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Offering Alternatives to Biblical Literalism May Be the Key to Increasing the Public's Acceptance of Evolution

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ABSTRACT

Evolution acceptance is lower among religious than nonreligious individuals. One potential factor involves how Judeo-Christian individuals interpret the Bible. We administered a nationwide survey to investigate the relationship between religiosity, biblical interpretation, and evolution acceptance. We also surveyed undergraduate students in a biology course before and after they underwent a culturally competent module on evolution. We found that religiosity predicted a more literal interpretation of the Bible, and these factors negatively predicted evolution acceptance in both samples. After the module, biblical literalism in the classroom decreased, predicting an increase in evolution acceptance without any decrease in religiosity. While the nationwide relationship between religiosity and evolution acceptance is generally understood, this study more directly reaffirms that biblical literalism is linked to evolution rejection and takes an important step into investigating interventions. Offering alternatives to biblical literalism may help educators increase evolution acceptance without threatening student religiosity.

1 | Introduction

1.1 | Background

Evolution is a central and well-supported scientific theory, yet it is rejected by up to 40% of Americans (Gallup 2019). Low evolution acceptance is apparent in the general public as well as in secondary and post-secondary schools (Miller et al. 2022; Wiles and Alters 2011). Research suggests that some students have a difficult time accepting evolution because it contradicts with their religious beliefs (Manwaring et al. 2015; Rissler et al. 2014). These data are evidence of the perceived conflict between religion and science. On the religious side, there are those who feel science is atheistic and a means to diminish their faith (Silva 2018). Meanwhile, on the scientific side, there are some who have negative attitudes toward Christians (Barnes et al.

2020) and believe religion “hampers” acceptance of evolution and science (Rissler et al. 2014). This negative relationship between science and religion is not new and creates unnecessary contention. This false dichotomy is harmful and the level of conflict that a student perceives between science and religion is a greater predictor of evolution acceptance than student religiosity, or commitment to religious practices and teachings (Barnes, Supriya, et al. 2021; Evans 2013; Manwaring et al. 2015). While religiosity, religious affiliation, understanding of evolution, and specific demographics may affect whether or not a student accepts evolution, the greatest predictor is still a student’s perceived conflict. A particularly salient influencing factor in this for many religious individuals and scientists alike is the real and perceived conflict regarding the interpretation of the biblical creation story found in the book of Genesis.

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1.2 | Biblical Interpretation

Biblical literalism is defined as an interpretation of the Bible in which the text is understood to be the direct strict word of God. Those who adopt this approach believe that the events and teachings in the Bible should be taken at face value rather than figuratively, metaphorically, or allegorically. When interpreted literally, some biblical stories appear to conflict directly with the theory of evolution, for example, the 7-day creation story, or the massive flood that wiped out much of life on Earth during Noah's lifetime (Barnes et al. 2020; Evans 2013). Particular to this paper is the potential conflict that students may feel if they literally interpret the creation story that is found in Genesis 1 and Genesis 2 of the Bible. For example, in referring to the creation of the earth, the book of Genesis states that "on the seventh day God ended his work which he had made" (King James Bible 1611/2013, Genesis 2:2). A literal interpretation of this verse may imply that God created all modern organisms on earth within seven 24-h periods of time, which directly conflicts with an evolutionary timeline. Not all Christians, however, interpret the Bible literally. About 52% of Christians who attend religious services weekly say the religious text should be interpreted literally, but 39% reject this literal interpretation (Pew Research Center 2024). When biblical literalism decreases, the creation story can be interpreted in ways that do not contradict the theory of evolution. As a result, it stands to reason that the perceived conflict between evolution and religion would decrease, thereby opening the door for religious individuals to accept evolution without giving up their personal beliefs. One study confirmed that a literal interpretation of the Bible is negatively correlated with evolution acceptance (Baker 2013). More study is necessary.

Christians who believe in a nonliteral interpretation of the biblical creation story can fall on a spectrum of positions regarding the relationship between creationism and evolution, some more scientifically compatible than others. Some of these positions include believing that (1) God created the different genera of animals, which have undergone small changes throughout time (microevolution only/higher genera creationism); (2) humans were created in their present form but other forms of life have evolved (human only creationism); (3) all forms of life have evolved but God has guided and/or occasionally intervened in order to direct the process (theistic evolution); and (4) God set evolution in motion but has not intervened (deistic evolution) (Scott 2009; Yasri and Mancy 2016). To increase the potential compatibility of evolution with religious ideologies, presenting religious students with perspectives that avoid atheistic viewpoints can be helpful (Barnes et al. 2020).

Ian Barbour, a Christian scientist, offered several ways to approach this intersection, some of which may be of value to consider. These approaches range from Conflict, the assumption that science and theology cannot come together, to Independence, the idea that science and religion have nonoverlapping boundaries—similar to Stephen Gould's Non-Overlapping Magisteria (NOMA; Gould 1997), to Dialogue, as an approach that allows for the discussion of an intersection with no requirement that they fit into one whole, to Integration, which stresses a smooth border crossing where science and theology align (see Barbour 1997).

The potential relationship between evolution acceptance and biblical interpretation has been acknowledged in previously published instruments that seek to assess evolution acceptance. The Measure of Acceptance of the Theory of Evolution (MATE), for example, asks respondents to rank the degree to which they agree that "the theory of evolution cannot be correct since it disagrees with the biblical account of creation" (Rutledge and Sadler 2007). Such questions suggest a connection between an individual's interpretation of the biblical account and their willingness to accept evolution—and further research has strengthened our understanding of this connection. In one study, researchers sought to help students at a religiously affiliated university (Church of the Nazarene) accept the theory of evolution by testing a teaching model that demonstrated religious cultural competence. Instructors discussed multiple perspectives of the relationship between biblical creationism and evolution, and helped students see how passages that seem to conflict with evolution could be understood in a way that accommodates contemporary science. The researchers ultimately found that evolution acceptance among the students significantly increased with no decrease in religiosity (Tolman et al. 2020). Such findings suggest that biblical interpretation is a significant factor in religious student acceptance of evolution. The question becomes how, or even if, this might be addressed in an instructional setting.

