. Publications were chosen to be included in the review if they matched the criteria listed in **Box 2**.

**Box 1:** A list of search terms used in the literature review.

"Evolution Understanding" AND "Evolution Acceptance"  
"Understanding of Evolution" AND "Evolution Acceptance"  
"Evolution Understanding" AND "Acceptance of Evolution"  
"Understanding of Evolution" AND "Acceptance of Evolution"  
"Evolution Knowledge" AND "Evolution Acceptance"  
"Knowledge of Evolution" AND "Evolution Acceptance"  
"Knowledge of Evolution" AND "Acceptance of Evolution"  
"Religiosity" AND "Acceptance of Evolution"  
"Religious Beliefs" AND "Acceptance of Evolution"

**Box 2:** Selection criteria for publications to be included in the literature review.

- The study is published in a peer-reviewed journal.
- The publication measures understanding or knowledge of evolution and/or religiosity (the extent to which participants are religious).
- The publication measures evolution acceptance (the extent to which participants accept evolution as the explanation for the diversity of life on Earth).
- The publication performs a correlation analysis or a regression analysis with evolution understanding and/or religiosity as an independent variable and evolution acceptance as a dependent variable. This may or may not include an interaction term between evolution understanding and religiosity.

52 publications were found that matched the search criteria and were included in the review. A table of these publications along with their characteristics can be found in

the **Appendix**. Out of these 52 publications, 39 analyzed the relationship between evolution understanding and evolution acceptance. Of those 39, 34 (87%) only found a significant positive relationship between the two variables, one (3%) study found a positive relationship with microevolution only (Barnes, Riley, et al., 2022), and another study only found a positive relationship in two of their three sampled populations (Fiedler et al., 2024). The other three (8%) studies found no significant relationship between evolution understanding and evolution acceptance (Bishop & Anderson, 1990; Lawson, 1983; Sinatra et al., 2003). 31 of the studies in the review analyzed the relationship between religiosity and evolution acceptance. Of those studies, 28 (90%) only found a significant negative relationship between the two variables, one study (3%) found a negative relationship in one of the two populations they sampled for the analysis, and two (6%) found no significant relationship between religiosity and evolution acceptance (Gefaell et al., 2020; Tolman et al., 2021). 18 studies in the review included both an analysis of the relationship between evolution understanding and evolution acceptance and the relationship between religiosity and evolution acceptance. However, only two (11%) studies analyzed how religiosity may impact the relationship between evolution understanding and evolution acceptance, with conflicting findings (Fiedler et al., 2024; Weisberg et al., 2018). I further elaborate on each of these areas of the literature review below.

### **Evolution understanding and evolution acceptance**

Research has shown that biology instructors can conflate student evolution understanding with student evolution acceptance, thinking that if a student understands evolution well that this means they accept evolution (Barnes & Brownell, 2016).

However, understanding and acceptance are two distinct psychological constructs (Barnes & Brownell, 2017; Sinatra et al., 2003; Smith, 2010). Evolution understanding refers to the extent to which one's conceptions of evolution are scientifically accurate and the extent to which they can correctly answer questions testing their understanding of evolutionary theory (Barnes, Roberts, et al., 2021; Nadelson & Southerland, 2009; Weisberg et al., 2018). Evolution acceptance, however, is based on one's personal evaluation of evolutionary theory as scientifically valid (Barnes et al., 2024) and is often measured by the extent of agreement with evolutionary claims (Barnes, Misheva, et al., 2022; Glaze et al., 2020; Nadelson & Southerland, 2012; Rutledge & Warden, 1999). Although most quantitative studies find correlations between acceptance and understanding (**Appendix 1**) (Barnes et al., 2019; Dunk et al., 2017; Glaze et al., 2014; Rutledge & Warden, 1999; Trani, 2004), some studies find little or no relationship between the two constructs (Bishop & Anderson, 1990; Lawson, 1983; Sinatra et al., 2003). This may be due to moderating variables, such as religion, that are not taken into account in these studies. For instance, qualitative research has illuminated ways in which religious individuals can understand evolution well and yet still reject it. A study by (Hermann, 2012) interviewed high school students who had a high understanding of evolution but still "did not believe evolution". These students reported their lack of evolution acceptance was due to a perceived conflict with their religious beliefs. Perhaps the extent to which understanding evolution is related to acceptance of evolution depends on students' religion. Thus, instructors may need to take into account not only their students' conceptual understanding of evolution but also their students' religious background in order to support their evolution acceptance.

## **Religiosity and evolution acceptance**

Religious denomination, religious commitment (religiosity), and perceived conflict between religion and evolution are often the strongest variables predicting evolution acceptance in quantitative studies. Students from Judeo-Christian affiliations who score high on religiosity and/or perceived conflict between religion and evolution tend to have the lowest evolution acceptance (Barnes, Supriya, et al., 2021; Jensen et al., 2019). Students' perceived conflict between their religion and evolution can stem from a variety of factors. If students interpret creation narratives literally that describe a God/god(s) creating groups of organisms separately from one another (fish, birds, humans, etc.), this would be in direct conflict with the claim from evolutionary theory that all life shares common ancestry (Baker, 2013). There also may be a lack of apparent religious individuals who accept evolution within their close friends and family groups (Hill, 2014) making it seem implausible that religion and evolution could be compatible. Finally, church leaders, science instructors, and media might emphasize only conflict between religion and evolution without discussing areas of potential compatibility (Barnes, Truong, et al., 2017; Jackson et al., 1995; Unsworth & Voas, 2021). All of these factors could lead religious students to perceive that their religious identity and evolution can only be in conflict, and a student who perceives high conflict between their religion and evolution may learn about evolution but still choose to reject it.

## **Evolution understanding, religiosity, and evolution acceptance**

Although religious views, evolution understanding, and evolution acceptance have often been measured in past studies, very few have explored the specific relationship between all three. Those that have, have found conflicting results. For

example, a study with individuals from the American general public (Weisberg et al., 2018) found that when religiosity increased, the strength of the positive relationship between evolution understanding and evolution decreased. However, an opposite relationship was uncovered in a sample of secondary school students in Germany where higher levels of religiosity were associated with a stronger relationship between evolution understanding and evolution acceptance (Fiedler et al., 2024). So, what relationship may be uncovered in American undergraduate biology students? It may be important for college biology instructors to recognize how these variables interact to understand the best instructional practices to use for this population. If highly religious students show patterns similar to those previously found in the United States and understand evolution but do not accept it, they may be less likely to apply their knowledge of evolution in their scientific reasoning (Nadelson & Hardy, 2015; Sickel & Friedrichsen, 2013; Smith, 2010). Thus, instructors may need to reduce perceived conflict between religion and evolution in conjunction with increasing understanding of evolution to teach evolution in a way that leads to true conceptual change of both understanding and accepting evolution (Dole & Sinatra, 1998).

### **Microevolution acceptance, macroevolution acceptance, and human evolution acceptance**

Despite the fact that many incoming college biology students reject the common ancestry of life, these students often still accept small genetic and trait changes in populations over a few generations (sometimes called “microevolution”) indicating that different time scales and species contexts of evolution can impact how evolution is perceived (Beniermann et al., 2023; Nadelson & Southerland, 2012; Sbeglia & Nehm,

2019). For instance, when students are given the opportunity to identify their position on evolution, some will indicate they accept that modern reptiles, mammals, and birds evolved from previous animals of the same clade, but that these different clades were created separately from one another, indicating an acceptance of common ancestry at the level of a clade but not at the level of all of life on Earth. In the same study, other students indicated they believe that humans have remained relatively unchanged while other organisms have evolved over time, indicating an acceptance of evolution for species other than humans (Yasri & Mancy, 2016). Thus, researchers have differentiated between acceptance of microevolution (small changes within a species), acceptance of macroevolution (large evolutionary changes and common ancestry) and acceptance of human evolution.

