RESEARCH ON LEARNING

A Mixed Exam Format Closes the Gap for Students with a Conflict between Their Religious Belief & the Theory of Evolution

KATHRIN F. STANGER-HALL,
JULIANNE A. WENNER

Abstract

We assessed the performance of students with a self-reported conflict between their religious belief and the theory of evolution in two sections of a large introductory biology course (N = 373 students). Student performance was measured through pretest and posttest evolution essays and multiple-choice (MC) questions (evolution-related and non-evolution-related questions) on the final exam and posttest. The two class sections differed only in exam format: MC with or without constructed-response (CR) questions. Although students with a reported conflict scored significantly lower on the final exam in the MC-only section, they scored equally well in the MC+CR section, and all students in the MC+CR section performed significantly better overall. As a result, (1) a religious conflict with evolution can be negatively associated with student achievement in introductory biology, but (2) assessment with constructed response was associated with a closed performance gap between students with and without a conflict. We suggest that differences in exam format and focus on student acceptance of evolution (either evidence-based or opinion), rather than reported conflict, may contribute to the inconsistencies in student learning of evolution across research studies, and that CR questions may help students overcome other obstacles to learning evolution.

Key Words: *Evolution; religious conflict; learning assessment; introductory biology.*

Introduction

As Theodosius Dobzhansky (1973) famously stated, "Nothing in biology makes sense except in the light of evolution." When appreciating the strides that have been made in biomedical research, such as the development of antibiotic drugs, and research surrounding the control of complex viruses like HIV, the truth of Dobzhansky's statement is immediately evident (e.g., Mindell, 2006). But as much as the general public is benefiting from these scientific advances, the theory of evolution is not widely accepted by the American public (Miller et al., 2006). The most recent Gallup poll concerning evolution (Gallup, 2007) found that 44% of those surveyed stated that evolution is either "probably" or "definitely" false, and only 61% of those surveyed in 2005 thought that evolution should be taught in public schools (Gallup, 2005). Moreover, fewer than 50% of Americans accept Darwin's theory of evolution by natural selection (Miller et al., 2006), which is a major contrast to the overwhelming support for evolution in most industrialized nations and within the scientific community (National Academy of Sciences [NAS], 1999; AAAS, 2006; Miller et al., 2006; Lombrozo et al., 2008). This public attitude has an impact on the scientific preparedness of college students, especially, but not exclusively, in the southern United States, where religious beliefs are often framed in opposition to the theory of evolution (Jones, 2007; Donnelly et al., 2008), even though major religious leaders have stated that there is no conflict between the theory of evolution and faith (Pope John Paul II, 1996; Pope Benedict XVI, 2007; NAS, 1999), and more than 13,000 clergy and rabbis in the U.S. publicly support the theory of evolution as a foundational scientific truth (Zimmerman, 2006).

One cannot help but wonder whether some students in an introductory biology class may struggle with learning evolution because of a perceived conflict with their religious beliefs.

In recent years, the perceived conflict between evolution and faith has inspired several studies that have focused on the possible relationship between acceptance of evolution and academic achievement in relevant biology coursework. The major concern that has led to these studies is that lack of acceptance could serve as a barrier to developing a scientific understanding of the concept of evolution (Sinatra et al., 2003). As an instructor, one cannot help but wonder whether some students in an introductory biology class may struggle with learning evolution because of a perceived conflict with their religious beliefs, and if so, how does one support their learning without spending too much class time at the cost of (usually the majority of) students who do not have such a conflict. Unfortunately, the findings of published research studies are inconclusive. This may be partly due to the focus on "acceptance" of evolution (rather than on a

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perceived conflict), and to inconsistent definitions of "acceptance" across studies. For example, some authors defined "acceptance" as an attitude or opinion, which did not necessarily require understanding (e.g., McKeachie et al., 2002; Ingram & Nelson, 2006; Miller et al., 2006; Lombrozo et al., 2008), whereas others defined it as based on knowledge and evaluation of scientific evidence (e.g., Allmon, 2011). Therefore, nonacceptance could be due to a perceived religious conflict (Lawson & Worsnop, 1992), unfamiliarity with the theory of evolution (Jones, 2007), hesitancy about accepting evolution due to the public climate (Miller et al., 2006), or other factors (Dagher & BouJaoude, 1997; Miller et al., 2006).

Here, we focus on students' self-reported religious conflict with the theory of evolution. Research has shown that Christians who are involved in science often fall into the following conflict (resolution) categories: being unaware of a conflict, avoiding the conflict, being disturbed by the conflict, and managing the conflict (Meadows et al., 2000). Consequently, it would seem that a reported "religious conflict" may be a good indicator of possible struggles in an evolution-based course.

Does a Perceived Religious Conflict Hinder Student Learning of Evolution?

We focused on student learning of evolution in a large introductory biology course at a Research University in the southeastern United States. This course is the second in the introductory biology sequence for biology majors. In the prerequisite course, students were exposed to the concept of evolution, along with principles of genetics. The course described here is focused on organismal diversity, structure and function of plants and animals, and ecology and is taught from an evolutionary perspective (i.e., how different environments have shaped structures and functions of organ systems throughout the evolutionary history of plants and animals). In this respect, this course represents strategy 2 for teaching evolution effectively (i.e., making evolution and the nature of science central course themes) as described by Nelson (2007).

Given that students in this course were exposed to evolution in the prerequisite course, that this was a course for biology majors (with 70% of students reporting a career goal in the health professions), and that this course was taught from an evolutionary perspective, we wanted to know how prevalent a perceived conflict between religious belief and the theory of evolution was among the students in this course, and whether a perceived conflict would affect student performance in this course. We were specifically interested in the following research questions: (1) How many students in this course report a conflict between their religious belief and the theory of evolution? (2) Does self-reported religious conflict affect student achievement on evolution-related (and other) assessments in this evolution-centered introductory biology course?