1.3 | Culturally Competent Instructional Model (CCIM)

One successful method that educators have used to bridge the gap between evolution and religion lies within the Religious Cultural Competence in Evolution Education (ReCCEE) framework, a framework designed to guide undergraduate instructors (even at public institutions) on how to approach evolution in a culturally sensitive way. Introduced in 2018, ReCCEE is an instructional framework that emphasizes acknowledging perceived conflict, exploring personal views, teaching the nature of science, outlining a spectrum of viewpoints, providing role models, and highlighting potential compatibility (Barnes and Brownell 2018). Various forms of it have been introduced in both private and public classrooms with consistent success in increasing evolution acceptance (e.g., Bertka et al. 2019; Ferguson et al. 2022; Tolman et al. 2021). We have developed a methodology that targets the final ReCCEE practice (highlighting potential compatibility) and have termed this specific methodology the CCIM. The CCIM minimizes the perceived dichotomy between Judeo-Christian religious beliefs and science by helping students find compatibility between evolution knowledge and their religious worldview (Manwaring et al. 2015; Lindsay et al. 2019; Ferguson and Jensen 2021; Tolman et al. 2020). Less effective teaching methods ignore religious worldviews by assuming that increasing evolutionary understanding alone leads to higher evolution acceptance or by mentioning that religious worldviews are not scientifically supported (Glaze et al. 2015; Rissler et al. 2014). These less effective strategies can give students the perception that evolution and religion must be incompatible (Barnes et al. 2020). Contrarily, ReCCEE practices, and the CCIM in particular, help students retain their religious identity while developing scientific literacy. While student religiosity has been found to be an *initial* negative predictor of evolution acceptance (Rissler et al. 2014), religiosity

is no longer a barrier to many religious students after discussions about compatibility (Barnes, Elser, and Brownell 2017; Ferguson and Jensen 2021; Lindsay et al. 2019; Manwaring et al. 2015; Tolman et al. 2020). If students can accept evolution while maintaining their religious identity, then what particular attitudinal changes are allowing them to reconcile and accept evolution?

1.4 | The Current Study

To help answer this question, we explored the relationship between biblical interpretation and evolution acceptance in two distinct phases. In one phase, an internet-based survey was administered to Judeo-Christian religious individuals nationwide. In another phase, we gathered surveys from an ecologically homogenous population of introductory biology students at a religiously affiliated university before and after a discussion of evolution that included the CCIM.

One purpose in performing this research was to learn whether biblical interpretation can be used as a predictor for evolution acceptance. While the nationwide relationship between religiosity and evolution acceptance is generally understood, this study more directly reaffirms that biblical literalism is linked to evolution rejection and takes an important step into investigating interventions. We hypothesized that biblical interpretation is a causal factor in evolution acceptance. Thus, in both the nationwide survey and the college intervention we predicted a negative correlation between biblical literalism and evolution acceptance.

Our second purpose was to determine if a change in biblical interpretation coincides with an increase in student acceptance of evolution. In previous studies, the CCIM has been shown to increase evolution acceptance while religiosity remains unchanged (Lindsay et al. 2019; Manwaring et al. 2015; Tolman et al. 2020). Because student religiosity was maintained in these studies, it is possible that a change in biblical interpretation is the contributing factor to the shift in evolution acceptance. By better understanding the causal mechanisms that contribute to an increase in evolution acceptance, biology instructors can tailor evolution teaching strategies to address these factors.

2 | Data And Methods

2.1 | Informed Consent

We obtained IRB approval from the institutional review board at the primary author's institution. Survey respondents and students were informed of the research and gave consent for their data to be used prior to taking surveys.

2.2 | Research Design

This study had two components: a nationwide survey and a classroom intervention. In the nationwide survey, we targeted individuals who identified with a Judeo-Christian religion to determine the relationships between biblical literalism and evolution acceptance. In the classroom intervention, we used a CCIM to target potential compatibility between evolution and

The Church of Jesus Christ of Latter-day Saints (CJC) theology, including suggestions for alternative interpretations of the biblical creation story. We then measured changes in evolution acceptance and biblical literalism.

2.3 | Sample Population

Our nationwide sample included 408 religious individuals of 19 different Judeo-Christian religions (see Table 1). All participants were 18 or older with about 33% being between 18 and 34, 33% were 35–54, and 33% were older than 55. Participants were from the west, midwest, northeast, and south. The survey was distributed through Qualtrics paneling meaning that a panel was selected based on criteria we provided. The filters included the following: affiliation with a Judeo-Christian religion, evenly distributed by age ranges shown above, distributed by education such that half had some college or less and half had an associate's degree or above. Demographic information is provided in Table 1.

Participants in the classroom intervention were recruited from the highly religious student body at a large (approximate student body of 35,000), private university in the western United States. From an ecological standpoint, this is an ideal population because they represent a highly religious and culturally homogenous population. About 92% of the student body are members of the CJC. Additionally, the institution's student body is relatively similar in religious views, life experience, age, and moral views compared to large public institutions. All participants were enrolled in a nonmajors introductory biology course. Students in these classes had one hour of class time during the semester devoted to the discussion of CJC doctrine and how it relates to evolution in the classroom. In all 186 students completed both pre-discussion and post-discussion surveys.

2.4 | CJC Theology

In order to help the reader understand the population of our classroom study more clearly, we will outline the position and history of the sponsoring religion with regard to evolution. The CJC is a Christian religion that holds a neutral position regarding the theory of evolution. In a recent publication of a magazine written for the youth members of the church, the following statement was made: "The Church has no official position on the theory of evolution. Organic evolution, or changes to species' inherited traits over time, is a matter for scientific study" (Church of Jesus Christ 2016). The CJC does hold a strong position on the origin of humankind as the literal offspring of, and created in, the image of deity (First Presidency 1925, 2002). However, this does not preclude an evolutionary origin of the human body (Church of Jesus Christ n.d. a).

This neutral position of the CJC has not resulted in a high acceptance among members of the church, however. The culturally held attitude toward evolution among members of the CJC has been primarily opposed to the theory (Evenson and Jeffery 2005). A 2015 study that looked at evolution acceptance and attitudes among introductory-level nonmajor biology students at the CJC's flagship university, Brigham Young University, showed that only 39% of students entered the class accepting

TABLE 1 | Demographics of nationwide sample.