The varied acceptance of evolution for different contexts (humans and nonhumans) and scales (microevolution and macroevolution) among students is not representative of expert thinking in biology. Within biology, the strength of evidence for evolution across scales and contexts is seen as equally strong and valid (Dietrich, 2010). Despite the mismatch with expert thinking in biology, the differential acceptance of evolution based on time scale and species context has been a prominent pattern uncovered in evolution acceptance research. In fact, survey measures for evolution acceptance often differentiate between students' acceptance levels of microevolution, macroevolution, and human evolution (Barnes, Misheva, et al., 2022; Beniermann et al., 2023; Glaze et al., 2020; Nadelson & Southerland, 2012; Sbeglia & Nehm, 2019). When they do not differentiate these constructs in survey items, this can lead to validity issues

with the surveys (Barnes, Supriya, et al., 2021; Misheva et al., 2023), which supports the claim that these three concepts exist as separate constructs in many students.

Low levels of macroevolution acceptance in students could be caused by cognitive constraints that make it conceptually difficult for students to imagine large transformations of species over periods much longer than the human life span (Blancke & Smedt, 2013). However, it may also be caused by perceived conflicts with religion that are apparent with macroevolution and human evolution but not for microevolution. For instance, Judeo-Christian creation narratives are often seen as in direct conflict with claims that humans have evolved from prior species but are not seen as in conflict with what is perceived as small evolutionary changes. For example, antibiotic resistance in bacteria are readily accepted with no perceived conflict in many religious individuals (Numbers, 2006). So, while most students may not have trouble using their understanding of evolution to inform their decision to accept microevolution, some students (particularly religious students) may have trouble using their evolution understanding to inform their decision to accept larger evolutionary changes even though they are just as scientifically valid.

Considering that the different contexts of evolution are not perceived by students uniformly, this study looks at how student religiosity levels may differentially impact the relationship between their evolution understanding and acceptance of these different scales and contexts of evolution.

### **Current Study and Research Questions**

As part of a larger nationwide survey-based study of American undergraduate biology students, we analyzed the relationships between students' evolution

understanding, evolution acceptance, and religiosity to determine to what extent students' religiosity impacts the relationship between their evolution understanding and evolution acceptance. We also looked at these relationships as they relate to different scales and contexts of evolution (microevolution acceptance, macroevolution acceptance, and human evolution acceptance). Considering that most evolution education studies are completed with samples of a few hundred students or fewer, this study, which reached over 11,000 undergraduate biology students across 13 states, serves to illustrate broad trends in these relationships across multiple national samples.

## **METHODS**

### **Survey Distribution**

Researchers contacted biology instructors from across the country via email and listservs to recruit participants for this study. Between Fall 2018 and Spring 2021, surveys were administered to undergraduate biology students across 74 different biology courses throughout the United States. Before receiving evolution instruction, students completed the survey in exchange for a small amount of extra credit.

The survey was administered as part of a larger study to explore how evolution instruction impacts evolution acceptance in undergraduate biology students and was approved through Arizona State University's institutional review board protocol #8191. In addition to a demographic questionnaire, previously published measures of religiosity (Cohen et al., 2008), acceptance of evolution (Nadelson & Southerland, 2012), and evolution understanding (Hawley et al., 2011) that have previous validation evidence

with college biology students were included in this study. All questions analyzed for this article can be found in the **Appendix**.

## **Measures**

*Religiosity* of students was measured using four statements from a previously published measure meant to capture the extent of students' religious tendencies (Cohen et al., 2008). Students agreed or disagreed with four statements on a 5-point Likert scale (for example, "I believe in God." and "I attend religious services regularly") Likert scores of all four items were averaged to produce a composite religiosity score ranging from 1 to 5, with 1 being the least religious and 5 being the most religious.

*Acceptance of Evolution* was measured using 24 items from the Inventory of Student Evolution Acceptance (I-SEA) (Nadelson & Southerland, 2012). Eight items measured microevolution acceptance (i.e., "I think that species exist today in exactly the same shape and form in which they always have."), eight items measured macroevolution acceptance (i.e., "I think the forms and diversity of organisms have changed dramatically over time.") and eight items measured human evolution acceptance (i.e., "I think that humans and apes share an ancient ancestor.") for a total of 24 items. Students could agree or disagree with each statement on a 5-point Likert scale. Answers to these items were averaged to produce three evolution acceptance scores (one for each context of evolution) ranging from 1-5, with 1 being the least accepting and 5 being the most accepting.

*Evolution Understanding* was measured using 14 true or false items from the Evolutionary Attitudes and Literacy instrument (EALS) (Hawley et al., 2011). Example items included "In most populations, more offspring are born than can survive" and "Evolution is a linear progression from primitive to advanced species". Students were

given the opportunity to choose “I don’t know enough to answer” for each item, which was coded as incorrect. Students’ understanding scores were calculated using the proportion of correct answers. For example, a score of 0.5 would indicate the student answered 7 out of 14 items correctly. A limitation of this measure is that it does not disaggregate student understanding of evolution by different scales and contexts like the evolution acceptance measure. So, although this measure allows us to probe relationships between a general understanding of evolution and acceptance of different scales and contexts of acceptance (microevolution, macroevolution, and human evolution) we were not able to look specifically at, for instance, the relationships between microevolution understanding and microevolution acceptance or human evolution understanding and human evolution acceptance because this measure of understanding is not disaggregated by these areas in the same manner as the acceptance measure.

### **Analyses**

To test whether the relationship between students’ evolution understanding and evolution acceptance depends on student religiosity level, we ran mixed-effects linear regression models using the lme4 package in R (Bates et al., 2015). Mixed-effects regressions were used to account for the lack of independence in the data. In other words, students were hierarchically grouped in different classes at different universities, so those variables, or random effects, needed to be considered to get the most accurate model. Multiple models were created, each with various combinations of random effects included. As recommended by (Theobald, 2018), the model with the lowest Akaike Information Criterion (AIC) value and the smallest number of random effects was determined to be the best fitting model. The best fitting model in this study includes

course and institution as random effects. We ran three regression models with microevolution acceptance, macroevolution acceptance, and human evolution acceptance as the dependent variables so that the relationships could be compared across the different contexts of evolution. All regressions contained the same independent variables: evolution understanding, religiosity, and an interaction between evolution understanding and religiosity. Including this interaction in the analyses tested whether the relationship between understanding and acceptance depended on how religious students are. All regressions included course and institution as random effects. The regression equations used in the analyses are listed in **Box 3**.

**Box 3:** Regression Equations used to determine the interaction effect between religiosity and evolution understanding as predictors of the dependent variables: microevolution, macroevolution, and human evolution acceptance.

