Research Article

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A Comparison of Online and In-Person Evolution Instruction That Includes Religious Cultural Competence

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Evolution is one of the most important concepts in biology, but it is rejected by a substantial percentage of religious students due to a perceived conflict with their religious beliefs. The use of religious cultural competence in evolution education (ReCCEE) has been shown to effectively increase evolution acceptance among religious students during in-person instruction, but there is no research that we know of that indicates the effectiveness of these practices during online instruction. In this study, we explored the efficacy of online culturally competent practices for religious students on students' evolution understanding, evolution acceptance, and comfort learning evolution at a religious university. Before and after evolution instruction, we surveyed 178 students in online introductory biology courses and compared these student outcomes to 201 students in the same instructor's in-person introductory biology courses. We found that evolution acceptance and understanding increased in online classes with culturally competent practices, and these gains were similar to those observed in the in-person courses. Despite these similarities, we found that students were more comfortable learning evolution in person than online, but this difference was small. Our findings suggest that the use of culturally competent practices online can be as effective as their use for in-person instruction for improving students' attitudes toward evolution, but in-person instruction may be more effective for cultivating students' comfort while learning evolution.

KEYWORDS evolution, religion, remote learning, undergraduate

INTRODUCTION

Perceived conflict between religion and evolution

Evolution is an important concept of biology (1, 2), yet many introductory biology students do not fully accept evolution (3). Students' rejection of evolution often stems from their perceived conflict between evolution and their religious identity, which is the strongest factor predicting students' evolution acceptance (4–6). The specific religious affiliation of a student may influence the level of perceived conflict that they feel between their religion and evolution. For instance, Christian and Muslim biology students tend to have lower evolution acceptance levels than Hindu, Buddhist, and Jewish students (7). Even though the Church of Jesus Christ of Latter-Day Saints (CJCLDS) has a neutral stance on evolution, CJCLDS individuals tend to have the lowest evolution acceptance compared to students from other Christian denominations (7). This study focused on how instructors may be able to improve acceptance and understanding of evolution among CJCLDS students during both in-person and online instruction and shows how a resistant population might become more comfortable and accepting of evolution. One way that CJCLDS students may become more comfortable accepting evolution is if their instructors use culturally competent evolution education.

Religious cultural competence in evolution education

Research has shown that the use of religious cultural competence in evolution education (ReCCEE), which addresses the

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perceived conflict between religion and evolution, can significantly decrease students' perceived conflict between evolution and their religious identity (8). When an instructor uses culturally competent instruction in the context of evolution education, they are taking into account how the students' religious backgrounds may influence the students' learning experiences and providing instruction to try and maximize the experiences of students regardless of their cultural background and beliefs (8). Generally, using religious cultural competence involves discussing the potential compatibility between religion and evolution (4, 9, 10). One example of a culturally competent practice for religious students would be discussing the nature of science as being limited to investigations of the natural world, to emphasize different ways of knowing and to expose students to the notion that science does not address questions about the existence or influence of a God/god(s) (3, 11, 12). Additionally, evolution instructors can sympathetically acknowledge that for some students their religious identities may make learning evolution uncomfortable, and instructors can try to help these students feel recognized and understood while learning evolution (13). Instructors can also provide examples of religious scientists who accept evolution to give students the opportunity to see their religious identities reflected in scientists who accept evolution and to disrupt the misconception that one has to be an atheist to accept evolution (3, 14–16).

Although several studies have shown the effectiveness for increasing student acceptance and understanding of evolution during synchronous in-person instruction (4, 10, 15–18), we do not know the effectiveness of these culturally competent practices in online courses, which have become more prevalent both in response to the recent COVID-19 pandemic as well as a broader effort to expand college access (19). To address this gap in knowledge, we conducted a study examining introductory biology student comfort learning evolution, understanding of evolution, and acceptance of evolution before and after online instruction in which the instructor used religious cultural competence. We compared these outcomes to student outcomes from the same course in previous semesters in which instruction was delivered by the same instructor in person.