Religious affiliation			
Baptist	38	Catholic	102
Church of Jesus Christ of Latter-day Saints (CJC)	37	Church of Christ/ Disciples of Christ	6
Christian	93	Congregational	1
Episcopalian/Anglican	7	Jehovah's Witness	4
Jewish	17	Lutheran	27
Methodist/Wesleyan	23	Muslim	2
Orthodox (Eastern)	3	Pentecostal/ Charismatic	10
Protestant (Other)	30	Reformed/ Presbyterian	3
Seventh-Day Adventist	2	Other Christian	3
Education			
High school only	75	Some college	105
Associates degree	42	4-year college degree	97
Graduate/professional degree	89		
Gender			
Male	153	Female	254
Nonbinary	1		
Ideology			
Conservative	200	Moderate	103
Liberal	101		

the theory of evolution in its entirety; the rest of the students expressed some degree of conflict in fully accepting the theory of evolution (Bradshaw et al. 2018). The study also identified three potential influences on the cultural attitudes toward evolution in the CJC population as condemnatory opinion statements from church leaders, generational familial influences, and the public education curriculum (Bradshaw et al. 2018).

2.5 | Culturally Competent Instructional Model

The CCIM used was first described by Manwaring et al. (2015) and has shown to be effective in introductory biology classes across the country among various faiths (Lindsay et al. 2019; Ferguson and Jensen 2021) and even in theology classes (Tolman et al. 2020). Current materials and resources used in a culturally competent module can be found on the website cited (RecoEvo.BYU.edu). The CCIM utilizes the following practices including (1) in-class discussions about the nature of science—helping students understand what science can and cannot address emphasizing that science is agnostic and does not comment directly on the presence or absence of a deity, (2) encouraging students to explore their religious beliefs in relation to evolution with a discussion Genesis and its original literary intention to the Israelites, emphasizing that we cannot interpret it from a literal lens today, (3) providing religious scientist role models in the form of a instructors who openly reveal their religious faith while confirming an acceptance of evolutionary theory, and (4) explicitly highlighting potential compatibility between specific religions and evolution, in this case specific

compatibility between teachings of the affiliated religion of most students and evolutionary theory (Barnes and Brownell 2018; Ferguson and Jensen 2021). Instructors are careful not to dictate belief to the students from any place of authority, but rather to suggest potential ways to make it compatible, while leaving definitive statements out. The CCIM was implemented as an individual lecture during the 50-min class period prior to the traditional evolution unit. This was followed by ten 50-min lectures on evolution including phylogenetics, species concepts, human evolution, natural and sexual selection, and mechanisms of evolution (i.e., Hardy-Weinberg).

2.6 | Instrumentation

2.6.1 | Evolution Acceptance

To measure evolution acceptance in the nationwide survey as well as before (1 week prior) and after the evolution unit (1 to 3 weeks post) in the classroom intervention (which began with the CCIM), we administered the Inventory of Student Evolution Acceptance (I-SEA). This survey instrument was created and validated by Nadelson and Southerland (2012). As part of its design, the instrument measures evolution acceptance by asking respondents how much they agree with statements in three categories: microevolution (e.g., “I think there is an abundance of observable evidence to support the theory describing variation within a species”), macroevolution (e.g., “I think that new species evolved from ancestral species”), and human evolution (e.g., “I think humans evolve”).

Because the surveys were designed and administered at different times for different purposes, the surveys slightly differ. In the nationwide survey, we included all 24 I-SEA questions (8 for each category). In the classroom intervention survey, we included 12 questions (4 for each category, based on modifications in Ferguson and Jensen 2021). Respondents would mark agreement with the statement on a 6-point Likert scale. For analyses, all comparisons included only shared items that fit our confirmatory factor analysis (CFA) between the two samples. CFA indicated an acceptable fit of the four shared macroevolution items (items 3, 4, 6, and 7 from the original I-SEA), for three shared microevolution items (items 3, 6, and 8 from the original I-SEA), and four shared human evolution items (1, 4, 5, and 7 from the original I-SEA) in both populations according to root mean square error approximation (RMSE), comparative fit index (CFI), Tucker-Lewis index (TLI), and standardized root mean square residual (SRMR). Residual errors were allowed to correlate between macro items 5 and 7, human items 4 and 7, and macro item 5 and human item 5. See [Supporting Information S1](#) for full CFA statistics for each survey item.

2.6.2 | Religiosity

We surveyed respondent religiosity in the nationwide sample and classroom intervention, pre- and post-intervention, using an instrument that was validated in a previous study on undergraduates at the same institution (Manwaring et al. 2015). Respondents self-reported the frequency of their religious practice with five items (e.g., how often you pray/read scripture/attend church), religious influence with five items (e.g., religion's influence on daily choices and political decisions), and religious hope with five items (e.g., your belief in the afterlife). All items were on a 6-point Likert scale for a total of 90 points. CFA (and EFA) analyses indicated that religious practice did not fit, likely due to the highly homogenous nature of our classroom sample. Only religious influence and religious hope were included in the model. Additionally, religious hope item 2 did not fit the model. The resulting CFA model, with residual errors correlated between Influence item 3 and Hope item 5, showed an acceptable fit in both populations, see [Supporting Information S1](#).

2.6.3 | Biblical Interpretation

To determine how respondents believe the Bible should be interpreted, we used six items from the Evolution Attitudes and Literacy Survey-Short Form, each on a 6-point Likert scale, “Young Earth Creationist Beliefs” construct (EALS-SF; Short and Hawley 2012). The statements were as follows: “I read the Bible literally,” “The Earth isn’t old enough for evolution to have taken place,” “There was a time when humans and dinosaurs lived on the earth together,” “Present animal diversity can be explained by the Great Flood,” “Adam and Eve of Genesis are our universal ancestors of the entire human race,” and “All modern species of land vertebrates are descended from those original animals on the ark.” CFA analyses indicated that items 1 and 3 did not fit the model. The consequent model included four items with acceptable fit in both populations, see [Supporting Information S1](#). Residual errors for items 4 and 6 were allowed to correlate.