$\begin{aligned} \text{Micro} &\sim \text{Rel} + \text{EvoUnd} + \text{Rel}*\text{EvoUnd} \mid \text{Course} \mid \text{Institution} \\ \text{Macro} &\sim \text{Rel} + \text{EvoUnd} + \text{Rel}*\text{EvoUnd} \mid \text{Course} \mid \text{Institution} \\ \text{Human} &\sim \text{Rel} + \text{EvoUnd} + \text{Rel}*\text{EvoUnd} \mid \text{Course} \mid \text{Institution} \end{aligned}$
---

Simple slope analyses were performed to probe the different relationships between understanding and acceptance seen in students with different levels of religiosity. To do this, the data were divided into three groups based on students' religiosity scores, and three regressions were performed for each religiosity group to predict the extent evolution understanding predicts the three constructs of evolution for a

total of nine regressions (**Table 1**). Due to the large sample size of these data, we consider a result statistically significant when  $p < .001$ .

**Table 1:** A breakdown of the three religiosity groups, their corresponding religiosity scores and number of students in each group. Also included are nine regressions performed for simple slope analyses probing significant interactions. All regressions include evolution understanding as a predictor variable, acceptance of difference contexts of evolution as dependent variables, and course and institution as random effects.

Religiosity Group	Religiosity Score	n	Regression Equation
Low	1 - 2	2,268	Micro ~ EvoUnd   Course   Institution
			Macro ~ EvoUnd   Course   Institution
			Human ~ EvoUnd   Course   Institution
Moderate	2.25 – 3.75	5,443	Micro ~ EvoUnd   Course   Institution
			Macro ~ EvoUnd   Course   Institution
			Human ~ EvoUnd   Course   Institution
High	4 - 5	4,075	Micro ~ EvoUnd   Course   Institution
			Macro ~ EvoUnd   Course   Institution
			Human ~ EvoUnd   Course   Institution

After the above regressions were completed, descriptive statistics of each item in the evolution acceptance survey were reviewed. It was found that two of the eight items in the macroevolution acceptance measure elicited lower average acceptance levels

compared to the other six items. The two items were the only macroevolution acceptance items directly related to students' acceptance of the common ancestry of all life on Earth ("I think all complex organisms evolved from single celled organisms" and "I think that all organisms come from a single common ancestor"). Thus, a new variable was created, CA, which represents the mean acceptance of the two common ancestry related macroevolution items listed above. For comparison, a second new variable was also created: NCA, which represents the mean acceptance of non-common ancestry related macroevolution items. Examples of these items include "I think that new species evolved from ancestral species" and "I think that new species evolve from a lot of small changes occurring over relatively long periods of time". Additional mixed effects regressions (**Box 4**) and simple slope analyses (**Table 2**) were performed with CA and NCA as the dependent variables to probe the unexpected findings.

All R code and data used for the analyses in this study can be accessed at

<https://github.com/BioedSPSlab/Evolution.Understanding.Acceptance.Religiosity>.

**Box 4:** Regression Equations used to determine the interaction effect between religiosity and evolution understanding as predictors of the dependent variables: Common Ancestry Acceptance (CA) and Non Common Ancestry Acceptance (NCA).

$\begin{aligned} \text{CA} &\sim \text{Rel} + \text{EvoUnd} + \text{Rel} * \text{EvoUnd} \mid \text{Course} \mid \text{Institution} \\ \text{NCA} &\sim \text{Rel} + \text{EvoUnd} + \text{Rel} * \text{EvoUnd} \mid \text{Course} \mid \text{Institution} \end{aligned}$
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**Table 2:** A breakdown of the six regressions performed for the simple slope analyses using the acceptance of common ancestry (CA) and non-common ancestry related (NCA) macroevolution acceptance items as dependent variables. All regressions included course and institution as random effects to achieve the best fitting model.

Religiosity Group	n	Regression Equation
Low	2,268	CA ~ EvoUnd   Course   Institution
		NCA ~ EvoUnd   Course   Institution
Moderate	5,443	CA ~ EvoUnd   Course   Institution
		NCA ~ EvoUnd   Course   Institution
High	4,075	CA ~ EvoUnd   Course   Institution
		NCA ~ EvoUnd   Course   Institution

## RESULTS

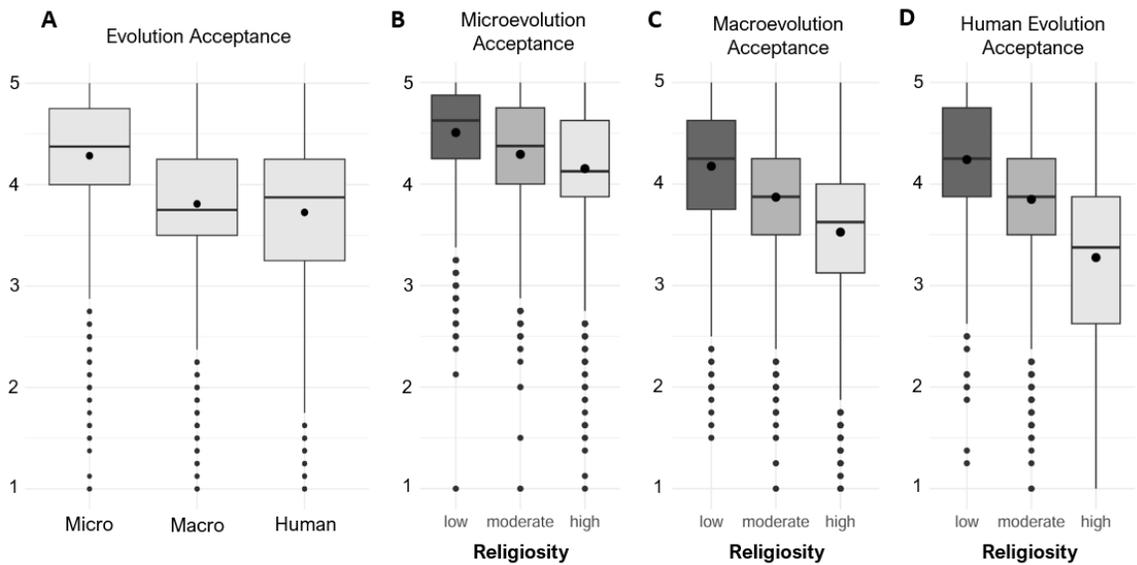
Surveys were made available to approximately 16,894 students and 11,995 responses were collected for a response rate of approximately 71%. After removing data from individuals who indicated that they did not provide honest and thoughtful responses, individuals in courses with less than 20 students (Simmons et al., 2011), and individuals who had missing data from necessary items, the sample included 11,786 students. For a detailed breakdown of the demographics of the sample, see **Table 3**. Our sample represented 72 different introductory level biology classes at various colleges and universities across 14 states. A breakdown of the proportion of students in each state can be found in the **Appendix**.

**Table 3:** Demographics of students. ( $n = 11,786$ )

<b>Religion</b>		<b>Race</b>	
Atheist / Agnostic	30.2%	Asian	17.0%
Buddhist	2.0%	Black	6.4%
Christian	53.7%	Latin(x)	17.0%
Hindu	2.0%	Multiracial	9.3%
Jewish	1.7%	Native Pacific Islander	0.3%
Muslim	2.6%	White	47.5%
Other	4.8%	Other	0.3%
Decline to State	3.0%	Decline to State	1.7%
<b>Gender</b>		<b>Major</b>	
Woman	67.1%	Biology	52.8%
Man	31.5%	Non-Biology	47.0%
Non-Binary	0.8%	Decline to State	0.2%
Other	0.1%		
Decline to State	0.5%		

### **Descriptive Statistics**

The average microevolution score for the sample was 4.3 out of 5 with a standard deviation of 0.55, the average macroevolution score was 3.8 out of 5 with a standard deviation of 0.65, and the average human evolution acceptance score was 3.7 out of 5 with a standard deviation of 0.81. See **Figure 1** for a breakdown of average scores of microevolution, macroevolution, and human evolution acceptance disaggregated by religiosity levels.