Perceptions of online and in-person instruction for controversial topics

Evolution is considered a controversial topic in society, and past research that focused on online discussions of controversial topics indicated that the online modality may be beneficial for a subset of students. Two studies comparing the discussion of controversial topics online versus in person found that students who were the least talkative were more likely to prefer the online setting instead of the in-person setting (20, 21). Many students who are shy may prefer online courses because they feel less judgment by their peers. In a study seeking to explore students' experiences and perceptions of an online course, students who had positive experiences with the online environment shared that they felt as though they were able to share opinions without facing stigma (22). The online environment allowed these students to present their ideas with more confidence, improving their overall experience in the courses.

However, students may also experience negative outcomes when controversial topics are presented online. Several studies comparing online versus in-person courses indicated that students are less satisfied with online courses than with in-person courses due to lack of interaction and connection with peers and their instructor in the course (21, 23, 24). This is important to note, because evidence indicates that students who rank social interaction as the highest barrier to online learning are less likely to enroll in future online courses, less likely to enjoy online learning, and less likely to feel that they can learn as well online as they do in person (25). Further, in evolution education specifically, examples of religious scientists can be influential for religious student outcomes (16, 26) and online instruction may make it harder for religious students to connect with these potential role models. Thus, lack of social interaction between students, their peers, and the instructor in online courses can be a hindrance to students' perceptions of the course material and learning outcomes.

There is some evidence that in-person courses on controversial topics may be perceived as more beneficial than online instruction for some students. In one study, the majority of students preferred face-to-face discussions of controversial topics compared to online discussion (21). Another study showed that students felt that they learned more in person and that these face-to-face discussions were beneficial in remembering more details and "who said what" in these discussions (27). However, students may feel less comfortable discussing controversial topics in person compared to online because they worry about hurting another student's feelings in the face-to-face discussion (21). This was also reflected in a study in which in-person discussions were dominated by a small group of students with strong opinions, which left those with a different stance feeling that they were unable to have the space to speak (28).

Current study and research questions

Our literature review indicated that although ReCCEE has been shown to be effective in person (4), it has not been shown whether it can be effective online. In this study, we use a pre-course-postcourse design with a comparison group to explore student evolution education outcomes online versus in person when an instructor used religious cultural competence. First, to see if culturally competent practices used online could improve student evolution acceptance and understanding, we explored whether student outcomes improved in the online courses alone. Next, we wanted to see how any improvements in student outcomes online compared to student outcomes with in-person instruction. Finally, we wanted to compare student comfort learning evolution between the online and in-person courses with religious cultural competence. For all courses, the ReCCEE materials and the instructor were identical, and the only major difference was the modality of delivery.

TABLE 1
Summary of similarities and differences between online and in-person biology classes

	Majors		Non-majors	
Category	In-person (*n* = 86)	Online (*n* = 53)	In-person (*n* = 115)	Online (*n* = 125)
Delivery	Face to face	Hybrid[a]	Face to face	Asynchronous
Level of interaction	Frequent	Infrequent	Frequent	Infrequent
Evolution introduced	Midsemester	Midsemester	Beginning	Beginning
ReCCEE presentation	Feedback	No feedback	Feedback	No feedback
Nature of science	Group discussions	Interactive media	Group discussions	Interactive media
Lab	Yes	Yes	No	No

[a]Hybrid delivery entailed in-person recitation once a week (non-ReCCEE evolution instruction).

Our specific research questions were the following:

1. To what extent is evolution instruction with online ReCCEE practices effective for increasing students' evolution acceptance and understanding of evolution?
2. To what extent can evolution instruction with ReCCEE be as effective online as it is in person for increasing student acceptance and understanding of evolution?
3. When an instructor uses ReCCEE, to what extent are students as comfortable learning evolution online compared to in person?

METHODS

Study context and population

We surveyed undergraduate students enrolled in one instructor's introductory biology courses in fall 2018 (in-person) and fall 2020 (online). Students received a survey through email from the professor prior to any evolution instruction in the course and were offered extra credit for participation. The COVID-19 pandemic and switch to online instruction allowed the opportunity to study the effects of ReCCEE when used online. Each semester, the same majors and nonmajors introductory biology courses were taught by the same instructor.

This study was approved by Arizona State University's Institutional Review Board, protocol number 8191.