2.7 | Statistical Analyses

We calculated an average total agreement for each student on each instrument by summing their Likert responses and dividing by the number of items. Average scores for both evolution acceptance and biblical literalism ranged from 1 (strongly disagree) to 6 (strongly agree). Average scores for religious influence ranged from 1 (no influence at all) to 6 (extreme influence) and religious hope from 1 (strongly disagree) to 6 (strongly agree). To determine the effects of the CCIM on acceptance, religiosity, and biblical interpretation in the classroom intervention, we used a nonparametric Wilcoxon signed-rank tests (due to a violation of the assumption of normality) to compare students’ pre-religiosity average scores to post-religiosity average scores and their pre-evolution acceptance average scores to post-evolution acceptance average scores, and pre-biblical interpretation average scores to post-biblical interpretation average scores. To determine relationships between variables in both studies, we used structural equation modeling (SEM). To determine whether changes in biblical interpretation were a predictor of evolution acceptance, we used multiple linear regression. Data are available at <https://scholarsarchive.byu.edu/data/75>.

3 | Results

3.1 | Nationwide Survey

3.1.1 | SEM Analyses

A structural equation model indicated a positive relationship between both religious influence (0.125; $p < 0.05$) and biblical literalism and religious hope (0.663; $p < 0.001$) and biblical literalism (Figure 1A). Biblical literalism is also significantly negatively correlated with microevolution acceptance (-0.600 ; $p < 0.001$), macroevolution acceptance (-0.783 ; $p < 0.001$), and human evolution acceptance (-0.790 ; $p < 0.001$) (Figure 1B).

3.2 | Classroom Intervention

3.2.1 | SEM Analyses

In the classroom intervention, we measured religiosity, biblical literalism, and evolution acceptance of introductory college biology students at the beginning of the semester. In accordance with the variable relationships discovered in the nationwide survey, religious influence (0.176 , $p < 0.001$) and religious hope (0.478 , $p < 0.001$) were both found to positively correlate with biblical literalism (Figure 1C). Biblical literalism was also found to negatively correlate with microevolution acceptance (-0.556 , $p < 0.001$), macroevolution acceptance (-0.717 , $p < 0.001$), and human evolution acceptance (-0.787 , $p < 0.001$) (Figure 1D).

3.2.2 | Changes in Evolution Acceptance

We saw significant increases in evolution acceptance in each of the three categories after the classroom intervention (Figure 2). Average agreement on the I-SEA for microevolution increased from 5.06 to 5.27 (with 6.0 being strongly agree) ($z = 3.55$,

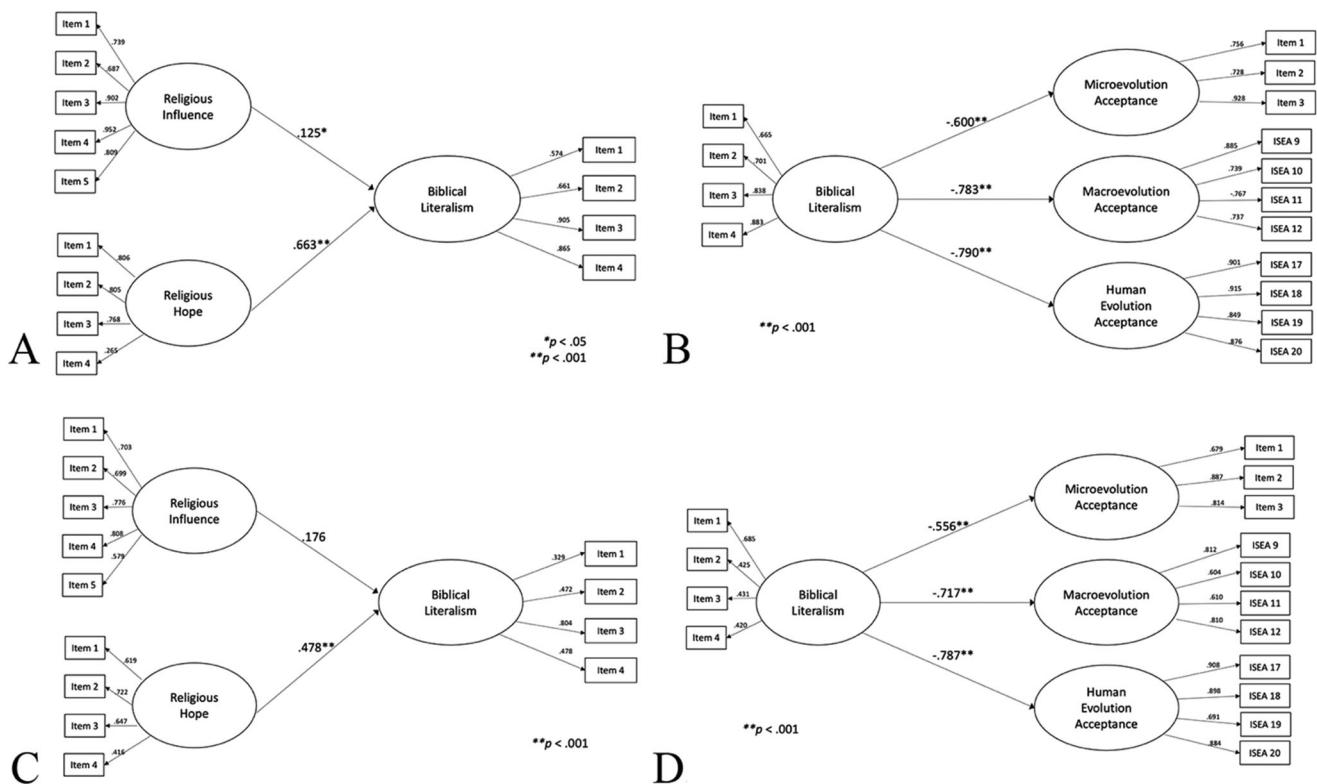


FIGURE 1 | Structural equation model showing the correlations in the nationwide survey and classroom intervention. SEM for the nationwide survey showing the relationship between religiosity and biblical Literalism (A) and the relationship between biblical literalism and evolution acceptance. (B) SEM for the classroom intervention showing the relationship between religiosity and biblical Literalism (C) and the relationship between biblical literalism and evolution acceptance (D).