**Figure 1:** (A) Box and whisker plots of all students’ acceptance of microevolution, macroevolution, and human evolution. (B-D) Students’ microevolution, macroevolution, and human evolution acceptance disaggregated by religiosity group. 1 represents the lowest acceptance while 5 represents the highest acceptance. Each horizontal bar represents the median acceptance, each dot represents the mean acceptance, and each box represents the interquartile range.

**Finding 1: The relationship between students’ understanding of evolution and acceptance of evolution depends on students’ religiosity and the context of evolution.**

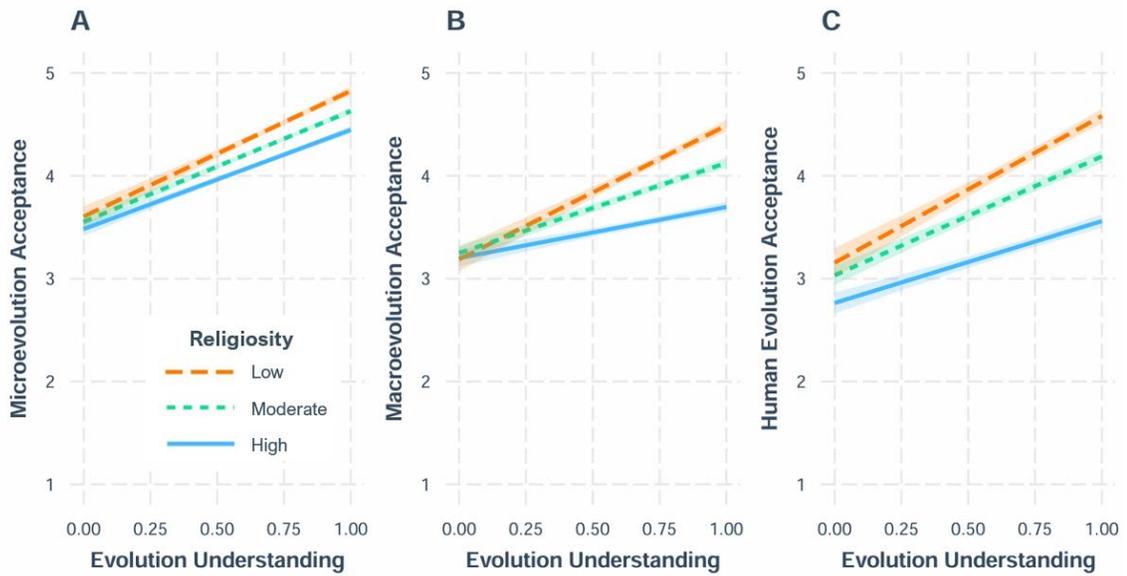
The results from the linear mixed-effects regression models indicated that the interaction effects between evolution understanding and religiosity were statistically significant as predictors of macroevolution acceptance and human evolution acceptance ( $p < .001$ , macroevolution coefficient = -0.21, human evolution coefficient = -0.12). The interaction effect as a predictor of microevolution was not significant ( $p = 0.048$ , coefficient = -0.05). These results are evidence that the relationship between evolution understanding and evolution acceptance depends on how religious students are. In other

words, religiosity moderated the relationship between understanding and acceptance. The larger coefficients seen in the interactions for macroevolution and human evolution acceptance compared to microevolution acceptance suggests that religiosity plays a smaller role in the relationship between evolution understanding and acceptance of microevolution. This was unsurprising as microevolution generally elicits lower levels of conflict between individuals' religious views compared to macroevolution and human evolution (Beniermann et al., 2023; Nadelson & Southerland, 2012; Sbeglia & Nehm, 2019). A regression table with coefficients, confidence intervals, p-values, and omnibus statistics for these analyses can be found in **table 4**.

**Table 4:** Summary of results from the interaction effect analysis between evolution understanding and religiosity as predictors of the three contexts of evolution (the dependent variables). Marginal  $R^2$  was used. The regression equations used for these results can be found in **box 3**.

<b>Dependent Variable</b>	<b>Coefficient</b>	<b>Confidence Interval</b>	<b>P</b>	<b>R<sup>2</sup></b>
Microevolution Acceptance	-0.05	-0.09 – 0.00	0.048	0.168
Macroevolution Acceptance	-0.21	-0.26 – -0.15	< 0.001	0.187
Human Evolution Acceptance	-0.12	-0.18 – -0.05	< 0.001	0.251

Since there were significant interactions between evolution understanding and religiosity, further simple slope analysis regressions were completed to probe the relationships between understanding and acceptance for students at each religiosity level: low, moderate, and high. Although there was a decreasing trend of explained variance as religiosity increased evolution understanding did significantly predict acceptance of NCA at all religiosity levels ( $p < 0.001$ ). Evolution understanding significantly predicted acceptance of all contexts of evolution at all religiosity levels ( $p < 0.001$ ). However, while the relationship between acceptance and understanding was strong for non-religious students across all three contexts, for highly religious students, the relationship was weaker for macroevolution and human evolution acceptance. In other words, for highly religious students their understanding was a greater predictor of their acceptance of microevolution than macroevolution and human evolution. The coefficients, confidence intervals, and omnibus statistics of these relationships can be found in **Table 5** and displayed graphically in **Figure 2**.



**Figure 2:** Results of the simple slope analyses from Table 5 displayed graphically. Relationships between students’ evolution understanding and acceptance of (A) microevolution, (B) macroevolution, and (C) human evolution are disaggregated by religiosity level groups, determined by mixed effects regressions. The interaction between understanding and religiosity was statistically significant for macroevolution and human evolution ( $p < .001$ ) but not for microevolution ( $p = .048$ ).

**Table 5:** Results for the simple slope analysis regressions from **table 1** testing to what extent evolution understanding predicts microevolution, macroevolution, and human evolution acceptance for students of different religiosity levels.  $p < 0.001$  for all values.

<i>Figure</i>	<i>Religiosity</i>	<i>Coefficients</i>	<i>Confidence Intervals</i>	<i>R<sup>2</sup></i>
<b>Microevolution Acceptance</b>				
2A	Low	1.21	1.10 – 1.32	0.17
	Moderate	1.08	1.00 – 1.16	0.13
	High	0.98	0.88 – 1.08	0.08
<b>Macroevolution Acceptance</b>				
2B	Low	1.31	1.18 – 1.44	0.15
	Moderate	0.87	0.79 – 0.96	0.07
	High	0.55	0.42 – 0.68	0.02
<b>Human Evolution Acceptance</b>				
2C	Low	1.42	1.28 – 1.56	0.15
	Moderate	1.14	1.04 – 1.24	0.09
	High	0.84	0.68 – 1.00	0.03

**Finding 2: Among highly religious students there was no relationship between students’ understanding of evolution and their acceptance of the common ancestry of life.**