Online and in-person evolution instruction

The instructor recorded her class sessions when teaching evolution and provided the research team with course materials. To determine any potential differences between the online and in-person instruction that could impact the study outcomes, two researchers (C.D.B. and A.R.S.) reviewed materials sent from the instructor to compare the recorded lectures and videos in the online and in-person settings and discussed with the instructor any noncontent differences between the courses other than modality. These similarities and differences are discussed below. See Table 1 for an overview of differences and similarities between course modalities.

Course characteristics

This study consisted of two introductory biology courses, one for biology majors and one for nonmajors; each course had two sections and was taught in person during fall 2018 and online in fall 2020. The instructor was the same for both iterations of both courses. The instructor had 12 years of teaching experience and has been implementing ReCCEE practices in her teachings for most of this time. When asked how experienced she was in teaching undergraduate students, she rated herself a 5 on a 1-to-5 scale.

Similarities

In all courses, the instructor used ReCCEE practices during instruction on evolution, which included teaching the bounded nature of science, giving examples of local scientists who regard their acceptance of evolution as compatible with their religious identity, and explaining that the Church of Jesus Christ of Latter-Day Saints, which is the locally dominant church, has no official stance on evolution (i.e., the doctrine is neutral toward evolution). The instructor acknowledged that evolution may be a sensitive topic to many students, but also that she wanted to try to ensure that students become comfortable with evolution. Identical ReCCEE materials were used in both the majors and nonmajors courses.

Differences in ReCCEE aspects of the courses

For in-person courses, ReCCEE instruction included students frequently engaging in dialogue with the instructor and other students. During the ReCCEE presentation, students in the in-person courses were encouraged at a few spots in the presentation to share any comments they might have. In-person students were taught the nature of science in groups in the classroom, where they participated in answering questions and making predictions and then offered feedback through group and

class discussions. In both online courses, ReCCEE instruction took place entirely asynchronously online with no instructor or peer interaction. However, identical slides were used and the presentation points were the same for both online and in-person courses. During the ReCCEE presentation, students in the online courses were asked to watch the video of the presentation without feedback. Online students were taught the nature of science through interactive media, as they answered questions and offered predictions. In the majors courses, ReCCEE instruction was implemented midsemester directly prior to when evolution was introduced in the course. In contrast, in the nonmajors courses, ReCCEE was implemented at the beginning of the semester, just prior to when evolution was first introduced.

Differences in non-ReCCEE aspects of the courses

Both in-person courses were face-to-face, nonflipped introductory biology courses taught by one instructor. The majors course included three 50-min lecture sections following a 3-h inquiry-based lab taught by teaching assistants. The nonmajors course included three 50-min lecture sections with no accompanying lab. Curriculum was taught more in depth in the majors course than the nonmajors course; assessments and assignments reflected these differences.

The online majors course was taught by one instructor with all lecture content being delivered primarily online with a once-a-week, in-person 50-min recitation and application session. In these sessions, the instructor reviewed content taught online and offered practice problems for students to apply the information. Students attended the same lab sessions in person, identical to the pre-COVID semester. All ReCCEE instruction was still entirely online. The online nonmajors course was taught entirely online with no weekly recitation sessions and no in-person labs.

Survey measures

The survey was part of a larger study exploring how ReCCEE affects student outcomes. In this study, we included the variables of evolution acceptance, evolution understanding, and comfort with learning evolution, because prior research showed students can have low acceptance and understanding of evolution (4, 29) and students can feel uncomfortable while learning evolution (3). Further, students' levels of comfort in class may be positively correlated with their participation and learning outcomes (30, 31). All questions used in analyses of this study can be found in their entirety in the supplemental material.

Acceptance of evolution

Acceptance of evolution is the extent to which students believe that evolution is valid and can include the acceptance of human evolution, macroevolution, and microevolution. To measure this acceptance, we used a previously published survey, the Inventory of Student Evolution Acceptance (32). Each scale consists of eight items in which students respond with their agreement on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). We calculated students' average composite scores to use in analyses.