$p < 0.001$). Macroevolution increased from 4.20 to 4.55 ($z = 5.48, p < 0.001$). Human evolution had the largest change, jumping from a 3.79 to 4.67, a 14.6% increase ($z = 9.06, p < 0.001$).

3.2.3 | Changes in Religiosity

To determine if students experienced a change in their religiosity, we surveyed students before and after the CCIM and evolution unit. According to the paired sample t -test, there was no statistically significant increase or decrease in students' religiosity scores over the course of the semester. Based on nine questions on a 6-point Likert scale, for a total of 54 points, the mean religiosity score began at 45.1 (83.5%; an average response of 5.01, with 6.0 being highest agreement) and remained nearly identical at 44.7 (82.7%; an average response of 4.97) post treatment (see Figure 2). This was not a significant change ($p = \text{NS}$).

3.2.4 | Changes in Biblical Interpretation

Each item was measured on a 6-point Likert scale, from strongly agree to strongly disagree, thus a low Likert score suggests a less literal interpretation of the Bible. The mean Likert scores for each of these questions decreased significantly from pre- to post-survey ($z = 5.83, p < 0.001$). Table 2 and Figure 3 show the decrease in mean Likert score for each of the statements, suggesting that after the CCIM and evolution unit, students were less likely to agree with literal interpretations of the Bible, although for most items, biblical literalism remained high.

3.2.5 | Biblical Interpretation as a Predictor of Evolution Acceptance

A linear regression controlling for pre-acceptance scores and pre-biblical literalism scores established that post-biblical literalism could statistically significantly predict a post-micro ($p = 0.007$), and human evolution ($p < 0.001$) acceptance, with macro evolution acceptance being suggestive ($p = 0.07$) (Table 3).

4 | Discussion and Conclusions

Our goal was to explore the relationship between biblical interpretation and evolution acceptance. We examined (1) whether biblical interpretation could be used as a predictor for evolution acceptance and (2) whether biblical interpretation changes by learning evolution with an accompanying CCIM. To answer these questions, our study included two phases: a nationwide survey and a classroom intervention.

4.1 | Biblical Literalism May Be a Causal Factor

We sought to better understand the relationship between a person's religiosity, how literally they interpret the Bible (biblical literalism), and evolution acceptance. From the nationwide survey, we see that religiosity predicts biblical literalism and biblical literalism predicts evolution acceptance. We saw the same trend among our religiously affiliated undergraduates. This means that

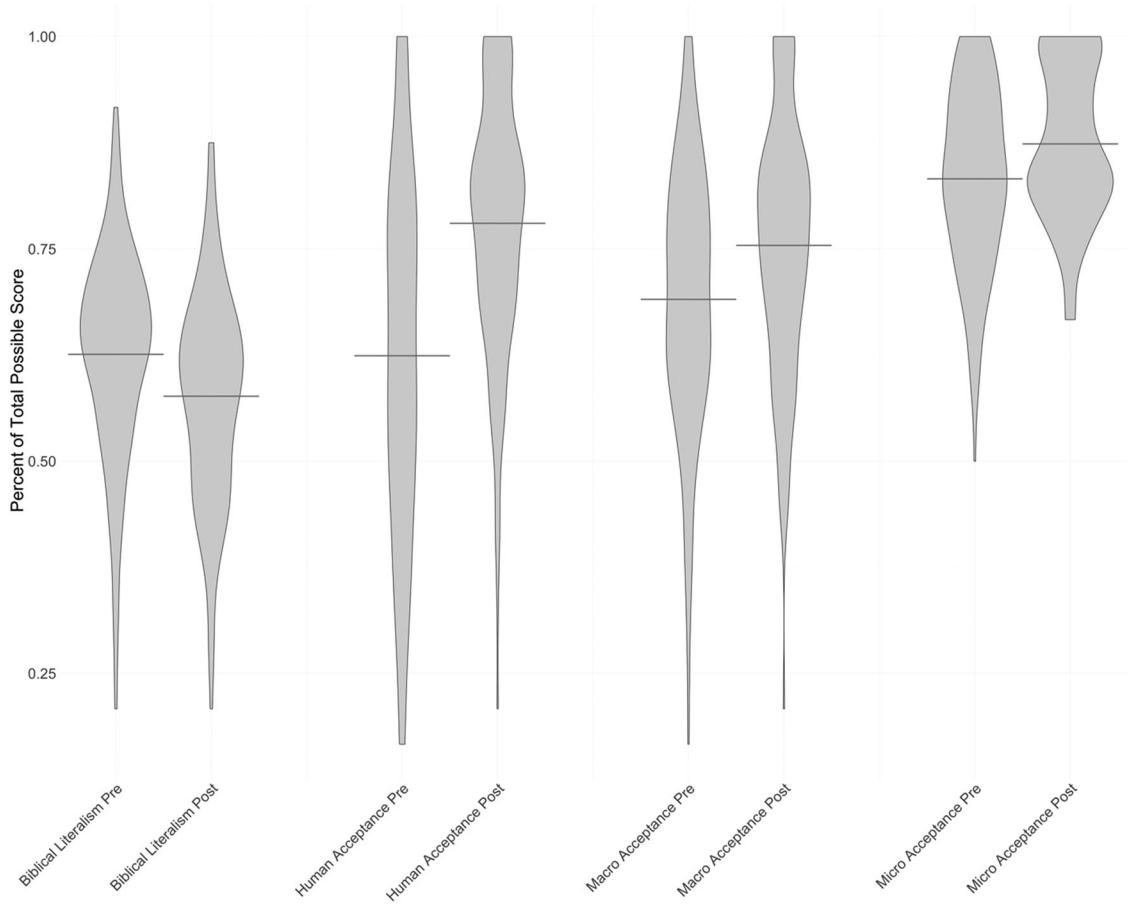


FIGURE 2 | Violin plot showing changes in the percentage of total points for biblical literalism, evolution acceptance, and religiosity before and after the culturally competent instruction unit of the classroom intervention.

TABLE 2 | Changes in biblical literalism.