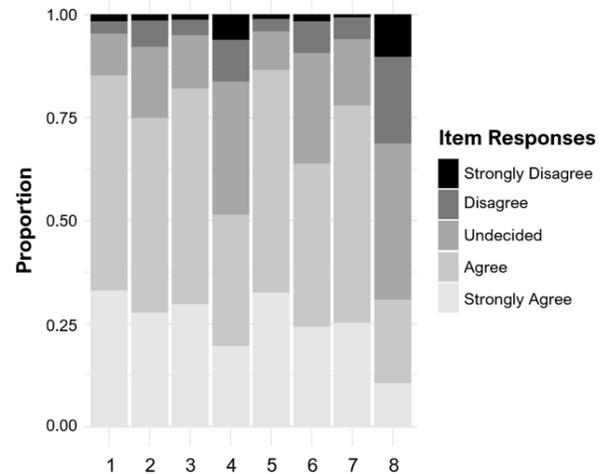
Since past research shows that human evolution generally elicits lower levels of acceptance compared to other contexts of evolution (Beniermann et al., 2023; Nadelson & Southerland, 2012; Sbeglia & Nehm, 2019), we predicted that the largest differences in

religiosity groups would be seen in the relationship between students' understanding and acceptance of human evolution. In our sample, average human evolution acceptance (3.7) was significantly lower than microevolution acceptance (4.3), and slightly lower than macroevolution acceptance (3.8). However, when looking at the relationships between evolution understanding and acceptance of macroevolution, there was a larger difference in slopes between high and low religiosity students (0.76 difference) compared to human evolution (0.58 difference). Thus, religiosity had a greater impact on the relationship between evolution understanding and macroevolution acceptance compared to the relationship between evolution understanding and human evolution acceptance.

Since this finding was contrary to what was expected, the average acceptance of all macroevolution and human evolution items were explored. It was found that two macroevolution items related to the common ancestry of life, "I think all complex organisms evolved from single celled organisms." (macroevolution item 4) and "I think that all organisms come from a single common ancestor." (macroevolution item 8) displayed lower levels of acceptance compared to the other six macroevolution items (**Figure 3**).

**A**

1. I think that new species evolved from ancestral species.
2. I think that the fossil evidence that scientists use to support evolutionary theory is weak and inconclusive.
3. I think there are a large number of fossils found all around the world that support the ideas that organisms evolve into new species over time.
4. I think all complex organisms evolved from single-celled organisms.
5. I think that new species evolve from a lot of small changes occurring over relatively long periods of time.
6. I think there is little or no observable evidence to support the theory that describes how one species of organism evolves from a different ancestral form.
7. I think the forms and diversity of organisms have changed dramatically over time.
8. I think that all organisms come from a single common ancestor.

**B**

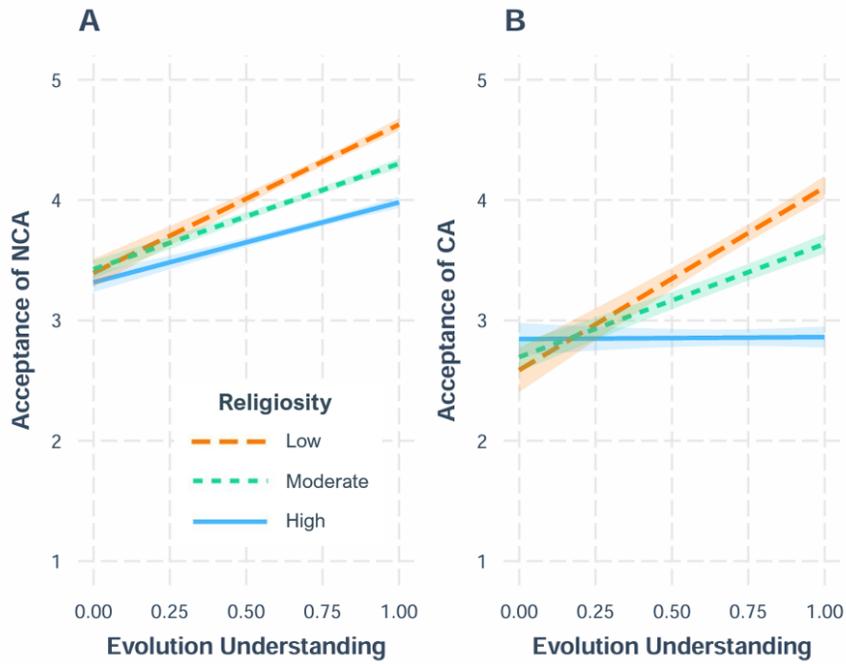
**Figure 3:** Items used to measure macroevolution acceptance (A) and the proportion of Likert scale responses from all students for all macroevolution acceptance items (B). Items that suggest non-acceptance of evolution (items 2 and 6) have been reverse coded.

To explore these unexpected findings, two new variables were created: mean acceptance of common ancestry related macroevolution items (CA) and mean acceptance of non-common ancestry related macroevolution items (NCA). Additional regressions with interaction effects between evolution understanding and religiosity (**Box 4**) were completed. The interaction between evolution understanding and religiosity was significant for both NCA acceptance and CA acceptance ( $p < 0.001$ ). The coefficients, confidence intervals, and omnibus statistics of these relationships can be found in **Table 6**.

**Table 6:** Summary of results from the interaction effect between evolution understanding and religiosity as predictors of NCA and CA. Marginal  $R^2$  was used. The regression equations used for these results can be found in **box 4**.

Dependent Variable	Coefficient	Confidence Interval	P	$R^2$
NCA Acceptance	-0.13	-0.19 - -0.08	< 0.001	0.156
CA Acceptance	-0.43	-0.51 - -0.35	< 0.001	0.143

Since there were significant interactions between evolution understanding and religiosity as predictors of NCA and CA, further simple slope analysis regressions were completed to probe the relationships between understanding and acceptance for students at each religiosity level: low, moderate, and high. Although there was a decreasing trend of explained variance as religiosity increased (similar to findings from micro, macro, and human evolution acceptance), evolution understanding did significantly predict acceptance of NCA at all religiosity levels ( $p < 0.001$ ). However, when looking at acceptance of CA, Evolution understanding was only a significant predictor in students with low and moderate religiosity ( $p < 0.001$ ). So, for students with a high religiosity, there was no relationship between evolution understanding and acceptance of the common ancestry of life ( $p = 0.265$ ). The coefficients, confidence intervals, and omnibus statistics of these relationships can be found in **Table 7** and displayed graphically in **Figure 4**.



**Figure 4:** Relationship between students' evolution understanding and (A) average acceptance of non-common ancestry macroevolution items (NCA) and (B) average acceptance of common ancestry related macroevolution items (CA) disaggregated by religiosity, determined by mixed effects regressions.

**Table 7:** Results for the simple slope analyses testing to what extent evolution understanding predicts the acceptance of common ancestry related macroevolution items and non-common ancestry related macroevolution items. Marginal  $R^2$  was used. Regression equations used can be found in Table 2.