Understanding of evolution

Understanding of evolution is the extent to which a student can answer questions correctly about standard concepts of evolution. Researchers who have studied online versus in-person learning of controversial topics often rely on students' self-report on their learning outcomes (25, 28). This is problematic when measuring student learning because students are not always accurate about their own learning (33–35). We used a published knowledge test with validity evidence pre- and postinstruction to compare students' understanding of evolution in person and online to avoid any bias of students' self-reporting. We used the Evolution Attitudes and Literacy survey (36), with 14 true, false, or "I don't know" questions. If the student answered incorrectly it was coded as a 0, and if a student answered the question correctly it was coded as a 1. To discourage false correct answers due to guessing, students had the option of "I don't know enough to answer," and these responses were coded as a 0.

Comfort learning evolution

Comfort learning evolution refers to how comfortable students felt about learning evolution after evolution instruction. We used a previously published instrument with eight items to measure students' comfort learning evolution on a Likert scale from 1 (strongly disagree) to 6 (strongly agree) (3).

Demographics

We also collected data on students' religious affiliation, religiosity (defined as strength of religious identity and level of participation in religious activities), parent education levels, and gender. These were not used in analyses but were meant to contextualize the sample.

Analyses

To determine if student evolution acceptance and understanding increased in the online courses, we ran paired-sample *t* tests with students' pre- and postcourse scores on each measure of acceptance and understanding. To identify the extent to which the instruction type (online versus in-person) predicted changes in evolution acceptance and evolution understanding, we ran four multiple linear regressions (human evolution acceptance, macroevolution acceptance, microevolution acceptance, and evolution understanding) with postcourse evolution acceptance and postcourse evolution understanding as the outcome variables and precourse evolution acceptance, precourse evolution understanding, instruction type, and course type (majors or nonmajors) as the predictor variables (outcome $\sim$ precourse score + online [in-person] + majors [nonmajors]). To identify the extent to which instruction type predicted students'

comfort learning evolution, we ran linear regressions using comfort learning evolution as the outcome and course type and instruction type as the predictor variables (comfort ~ online [in-person] + majors [nonmajors]). The full regression tables with omnibus statistics, coefficients for all variables, and standard errors for all coefficients in all analyses can be found in the supplemental material. All analyses were done in SPSS version 26. All data and syntax for analyses are included in the supplemental material. Here, we have included violin plots that illustrate the central tendencies and distributions of the outcome data.

RESULTS

In total, 379 students participated in the survey (90% response rate). Of these students, 178 students participated in online instruction and 201 students participated in in-person instruction; 240 students were in nonmajors courses and 139 students were in majors courses. The majority of students were members of the CJCLDS (98%) and highly religious (Likert scale mean, 4.81; standard deviation [SD], 0.54; range, 1 to 5). Students were on average 19 years old, primarily white (83%), approximately half were women (52%), and the majority of students had parents who had completed graduate-level education (59%). For a breakdown of student demographics by online versus in-person courses, see Table 2.

TABLE 2
Demographics of students, broken down by whether they were in online or in-person classes[a]

Demographic	Online (n = 178)	In person (n = 201)
Race or ethnicity		
Asian	3.4%	3.5%
BIPOC[b]	4.5%	2.5%
Multiracial	10.1%	5.0%
White	79.8%	86.6%
No answer	2.2%	2.5%
Gender		
Woman	46.6%	56.2%
Man	52.8%	42.8%
Nonbinary	0.6%	0.0%
No answer	0.0%	1.0%
Religion		
Christian CJCLDS	98.9%	97.5%
Agnostic	0.6%	0.5%
No answer	0.6%	2.0%
Parent education level		
<Bachelor's	14.0%	10.0%
Bachelor's	30.3%	27.4%
>Bachelor's	55.6%	61.7%
No answer	0.0%	1.0%
Continuous variables		
Mean age (SD)	19.4 (1.7)	19.2 (1.5)
Mean religiosity score (SD)	4.7 (0.65)	4.9 (0.41)

[a]Totals may exceed 100% due to rounding.
[b]BIPOC, Black, indigenous, people of color.