Question	Mean Likert score	
	Pre	Post
Q1: The Earth isn't old enough for evolution to have taken place	2.17	1.89
Q2: Present animal diversity can be explained by the Great Flood	3.77	3.49
Q3: Adam and Eve are our universal ancestors of the entire human race	5.05	4.80
Q4: All modern species of land vertebrates are descended from those original animals on the ark	3.97	3.67

those with higher religiosity scores were more likely to interpret the Bible more literally, and those who interpret the Bible more literally have a lower acceptance of evolution. Prior research (although sparse) has also found that a literal interpretation of the Bible can predict lower evolution acceptance (Baker 2013; Rissler et al. 2014). These data suggest that biblical literalism is a hypothesized causal mechanism in between religiosity and evolution acceptance. This suggests that an examination of biblical literalism is a more direct and effective predictor of evolution acceptance than a measure of religiosity.

While many have shown that religiosity predicts evolution acceptance (Glaze 2017; Dunk and Wiles 2018), the various studies differ in how they measure a person's religiosity. Many of them do not consider biblical interpretation as part of religiosity. For example,

Glaze et al. (2015) measured religiosity by asking participants to self-report if they thought themselves to be religious, nonreligious, atheistic, or agnostic. Respondents were also asked how influential their religious beliefs were when making decisions relative to science. Biblical interpretation was not assessed. Rissler et al. (2014) and Barone, Petto, and Campbell (2014) both measured religiosity with two questions asking the participants' religious affiliation and how often the participant attended a religious service. Carter and Wiles (2014) measured religiosity by asking, "How active do you consider yourself to be in the practice of your religious preference?" Dunk et al. (2017) used five items from the Evolutionary Attitudes and Literacy Survey (Hawley et al. 2011) to measure religiosity: "My religion impacts my daily life," "My religion influences my decisions," and "I am a religious person," along with the frequency of church attendance and

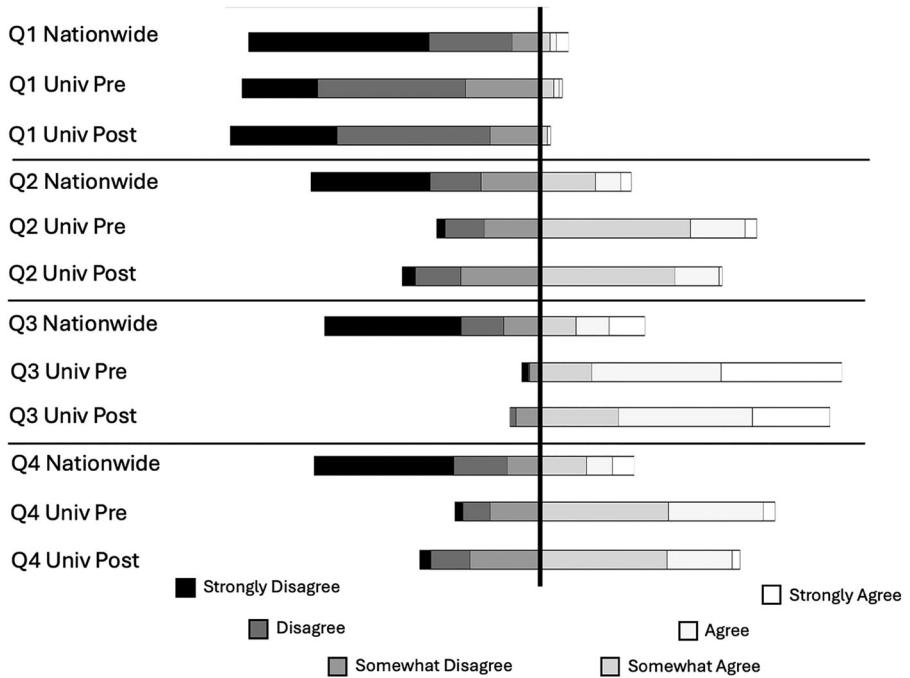


FIGURE 3 | Stacked bar chart comparing the percentage distribution of Likert biblical: literalism scores nationwide, pre-CCIM, and post-CCIM. Questions were opinion statements taken from the EALS-SF based on common misconceptions found among those who tend to interpret the Bible literally (Table 1). Darker represents a literal interpretation of the Bible while lighter represents a non-literal interpretation. For each question, the top bar represents the nationwide survey response. The two bars below represent the survey responses of the classroom intervention phase. **Q1:** The Earth isn't old enough for evolution to have taken place. **Q2:** Present animal diversity can be explained by the Great Flood. **Q3:** Adam and Eve are our universal ancestors of the entire human race. **Q4:** All modern species of land vertebrates are descended from those original animals on the ark.

TABLE 3 | Linear regression results for biblical literalism predicting evolution acceptance.

	β	<i>t</i>	<i>p</i>
Microevolution post-acceptance ($R^2 = 0.129, F = 7.63, p < 0.001$)			
Microevolution pre-acceptance	0.308	3.87	<0.001
Pre biblical literalism	0.186	1.79	0.076
Post biblical literalism	-0.272	-2.72	0.007
Macroevolution post-acceptance ($R^2 = 0.358, F = 28.62, p < 0.001$)			
Macroevolution pre-acceptance	0.565	7.68	<0.001
Pre biblical literalism	0.079	0.87	0.387
Post biblical literalism	-0.156	-1.81	0.073
Human evolution post-acceptance ($R^2 = 0.312, F = 722.96, p < 0.001$)			
Human evolution pre-acceptance	0.425	5.25	<0.001
Pre-biblical literalism	0.135	1.37	0.172
Post-biblical literalism	-0.349	-3.91	<0.001

importance of their church in their lives. Heddy and Nadelson (2013) and Barnes, Elser, and Brownell (2017) measured religiosity with one question asking participants on a scale of 1–4 (not important to very important) how important religion is in their lives. More recently, Jensen et al. (2019) measured religiosity with a much more extensive questionnaire, with 15 items on a 6-point Likert scale. These 15 items included multiple questions about religious practices, influence, and religious hope. None of these studies directly assessed biblical interpretation.

These differences in how religiosity has been measured and reported may be incorrectly associating certain religious practices with a person's acceptance of evolution when the actual barrier may be something more nuanced. Measuring religiosity with these questions also may give the impression that actions such as attending church on a regular basis or participating in church-related events are directly related to a person's willingness to accept evolution when it may have more to do with how they are interpreting the Bible. More recent studies show that a perceived

conflict between evolution and one's religious beliefs is a better predictor of evolution acceptance than overall religious practice (Barnes, Supriya, et al. 2021). We suggest that this perceived conflict may be due in part to a literal interpretation of the Bible.