<i>Figure</i>	<i>Religiosity</i>	<i>Coefficients</i>	<i>Confidence Intervals</i>	<i>R<sup>2</sup></i>	<i>p</i>
<b>Average acceptance of non-common ancestry items (NCA)</b>					
4a	Low	1.23	1.10 – 1.37	0.13	< 0.001
	Moderate	0.86	0.77 – 0.94	0.07	< 0.001
	High	0.70	0.57 – 0.83	0.03	< 0.001
<b>Average acceptance of common ancestry items (CA)</b>					
4b	Low	1.51	1.31 – 1.72	0.09	< 0.001
	Moderate	0.91	0.78 – 1.04	0.03	< 0.001
	High	0.11	-0.08 – 0.31	0.00	0.265

## DISCUSSION

This is the first quantitative study to our knowledge that has established that the relationship between evolution understanding and macroevolution acceptance, as well as the relationship between evolution understanding and human evolution acceptance, for college biology students in the United States, is moderated by religiosity. This quantitative study corroborates the qualitative work that has previously been done with biology students in the United States that has indicated religiosity as a factor in the relationship between understanding and acceptance of evolution (Hermann, 2012). It also

informs comparisons with work done with the United States public (Weisberg et al., 2018) in which similar results were found and with students in Germany in which contrary results were found for secondary school students (Fiedler et al., 2024).

In this study of introductory college biology students across a wide range of classes and geographical contexts, we found that among highly and moderately religious students there is a weaker relationship between their evolution acceptance and their evolution understanding compared to non-religious students. These results were statistically significant and pronounced for macroevolution acceptance and human evolution acceptance but not microevolution acceptance. Further, we discovered that the most prominent differences between highly, moderately, and low religiosity students in terms of the relationship between their understanding and acceptance was found for evolution acceptance items that inquired about students' acceptance of the common ancestry of life. These results are in line with and extend upon prior research showing that students tend to more readily accept small evolutionary change among non-humans but are more resistant to broader ideas of species changing dramatically over time and the extension of evolution to humans (Beniermann et al., 2023; Nadelson & Southerland, 2012; Sbeglia & Nehm, 2019; Yasri & Mancy, 2016). Here we show that students also seem to connect their understanding of evolution to their acceptance of microevolution more readily than macroevolution and human evolution. Further, we show that this pattern of reasoning is more likely to occur among students who are highly or moderately religious.

***Differential relationships based on religious identity may explain past conflicting findings in evolution education.***

These results may explain conflicting findings between evolution education studies about the extent to which evolution understanding is related to evolution acceptance. While some studies show strong relationships between evolution acceptance and understanding (Rutledge & Warden, 1999; Trani, 2004), other studies show no relationship (Bishop & Anderson, 1990; Lawson, 1983; Sinatra et al., 2003) or a weak relationship (Athanasίου & Papadopoulou, 2012; Cavallo et al., 2011; Deniz et al., 2008; Großschedl et al., 2014; Nadelson & Sinatra, 2009). The results of this study suggest that perhaps differences in the religiosity of the populations being studied or the context/scale of evolution being measured may account for these conflicting findings. If a researcher is relating evolution understanding to acceptance in a geographic region in which religiosity is high among the population, they will likely find weaker relationships between understanding and acceptance. Further, if researchers are measuring acceptance of macroevolution, human evolution, or the common ancestry of life, they also may see weaker relationships between understanding and acceptance compared to if they are measuring acceptance of microevolution. Since evolution acceptance has been measured quite differently by different researchers, (Barnes et al., 2019, 2024; Misheva et al., 2023) it's important to consider this when interpreting past and future studies on the relationship between evolution acceptance and understanding. Further, it indicates that future studies should include students' religiosity when interpreting relationship between acceptance and understanding or they may make conclusions about this relationship that is not generalizable to students from different religious backgrounds. Looking at

interactions with religious identity in these studies will be important because it has implications for the teaching and learning of evolution. When the relationship between evolution understanding and acceptance is weak among only religious students, it indicates that evolution instruction that does not address student religious identity barriers may be ineffective for increasing acceptance because it is not a lack of understanding causing rejection of evolution but perhaps identity and belief protection.

***Patterns detected are reflective of identity protective cognition.***

This differential pattern of understanding being more related to microevolution acceptance than macroevolution, human evolution, and the common ancestry of life on Earth among students from a religious background could indicate that students are engaging in identity protective cognition. Identity-protective cognition is a form of directional motivated reasoning (Kahan et al., 2016) that occurs when one's identity or culture guides reasoning in a way that is not accuracy-oriented (Kahan et al., 2007). Motivated reasoning explains how individuals' directional goals might bias how they assess information, construct ideas, and develop conclusions despite their attempts at being purely rational (Kunda, 1990; Sinatra et al., 2014). Evidence that individuals may have engaged in directional motivated reasoning about a scientific topic can be found when a source of cognitive bias (e.g. being affiliated with a specific social group) is associated with an evaluation of scientific information that favors the values of the individuals' group regardless of scientific understanding (Kunda, 1990). Although evidence for directional motivated reasoning about evolution has been uncovered in public samples (Kahan, 2017; Weisberg et al., 2018) this is the first time to our knowledge that evidence of directional motivated reasoning about evolution has been

detected in undergraduate biology students who represent a large pool of our future scientists, doctors, and science educators. Since the evidence for evolution is strong for all scales and contexts (American Association for the Advancement of Science, 2011; Freeman et al., 2019), these biology students should be showing similar relationships between evolution acceptance and understanding if we are meeting our goals as evolution educators to produce future scientists that are capable of distinguishing between strong and weak scientific evidence. How might we reduce identity protective cognition among undergraduate biology students?

***A potential solution: reduce perceived conflict between religion and evolution.***

One solution may be to reduce the perceived conflict between students' religious identity and evolution (Barnes, Supriya, et al., 2021; Barnes & Brownell, 2017) has been recommended to create more inclusive biology classrooms for Judeo-Christian students (Barnes, Truong, et al., 2017) and students from minoritized groups who tend to identify as religious at high rates (Barnes, Supriya, et al., 2020; Barnes, Roberts, et al., 2021; Google et al., 2024). Academic biology is often seen as an atheistic discipline for which religious individuals are not welcome (Barnes, Maas, et al., 2021; Scheitle & Ecklund, 2018) which can create an exclusive environment for students of color (Bailey et al., 2011; Mead et al., 2015; O'Brien et al., 2020). About half of both religious and non-religious college biology students were found to believe that in order to accept evolution, one had to be an atheist, but this belief was only negatively related to religious students' evolution acceptance (Barnes, Dunlop, et al., 2020). However, when educators implement instruction that dispels the false dichotomy between evolution and religion, this can help religious students with a perceived conflict increase their acceptance of evolution

(Barnes, Elser, et al., 2017; Ferguson & Jensen, 2021; Lindsay et al., 2019; Truong et al., 2018) and see biology as a more welcoming environment (Barnes & Brownell, 2017). Religious Cultural Competence in Evolution Education (ReCCEE) (Barnes & Brownell, 2017), Reconciliation Instruction (Lindsay et al., 2019) and Cultural and Religious Sensitivity (CRS) instruction (Bertka et al., 2019) have been recommended and shown to improve students' evolution education outcomes. These instructional strategies include teaching evolution as more accurately agnostic rather than atheistic (Barnes, Dunlop, et al., 2020), teaching the bounded nature of science (Carter & Wiles, 2014; Cavallo et al., 2011; Ingram & Nelson, 2006; Ladine, 2009; Martin-Hansen, 2008; Nehm & Schonfeld, 2007; Rutledge & Warden, 2000; Scharmann et al., 2005), showing examples of religious scientists and leaders who accept evolution (Barnes, Elser, et al., 2017; Winslow et al., 2011), showing the spectrum of views on the relationship between religion and evolution (including views in which people both accept evolution and believe in God/god(s) (Barnes, Elser, et al., 2017; Donnelly et al., 2009; Ingram & Nelson, 2006; Martin-Hansen, 2008; Verhey, 2005; Wiles & Alters, 2011), and treating the subject of between religion and evolution, reduce identity protective cognition when students reason about their evolution acceptance, and create more inclusive and welcoming biology environments for a wide range of students. Future research should explore whether reducing this perceived conflict between students' religious identity and evolution may increase the relationship between their understanding of evolution and their acceptance.