Finding 1. Students gained in their acceptance and understanding of evolution in online courses

In the online courses, students' acceptance of human evolution, macroevolution, and evolution understanding increased ($P < 0.001$) (Fig. 1). Students gained an average of 0.55 Likert point on human evolution acceptance and 0.27 Likert point on macroevolution acceptance. Additionally, students gained 10% on their understanding of evolution scores over the semester. Gains in microevolution acceptance were not significant, perhaps due to already-high microevolution acceptance precourse scores.

These results indicated that students in the online courses gained human evolution acceptance and macroevolution acceptance from pre- to postinstruction. In addition, evolution understanding also increased in all online courses. Students came into the courses already highly accepting of microevolution, and we did not see a significant increase over the semester. Next, we present the change in scores for in-person students and compare those with changes seen online.

Finding 2. Students' gains in evolution acceptance and understanding were similar online and in-person

We wanted to see if the gains we documented in online instruction were similar to gains during in-person instruction. In our regression models, online instruction was neither negatively nor positively related to students' gains in acceptance of human evolution ($\beta = -0.016$, $P = 0.680$), macroevolution ($\beta = -0.060$, $P = 0.111$), microevolution ($\beta = -0.006$, $P = 0.890$), or evolution understanding ($\beta = -0.077$, $P = 0.089$), indicating that online instruction was as effective as in-person instruction for increasing evolution acceptance.

Majors' gains were greater in their acceptance of human evolution ($\beta = 0.080$, $P = 0.047$), macroevolution ($\beta = 0.082$, $P = 0.035$), and evolution understanding ($\beta = 0.175$, $P = 0.000$) than nonmajors' gains, but we did not see the same trend for their acceptance of microevolution ($\beta = 0.025$, $P = 0.550$). See the supplemental material for a summary of all regression coefficients in the analyses and their statistical significance. See Fig. 2 for students' gains in evolution acceptance and understanding of evolution pre- and postinstruction online and in person.

These results indicated that in these courses with this instructor, online instruction with religious cultural competence can be as effective as in-person instruction in increasing students' acceptance and understanding of evolution, and majors may experience more gains in their evolution acceptance than nonmajors.

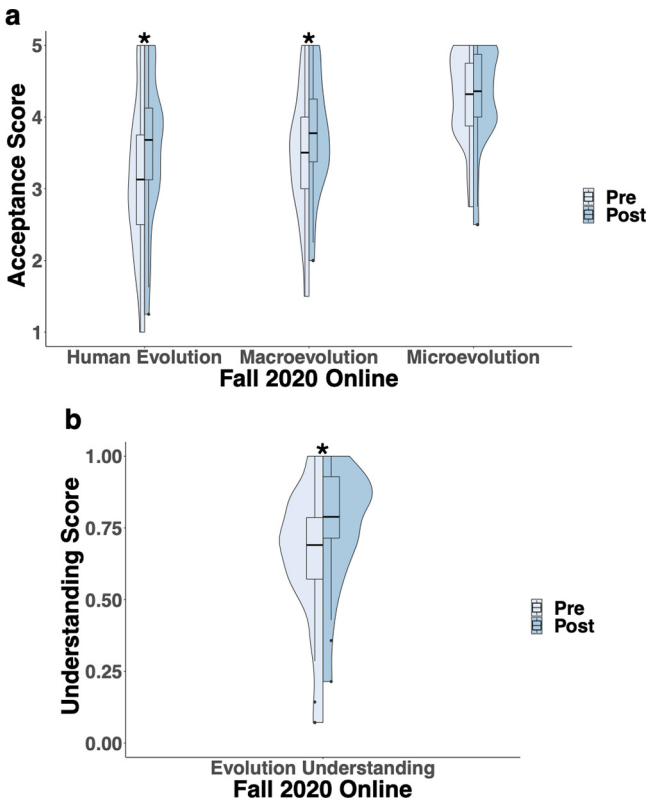

FIG 1. Online courses only: split violin plots of students' pre- and postcourse scores for human evolution acceptance, macroevolution acceptance, and microevolution acceptance (a) and evolution understanding (b) in online courses. The shape of each violin corresponds to the densities of data points on a given point on the *y* axis, the horizontal line represents the mean of the data, and the box shows the lower and upper quartiles of the data points. *, $P < 0.05$, determined by paired-sample *t* tests.