4.2 | Understanding the Source of Biblical Literalism

To address this issue from a culturally competent lens, it requires an understanding of the source of these conceptions. For many religious individuals, the Bible is seen as inherently authoritative because it is believed to be derived directly from a divine source (Church of Jesus Christ, n.d. b). Some religious stances, especially Protestantism and other evangelical faiths, have taken this further, endorsing the idea of *sola scriptura* (Mathison 2001), that is that the scriptures are the only infallible source of authority and truth concerning doctrinal issues. This idea was originally proposed by Martin Luther, an early Protestant Reformer, in direct response to what he perceived as corruption in the way that doctrines were being applied in the Catholic church (Britannica 2023). This idea continues to be prevalent in contemporary Protestant denominations. Thus, if individuals adopt the principle of *sola scriptura*, they are left with very little interpretative "wiggle room" when reading the creationist text in Genesis. Additionally, it may be cognitively easier to assume that the scriptures (presumably authored by divinity) are more reliable than the often-contentious voices of science. In fact, the self-correcting nature of science, a quality which most scientists would applaud, and which is required for science to progress, can understandably serve as a source of mistrust for individuals with a scriptural account that seems in direct conflict with the science.

Also of particular note, with the bloom of scientific discovery in astronomy, geology, and biology over the 18th and 19th centuries, it required a reevaluation of some of the assumptions made about the biblical text. This caused a division in interpretative streams to emerge, one of which was the principle of Fundamentalism (Sandeen and Melton 2022), an idea that affirmed the historical accuracy and inerrancy of the creation account in the Bible (i.e., a strictly literalist viewpoint). This viewpoint often includes the outright rejection of any natural phenomena that seem counter to the literal scriptural account. This idea is still prevalent among many denominations today and may be a source of contention for students.

Another issue that is important to discuss is the way in which scripture is interpreted. Even if religious individuals do not hold strictly to a literalist interpretation, the flexibility of interpretative options is highly dependent on religious denomination and even on local congregational authority. This issue is highly complex especially among evangelical Protestants where there is generally not a single authoritative body responsible for establishing scriptural interpretation (beyond potentially looking to early reformers such as Martin Luther, John Calvin, Richard Hooker, or John Wesley) (Bruce 1985). Often, interpretative authority is left to the local teacher or pastor of a particular congregation. Even in denominations where a more centralized authoritative figure can offer doctrinal clarity (e.g., the Pope for Catholics, the Prophet for CJC members), there rarely exists interpretive statements for every verse in the scriptures and often the interpretations

are broad enough to allow for variations; high-ranking church authorities may even lack consensus in their interpretations (see Evenson and Jeffery 2005, as an example). Being aware of this complex religious history that likely influences the viewpoints of incoming students can help instructors develop cultural competence and thus more effective communication strategies.

4.3 | Using a Culturally Competent Approach

We developed a CCIM to aid instructors in effective communication surrounding evolutionary theory. In this study, we show that the CCIM was effective in helping CJC students increase their acceptance of evolution across all categories without losing their religiosity, as has been shown in previous studies (Barnes, Elser, and Brownell 2017; Ferguson and Jensen 2021; Lindsay et al. 2019; Manwaring et al. 2015; Tolman et al. 2020). The categories that showed the largest change were macroevolution and human evolution. This difference is important to note because it further supports our claim that biblical literalism is an important factor to consider.

From a biblical literalist perspective, microevolution is generally not a problem. Biblical literalism is more concerned with a change in species and human evolution since it may appear to conflict directly with the creation story. In the Bible, when referring to the creation of land animals, the book of Genesis 1:24-25 reads, "And God said, Let the earth bring forth the living creature after his kind... And God made the beast of the earth after his kind, and cattle after their kind, and every thing that creepeth upon the earth after his kind." Interpreting these verses literally may suggest that God created every species in its present form. This would not allow for any speciation to occur, because the biblical verses clearly state that God created all the organisms after their own kind in a single time period, or day.

When referring to the creation of humans, Genesis 1:26-27 reads, "And God said, Let us make man in our image, after our likeness... So God created man in his own image, in the image of God created he him; male and female created he them." Interpreting this scripture literally may suggest that humans could not have arisen from a common ancestor with other organisms because God created humans separately from other land animals and made humans physically appear exactly as we do today. As such, it makes sense that large changes in macroevolution and human evolution are associated with changes in biblical literalism.

4.4 | Limitations

Taken as a whole, our research seems to suggest that biblical literalism is an important causal factor contributing to a perceived conflict between religious beliefs and the theory of evolution that ultimately results in a rejection of the theory. However, despite the evidence pointing in this direction, we are still faced with some limitations and unanswered questions.

First, it is important to acknowledge that the classroom study was performed on a largely homogenous CJC population. It did not examine other Christian or non-Christian religious populations, thus results lack generalizability. However, our nationwide survey

included a variety of Judeo-Christian religions. Additionally, different religious sects and cultures (outside of Judeo and Christian faiths) have varying creation doctrines and some do not use the Bible at all.

A second limitation is that the surveys in our study slightly differed between the nationwide and classroom populations because they were designed and administered at different times and for different purposes. Additionally, while the post-instruction decrease in biblical literalism was significant, it is worth noting that students in the religiously homogeneous population continued to interpret the Bible more literally than the average respondent in the nationwide survey. While very few students agreed that “The Earth isn’t old enough for evolution to have taken place,” the majority of students continued to agree with statements that suggested a literal interpretation of the biblical flood and the story of Adam and Eve. Students were especially inclined to agree that “Adam and Eve are our universal ancestors of the entire human race” (90% agree after the classroom intervention). Why did students demonstrate such a significant increase in evolution acceptance while still interpreting these Bible stories literally? There are several possibilities we will propose to explain this apparent discrepancy.