This could also have implications for reducing patterns of identity protective cognition for other culturally controversial science topics (CCSTs) that have wide support within the scientific community like vaccines and climate change (Cook et al.,

2016; Dudley et al., 2020). As beliefs about these topics become heavily associated with specific political or religious groups (Hornung, 2022; Kahan et al., 2010; Viswanath et al., 2021), people may see these beliefs as affecting their sense of belonging in their social groups. While this phenomenon for climate change and vaccines is relatively recent (Bayes & Druckman, 2021; Fischer et al., 2022; Sylvester, 2021), evolution educators have been navigating identity protective cognition due to perceived conflicts with religion since at least the inception of Darwin's *Origin of Species* (Numbers, 2006). If we find in future studies that reducing perceived conflict between religion and evolution helps mitigate identity protective cognition about evolution, it may be that reducing perceived conflict between political/religious identities and other CCSTs like climate change and vaccines may also mitigate identity protective cognition for these topics as well.

### ***Other potential solutions and future research***

An additional factor that could reduce these patterns of identity protective cognition could be teaching the nature of science (NOS). One important characteristic of science is its tentative nature of changing in the light of new evidence that may conflict with our prior beliefs and to aim for objectivity while recognizing how our human biases can affect our reasoning about science (American Association for the Advancement of Science, 2009). Indeed, one significant predictor of evolution acceptance is a person's understanding of NOS (Carter & Wiles, 2014; Cofré et al., 2017; Lombrozo et al., 2008). However, we did not collect data on students' understanding of these aspects of NOS so we could not disaggregate whether a higher understating of NOS helped to mitigate weak relationships between evolution understanding and acceptance among religious students.

Finally, it may be useful for future research to explore further specifically student acceptance of the common ancestry of life. While researchers have distinguished between acceptance of microevolution, macroevolution, and human evolution acceptance, there has been very little research on students' understanding and acceptance of the relatedness of all species to one another due to a universal a common ancestor. Yet, our results showed the most striking patterns of identity protective cognition amongst items measuring students' acceptance of the common ancestry of life. This may be a distinct construct from acceptance of other scales and contexts of evolution, especially for students from highly and moderately religious backgrounds. However, the measure we used for acceptance only had two items that referred to the common ancestry of life and items on our evolution understanding measure did not explore students' understanding of common ancestry. It would be useful to know more about student conceptions of common ancestry (both understanding and acceptance) and why items measuring acceptance of common ancestry showed the weakest relationship between understanding and acceptance.

## **CONCLUSION**

In this study we found that introductory college biology students showed patterns of identity protective cognition about evolution based on their religious identity and different scales and contexts of evolution. This research, in conjunction with the wider body of evolution education research illuminates the potential for reducing perceived conflict between religion and evolution as a mechanism for reducing patterns of identity protective cognition among our college educated populace.



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## **APPENDIX 1: SURVEY ITEMS ANALYZED**

## Survey questions analyzed

### *Understanding of Evolution*

This portion of the survey is meant to determine how much you understand about current evolutionary theory as proposed by scientists. Please answer the following questions based on your understanding of evolution.

Please choose whether each statement is true, false, or you don't know enough to answer based on your **understanding of evolution**:

1. Individuals don't evolve, species do.
2. Evolution is a progression towards more advanced species.
3. Mutations occur all the time.
4. Species evolve to be perfectly adapted to their environments.
5. In most groups of organisms, more offspring are born than survive.
6. Mutations can be passed down to the next generation.
7. More genetic variability makes a population more resistant to extinction.
8. Natural selection is the same thing as evolution.
9. The characteristics an organism acquires during their lifetime are often genetically passed down to their offspring.
10. Natural selection is the only cause of evolution.
11. The more recently species share a common ancestor, the more closely related they are.
12. Evolution means progression towards perfection.
13. Natural selection is a random process.
14. Natural selection means that only the smartest and physically strongest organisms survive.

### *Acceptance of Human Evolution*

Please indicate whether you agree or disagree with the following statements, **based on your personal opinion**. (5-pt Likert-scale, strongly disagree – strongly agree)

1. I think there is reliable evidence to support the theory that describes how humans were derived from ancestral primates.
2. I think that humans adapt, but they have not/do not evolve.
3. I think that the physical structures of humans are too complex to have evolved.
4. I think that humans and apes share an ancient ancestor.
5. I think that humans evolve.
6. I think that humans do not evolve; they can only change their behavior.

7. I think the many characteristics that humans share with other primates (i.e., chimpanzees, gorillas) can be best explained by our sharing a common ancestor.
8. I think physical variations in humans (i.e., eye color, skin color) were derived from the same processes that produce variation in other groups of organisms.

### *Acceptance of Macroevolution*

Please indicate whether you agree or disagree with the following statements, **based on your personal opinion**. (5-pt Likert-scale, strongly disagree – strongly agree)

1. I think that new species evolved from ancestral species.
2. I think that the fossil evidence that scientists use to support evolutionary theory is weak and inconclusive.
3. I think there are a large number of fossils found all around the world that support the ideas that organisms evolve into new species over time.
4. I think all complex organisms evolved from single-celled organisms.
5. I think that new species evolve from a lot of small changes occurring over relatively long periods of time.
6. I think there is little or no observable evidence to support the theory that describes how one species of organism evolves from a different ancestral form.
7. I think the forms and diversity of organisms have changed dramatically over time.
8. I think that all organisms come from a single common ancestor.

### *Acceptance of Microevolution*

Please indicate whether you agree or disagree with the following statements, **based on your personal opinion**. (5-pt Likert-scale, strongly disagree – strongly agree)

1. I think that organisms, as they exist now, are perfectly adapted to their natural environments and so will not continue to change.
2. I think all groups of organisms will continue to change.
3. I think there are a large number of examples of organisms that have undergone evolutionary changes within the species (i.e., antibiotic resistance in bacteria, production of new strains of the flu virus).
4. I think that species were created to be perfectly suited to their environment, so they do not change.
5. I don't accept the idea that a species of organism will evolve new traits over time.

6. I think there is an abundance of observable evidence to support the theory describing how variations within a species can happen.
7. I think that species exist today in exactly the same shape and form in which they always have.
8. I think there is overwhelming evidence supporting the theory of evolution to explain how variations in a species develop over time.

***Religiosity***

Please indicate how much you agree or disagree with the following statements: (5-pt Likert-scale, strongly disagree – strongly agree)

1. I attend religious services regularly (when they are available)
2. I believe in God
3. I consider myself a religious person
4. I consider myself a spiritual person

***Gender***

I most closely identify as:

- Woman
- Man
- Nonbinary
- Decline to state
- Please describe your gender identity if the best option is not listed:

\_\_\_\_\_

***Race/ethnicity:***

What is your race/ethnicity? Please select all that apply.