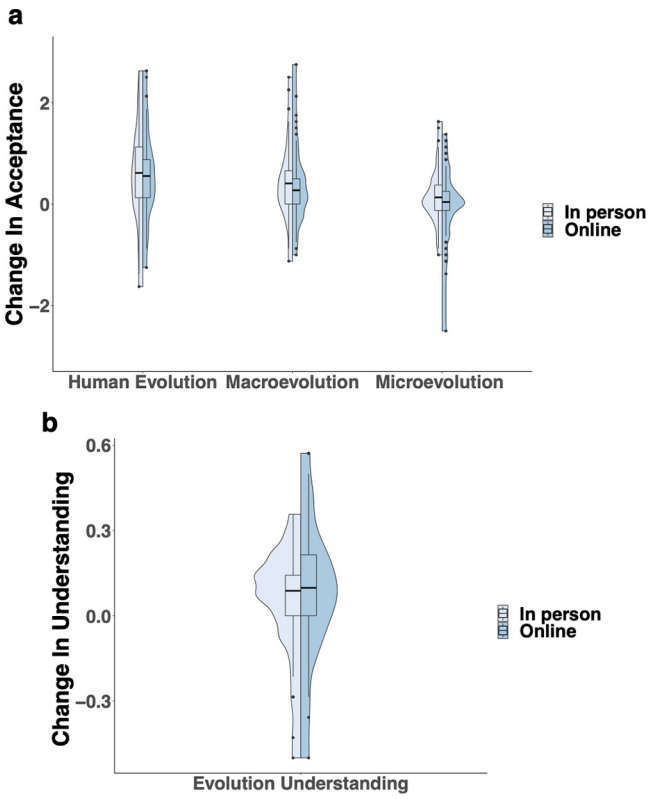

FIG 2. In-person versus online: split violin plots of students' mean difference (postcourse − precourse) of human evolution acceptance, macroevolution acceptance, and microevolution acceptance (a) and evolution understanding (b) scores in person versus online. The shape of each violin corresponds to the densities of data points on a given point on the *y* axis, the horizontal line represents the mean of the data, and the box shows the lower and upper quartiles of the data points. No statistically significant differences were found in our linear regressions ($P < 0.05$).

Finding 3. Students were more comfortable in person than online when learning evolution

In our regression models, we found that online instruction was a weak negative predictor of students' comfort learning evolution ($\beta = -0.100$, $P = 0.047$). Students' comfort learning evolution was moderate after both online (mean, 3.83; SD, 0.41; possible range, 1 to 6) and in-person instruction (mean, 3.93; SD, 0.35; possible range, 1 to 6). In addition, we found that majors were more comfortable when learning evolution compared to nonmajors ($\beta = 0.235$, $P = 0.000$). See Fig. 3 for students' mean comfort learning of evolution in person versus online.

This finding implies that students can be somewhat comfortable learning evolution online, but students may be more comfortable learning evolution in person. However, this difference was small and only marginally statistically significant.

DISCUSSION

In our study, we found that improvement of students' acceptance and understanding of evolution was similar during online and in-person courses for evolution instruction that included religious cultural competence. Our results corroborated those of studies that reported positive student outcomes after online discussion of controversial topics (20, 21) and specifically evolution (37–40). However, our study design with the same instructor using the same materials to teach online and in person allowed us to document that online instruction can be as effective as in-person instruction for improving

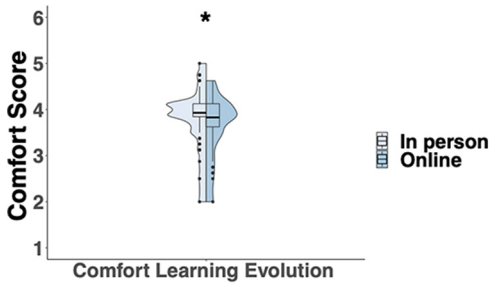

FIG 3. In-person versus online: split violin plot of students' mean comfort learning evolution in person and online. The shape of each violin corresponds to the density of data points on that specific point on the *y* axis, the horizontal line represents the mean of the data, and the box shows the lower and upper quartiles of the data points. *, $P < 0.05$, determined by linear regression.

students' acceptance and understanding of evolution. We also found that students may be more comfortable in person when learning evolution compared to when learning evolution online, but this difference was small. This aligns with literature which reports that students can be more comfortable discussing controversial topics in person than online (24).