First, it is possible that students were aware of the study’s purpose and answered in favor of evolution because they assumed that was the “right” answer. It was not possible for the study to have a control group because it would be disadvantageous to students’ learning outcomes who did not receive the CCIM. Therefore, we are unable to accurately assess if increases in evolution acceptance are because of the student’s awareness of the study’s purpose. Additionally, Christianity has been shown to be a concealed stigmatized identity (CSI) in science because Christians are stereotyped as less intelligent and less accepting of science (Barnes et al. 2020). Student’s may have been biased towards selecting answers that were more accepting of evolution after the study in order to avoid these stereotypes.

Another possible explanation is that, as students came to understand new ways to interpret the Bible, they developed a reconciliatory model based on the idea of theistic evolution (Scott 2009). This particular model would have allowed students to believe that evolution was divinely directed as part of the creation process and that this process of scientific evolution led up to certain key points in the biblical narrative. These “key points” would be events in the Bible which, if literally interpreted, students perceived as not being in conflict with scientific evidence. Given this explanation, students would interpret the seven-day creation story symbolically, believing it to be representative of a much longer creation period that involved divinely directed evolution. In students’ minds, this evolution process could then have led to, for instance, an Adam and an Eve who were the ancestors of today’s humans. This explanation is also a likely possibility within our student group in light of doctrinal statements by CJC religious leaders, who have expressed that “Adam was . . . the primal parent of our race” (First Presidency 2002). Certainly further study and follow-up on student responses is warranted.

A second possibility is that the students were demonstrating parallel collateral learning (Aikenhead and Jegede 1999). In parallel collateral learning, students construct separate cognitive

schemas—one based on their cultural beliefs, and another based on the science they are taught in the classroom. Given that the perceived conflict between personal beliefs and evolution—rather than the beliefs themselves—is at the heart of most evolution rejection (Barnes, Supriya, et al. 2021), it is possible that in order to avoid such conflict, students chose to keep what they are taught in the classroom separate from their religious beliefs. This method of learning has been observed in many individuals across the world, from students in the United Kingdom to children and adults in Nepal (Dart 1972; Goodman 1984; Hennessey 1993; Solomon 1983). Jegede (1995, 1997) has discussed parallel collateral learning in depth, focusing on how it relates to scientific teaching and learning. The reactions of the scientific community to this common method of learning have been mixed. Some researchers feel that it is “an effective survival technique” when students are faced with conflicting beliefs, whereas others believe collateral learning minimizes the positive impact that modern science can have on the lives of learners (Lowe 1995, 665; Waldrip and Taylor 1999). It is possible that parallel collateral learning was at play as these students were taught the module on evolution.

Of course, while aligned with the data and past research, the above explanations are largely conjecture. The question merits further research, including interviews or “think-alouds” with participating students that would allow us to determine their personal understanding, beliefs, and interpretations of the questions asked. Although this study is limited in its ability to explain these results, the data indicates that, when evolution is taught in a culturally competent manner, students are able to learn about and accept the theory without giving up their religious beliefs and practices. Our findings suggest that biblical literalism is an important factor to consider as instructors seek to teach in a way that reduces perceived conflict and increases student acceptance of evolution.

4.5 | Implications

The causal mechanisms for why the CCIM teaching approach increases acceptance of evolution among CJC religious audiences have not yet been thoroughly examined. However, our study uncovers one possible reason for why it is effective in increasing evolution acceptance. By introducing a discussion of biblical interpretation, biology instructors may be able to directly increase students’ acceptance of evolution without decreasing their religious beliefs. This is especially important in collegiate-level biology classes where it has been found that Christianity is a concealable stigmatized identity (Barnes et al. 2021). By acknowledging and helping students deal with the potential conflict, we may be able to decrease stigmatization and increase the inclusive nature of our classrooms.

Diving deeper into the structure and format of the Bible, instructors who address the historical applications and literary styles of Genesis may help reduce conflict between biblical interpretation and science. The collection of books in the Bible contain many different literary styles, primarily narrative, poetry, and discourse (Bible Project: Biblical Literary Styles 2017). Augustine of Hippo, an influential church leader and philosopher in the early Christian church, understood the creation story in Genesis 1 to be an allegory (Chaffey 2011). An allegory is a narrative that can be

interpreted to reveal a hidden meaning. Additionally, one might consider having students compare biblical creation stories in Genesis 1 and Genesis 2 that, if read through too strict of a lens, seem to conflict. Given that both are purportedly the word of God, it may help students consider more flexibility in their interpretive lens.

Another possible explanation for seemingly conflicting word choices in Genesis comes from the language in which the Bible was first written: Hebrew. In the Hebrew language, Genesis 1 contains vivid imagery, well-defined structure and clever wordplay, suggesting a poetic literary style (Patterson 2020). For instance, the parallel structure in each of the 6 days with the repetition of phrases like “God saw that it was good” (Genesis 1:31) suggests it is a poem. Because of the use of these poetic devices, the creation account in Genesis 1 is thought to have served as an ancient Israelite hymn or recitation (Patterson 2020). By addressing the poetic nature of Genesis as a hymn rather than a literal recounting of the Creation, biology instructors may be able to offer students potential ways to reconcile the biblical account with evolution while maintaining religiosity.

4.6 | Cultural Competency Versus Cultural Humility

Finally, we want to emphasize that we do not expect all educators to become experts in the CJC creation doctrine and use the CCIM, much less become experts in all religions to address potential conflict. Instructors of classrooms with diverse populations of students cannot possibly study in-depth the cultures of all the learners they encounter. However, using the principles of the CCIM, we do recommend that science educators recognize their own positionality, approach multicultural environments with a learner’s stance, and meet students where they are to help them reconcile their background with evolution. We call this “Cultural Humility.” By doing so, science educators will be able to help guide students who may perceive a conflict between their own culture and evolution toward scientific literacy.

5 | Conclusion

This study has shed light on one potential causal mechanism involved in the success of the CCIM, a form of culturally competent evolution education. A reconceptualization of biblical literalism could possibly be a factor that increases evolution acceptance without decreasing religiosity among CJC audiences. By understanding the factors involved, we can better inform our pedagogical decisions as we approach this topic in undergraduate classrooms, especially if our audience is likely to include Judeo-Christian individuals who may see a worldview conflict with the content being taught.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All data required to replicate findings will be available on the public repository BYU ScholarsArchive.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Supporting Table 1: Confirmatory Factor and Reliability Analysis for the Nationwide Sample and the Classroom Intervention Sample.