- Asian (East Asian, Southeast Asian, South Asian, West Asian, Middle Eastern)
- Black
- Latinx
- Native American, American Indian, or Alaskan Native
- Native Hawaiian or Other Pacific Islander
- White
- Decline to state
- Option not available, please describe: \_\_\_\_\_

## **APPENDIX 2: SUPPLEMENTAL TABLES**

**Table A1:** Publications included in the literature review.

Citation	Population	Location	Acceptance Measure	Relation b/w Evolution Understanding and Acceptance	Relation b/w Religiosity and Evolution Acceptance
(Akyol, Tekkaya, Sungur, et al., 2012)	Pre-service Teachers	Turkey	MATE	Positive	N/A
(Athanasidou & Papadopoulou, 2012)	Pre-service Teachers	Greece	MATE	N/A	Negative
(Barnes, Riley, et al., 2022)	College Students	United States	I-SEA	Positive for microevolution only	Negative
(Barnes, Roberts, et al., 2021)	College Students	United States	I-SEA	Positive	Negative
(Barnes, Supriya, et al., 2020)	College Students	United States	I-SEA	N/A	Negative
(Bishop & Anderson, 1990)	College Students	United States	Other	No Relationship	N/A
(Brown & Scott, 2016)	College Students	United States	MATE	Positive	N/A
(Carter & Wiles, 2014)	College Students	United States	MATE	Positive	Negative
(Coleman et al., 2015)	Pre-service Teachers	Turkey	MATE	Positive	N/A
(Deniz, 2011)	Pre-service Teachers	Turkey	MATE	N/A	Negative
(Deniz & Sahin, 2016)	Pre-service Teachers	Turkey	MATE	Positive	Negative
(Deniz et al., 2008)	College Students	United States	MATE	Positive	N/A
(Dunk et al., 2017)	College Students	United States	MATE	Positive	Negative
(Fiedler et al., 2024)	Pre-service Teachers, High School Students, Creationists	Germany	ATEVO, GAENE, I-SEA, MATE	Positive in students and pre-service teachers. No Relation in creationists.	Negative in pre-service teachers, Positive in students
(Fiedler et al., 2019)	College Students	United States	I-SEA, GAENE	Positive	N/A
(Fowler & Zeidler, 2016)	College Students	United States	MATE	Positive	N/A
(Gefaell et al., 2020)	College Students	Spain	MATE	Positive	No Relationship
(Glaze et al., 2014)	Pre-service Teachers	United States	MATE	Positive	Negative

<b>Citation</b>	<b>Population</b>	<b>Location</b>	<b>Acceptance Measure</b>	<b>Relation b/w Evolution Understanding and Acceptance</b>	<b>Relation b/w Religiosity and Evolution Acceptance</b>
(Großschedl et al., 2014)	Pre-service Teachers	Germany	MATE	Positive	Negative
(Gutowski et al., 2023)	High School Students	Germany	ATEVO 2.0	Positive	Negative
(Ha et al., 2012)	Pre-service Teachers	South Korea	MATE	Positive	N/A
(Ha et al., 2019)	Pre-service Teachers	China	MATE	Positive	Negative
(Heddy & Nadelson, 2013)	General Public	United States	Other	N/A	Negative
(Hermann, 2016)	College Students	United States	MATE	Positive	Negative
(Hermann, 2018)	Pre-service Teachers	United States	MATE	Positive	N/A
(Kuschmierz et al., 2021)	College Students	European Countries	ATEVO	Positive	Negative
(Lawson, 1983)	College Students	United States	Other	No Relationship	N/A
(Levesque & Guillaume, 2010)	Pre-service Teachers	United States	Other	N/A	Negative
(Lombrozo et al., 2008)	College Students	United States	Other	N/A	Negative
(Mantelas & Mavrikaki, 2020)	College Students	Greece	MATE	N/A	Negative
(Manwaring et al., 2015)	College Students	United States	MATE	Positive	Negative
(Manwaring et al., 2018)	General Public	United States	Other	N/A	Negative
(Nadelson & Hardy, 2015)	College Students	United States	I-SEA	N/A	Negative
(Nadelson & Sinatra, 2009)	Educational Professionals	United States	MATE	Positive	Negative
(Nadelson & Southerland, 2010)	College Students	United States	MATE	Positive	N/A
(Papadopoulou et al., 2012)	Teachers	Greece, Serbia	MATE	Positive	N/A

<b>Citation</b>	<b>Population</b>	<b>Location</b>	<b>Acceptance Measure</b>	<b>Relation b/w Evolution Understanding and Acceptance</b>	<b>Relation b/w Religiosity and Evolution Acceptance</b>
(Ramadani & Sukmawati, 2022)	College Students	Indonesia	MATE	Positive	N/A
(Rice et al., 2015)	College Faculty	United States	MATE	Positive	N/A
(Rissler et al., 2014)	College Faculty	United States	MATE	Positive	Negative
(Salazar-Enriquez et al., 2023)	High School Students	Mexico	I-SEA	Positive	N/A
(Shtulman, 2008)	College Students	United States	Other	Positive	N/A
(Sinatra et al., 2003)	College Students	United States	Other	No Relationship	N/A
(Sloane et al., 2023)	College Students	United States	MATE	Positive	N/A
(Stanisavljevic et al., 2013)	Teachers	Serbia	MATE	Positive	N/A
(Tavares & Bobrowski, 2018)	College Students	Brazil	MATE	Positive	N/A
(Teixeira, 2019)	High School Students	Brazil	Other	N/A	Negative
(Tolman et al., 2021)	General Public	United States	Other	N/A	No Relationship
(Trani, 2004)	Teachers	United States	MATE	N/A	Negative
(Unsworth & Voas, 2018)	General Public	United Kingdom	Other	N/A	Negative
(Weisberg et al., 2018)	General Public	United States	Other	Positive	Negative
(Wingert et al., 2022)	College Students	United States	I-SEA	Positive	Negative
(Zhang et al., 2022)	General Public	China, United States	Other	Positive	N/A

**Table A2:** Number of students in each state. n = 11,786

State	Number	Percentage
Alabama	688	5.8%
Arizona	1623	13.8%
California	1858	15.8%
Florida	1483	12.6%
Hawaii	182	1.5%
Michigan	308	2.6%
Minnesota	287	2.4%
North Carolina	920	7.8%
New York	977	8.3%
Oklahoma	37	0.3%
South Carolina	66	0.6%
Texas	2651	22.5%
Utah	662	5.6%
Wisconsin	44	0.4%

**Table A3:** AIC values were calculated for 24 different models each using religiosity and evolution understanding as predictor variables and one of the three contexts of evolution acceptance as outcome variables. Eight combinations of random effects were tested for each of the three outcome variables to determine the best fitting mixed effects model. The model with the lowest AIC value and the fewest number of parameters was chosen, and when the difference between two AIC values is 2 or less, the models are considered to have equivalent fit (Theobald, 2018).

Model	Random Effects (Parameters)	Microevolution Acceptance	Macroevolution Acceptance	Human Evolution Acceptance
1	No random effects (0)	17080.65	20596.03	24664.99
2	Course + Instructor + Institution (3)	17040.37	20544.78	24572.28
3	Course + Instructor (2)	17038.37	20548.04	24581.01
4	Course + Institution (2)	17038.37	*20542.78	*24570.28
5	Instructor + Institution (2)	17075.36	20567.04	24580.34
6	Course (1)	*17036.37	20546.09	24588.00
7	Instructor (1)	17073.36	20578.70	24590.01
8	Institution (1)	17095.93	20565.04	24578.34