It is important to highlight that online ReCCEE instruction could look different from what the instructor implemented in this study. This instructor quickly shifted her instruction online without using some tools that have now been recognized as beneficial for online learning. Instructional practices that this instructor didn't use that other instructors could use to increase student comfort include breakout room discussions, anonymous polls, and sharing ideas in the chat about their thoughts on religion and evolution. For instance, one study found that when the instructor combined asynchronous and synchronous instruction by providing annotated PowerPoint presentations, instructor voiceovers, and breakout rooms using video conferencing software, student attendance and participation increased compared to when synchronous instruction was not included (41). Further, another study found that the shift to online instruction was successful with a synchronized team-based learning format using breakout rooms (42). In our study, the instructor didn't use breakout rooms in the online courses, which could have decreased the opportunity for students to participate and be engaged with the course material. In addition, another study found that online instruction can be improved when the students and instructor are frequently interacting with each other to build rapport (43). The instructor in our study could have implemented activities that encourage frequent discussions between the students and their instructor to potentially improve student outcomes in the online courses. Other studies suggest that when students in online courses receive feedback from the instructor, their focus and learning can improve (44, 45). In our study, students in the online courses did not receive feedback from the instructor during the ReCCEE presentation, which could have reduced their comfort learning about evolution compared to students in the in-person courses, in which feedback was given. Future research should explore if online ReCCEE instruction can be even more effective when using these online-specific practices.

In summary, students in our study experienced similar positive outcomes in the online and in-person courses. This study counteracts concern that culturally competent instruction for religious students cannot be effective online and provides important foundational work to promote the use of using cultural competence for religious students in online learning environments. Although most universities that transitioned online due to COVID-19 have already returned to in-person courses, there is a larger movement to expand online course offerings and degree programs to expand access to higher education (19). Thus, this work indicates that instructors who teach online biology courses that include evolution could consider adopting religious culturally competent instructional practices.

Limitations

This study was done in one instructor's courses at a single institution, so any generalizations should be made with caution. This instructor has 12 years of teaching experience implementing culturally competent practices for religious students in her instruction and ranks herself as highly experienced as an evolution instructor to undergraduate students, so it is possible that she is more effective than other instructors due to this experience. In addition, the majority of participants in this study were members of the same religious community (CJCLDS). Other contexts with a more heterogeneous student body may present additional challenges when using ReCCEE online. For instance, the results might look different among a Protestant population for which there is substantial rejection of evolution, similar to CJCLDS populations, but in which there is no official neutral stance on evolution.

Our study was a naturalistic approach where we observed instruction that changed, and we wanted to see if student outcomes also changed. Thus, participants in this study were not randomized into the online or in-person groups. However, all students were required to move online during the pandemic, and thus students did not self-select into the online condition. We also saw no substantial demographic differences between the in-person and online students, but there may have been other differences of which we were not aware. Finally, we did not collect data on student comfort with topics other than evolution. It is possible that students were less comfortable learning online overall and not just when learning evolution.

CONCLUSION

In this study, we found that students' evolution acceptance and understanding increased both in person and online when an instructor taught evolution using Religious Cultural Competence in Evolution Education (ReCCEE). Student's gains in evolution acceptance and understanding were similar both in person and online in these courses. Comfort learning evolution in online instruction was moderate but was associated with less comfort learning evolution compared to in-person instruction, but this difference was small. These results indicate that online evolution instruction with cultural competence can be effective for improving students' acceptance and understanding of evolution even compared to in-person instruction. However, in-person instruction may be more effective for cultivating higher student comfort with learning evolution.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 0.1 MB.
SUPPLEMENTAL FILE 2, PDF file, 0.1 MB.
SUPPLEMENTAL FILE 3, PDF file, 0.2 MB.
SUPPLEMENTAL FILE 4, PDF file, 0.1 MB.

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We have no conflicts of interest to declare.

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