If a self-reported religious conflict affects student learning, we predicted that students with a self-reported conflict at the beginning of the semester would score significantly lower on evolution-related questions on the final exam and posttest, as well as on specific applications of the process of evolution, than students who did not report such a conflict. Additionally, because the course as a whole was taught from an evolutionary perspective, we also assessed whether students with a self-reported conflict would score significantly lower on questions that were not directly related to evolution.

Methods

This study was conducted during spring semester 2009. A total of 404 students were enrolled in two sections of this introductory biology course, and 373 consented to participate in this study. With the exception of exam format, the two sections were identical. One section was assessed exclusively with multiple-choice questions (MC-only), and the other section was assessed with both MC and constructed-response (CR; e.g., short essay, fill-in, labeling) questions (MC+CR). Because a previous study had shown that exam format influences student learning in this class (Stanger-Hall, 2012), we analyzed the two sections separately to control for differences due to exam format. For an overview of the data sets used for the study, see Figure 1.

Students' Self-Reported Attitudes

Data on student attitudes toward evolution were collected during class in the first week of the semester on a written pretest. Students were asked to complete the following statement:

I _____ believe that the theory of evolution is incompatible with my religious belief.

a. strongly

b. do

c. am not sure whether to

d. do not

e. do not at all

To simplify data analysis, we collapsed the categories into *conflict* (a+b) and *no conflict* (d+e), and omitted students who were undecided (c). All conflict categories for students in this study are

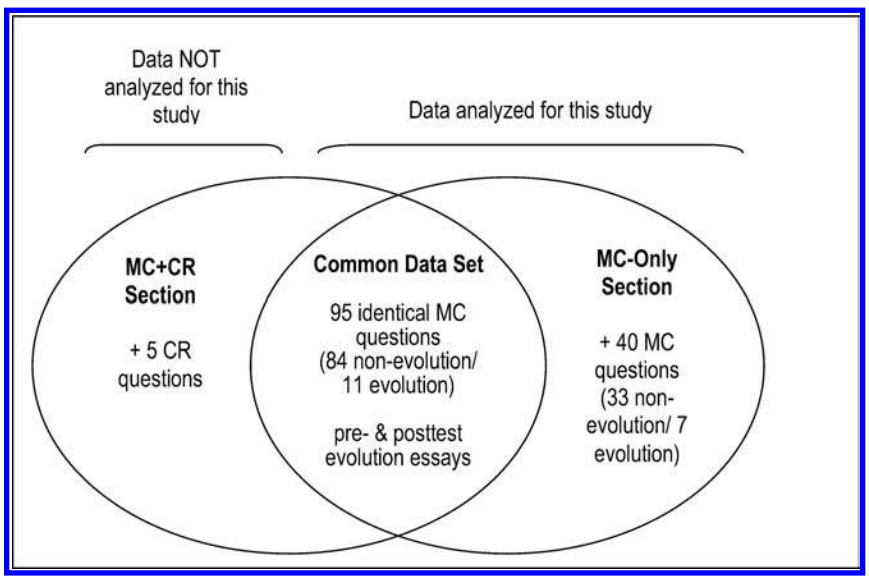

Figure 1. Assessments given in the two course sections and the common data set used for this study.

based on pretest measures, because we were interested in student attitudes going into the course. In the pretest we also asked students to report their start-of-semester GPA, and used it as a measure of previous accomplishment for comparisons between student groups.

MC Performance on Final Exam & Posttest

We analyzed student performance on the MC questions of the final exam and posttest. Both course sections had 95 identical MC questions (final exam and posttest combined), including 11 evolution-related questions and 84 questions that were not directly related to evolution. The MC-only section answered an additional 40 MC questions in lieu of CR questions for a total of 135 MC questions, including 18 evolution-related questions and 117 questions that were not directly related to evolution.

Knowledge of the Process of Evolution by Natural Selection

Students' knowledge of the process of evolution by natural selection was assessed at the beginning of the semester (pretest: week 1) and again at the end (posttest). During the second week of the semester, the instructor worked with students during class to develop a flow chart of the process of evolution by natural selection (Figure 2), which could be applied by students to different examples throughout the course.

On the pretest, we asked students, "Briefly explain: How did cheetahs evolve into the fast runners they are today?" On the posttest (administered with the final exam), we asked "Briefly explain: How did giraffes evolve the long necks that they show today?" The answers to both questions were coded for seven basic steps within the process of evolution by natural selection, as well as any misconceptions included in the answers (for the cheetah version of the coding schema, see Figure 3).

Statistical Analysis

We used SPSS 19.0 (2011, SPSS, Chicago, IL) for all statistical analyses. For each section, we tested all variables for normality (goodness of fit: Shapiro-Wilk test). Only the final exam and posttest questions (evolution and non-evolution MC questions combined) were normally distributed. As a result, we report the results of the nonparametric Mann-Whitney U-test (for independent samples) for all analyses. This is a test for both location and shape to test for differences between distributions of ranked variables. We calculated the normalized percentage of learning gains for the evolution essays (possible score = 7) as (posttest – pretest)*100/(7 – pretest). For a comprehensive analysis of the influences of previous student achievement (GPA, covariate), exam format, and reported conflict (independent factors) on student performance, we conducted an ANCOVA. We report means ± SD for all variables, and means ± SE in the figures. All reported statistical results are based on two-tailed tests and significance levels of $P < 0.05$.

Results

Overall, of the 373 students in the two sections, N = 112 students (30.03%) reported a conflict between their religious belief and the

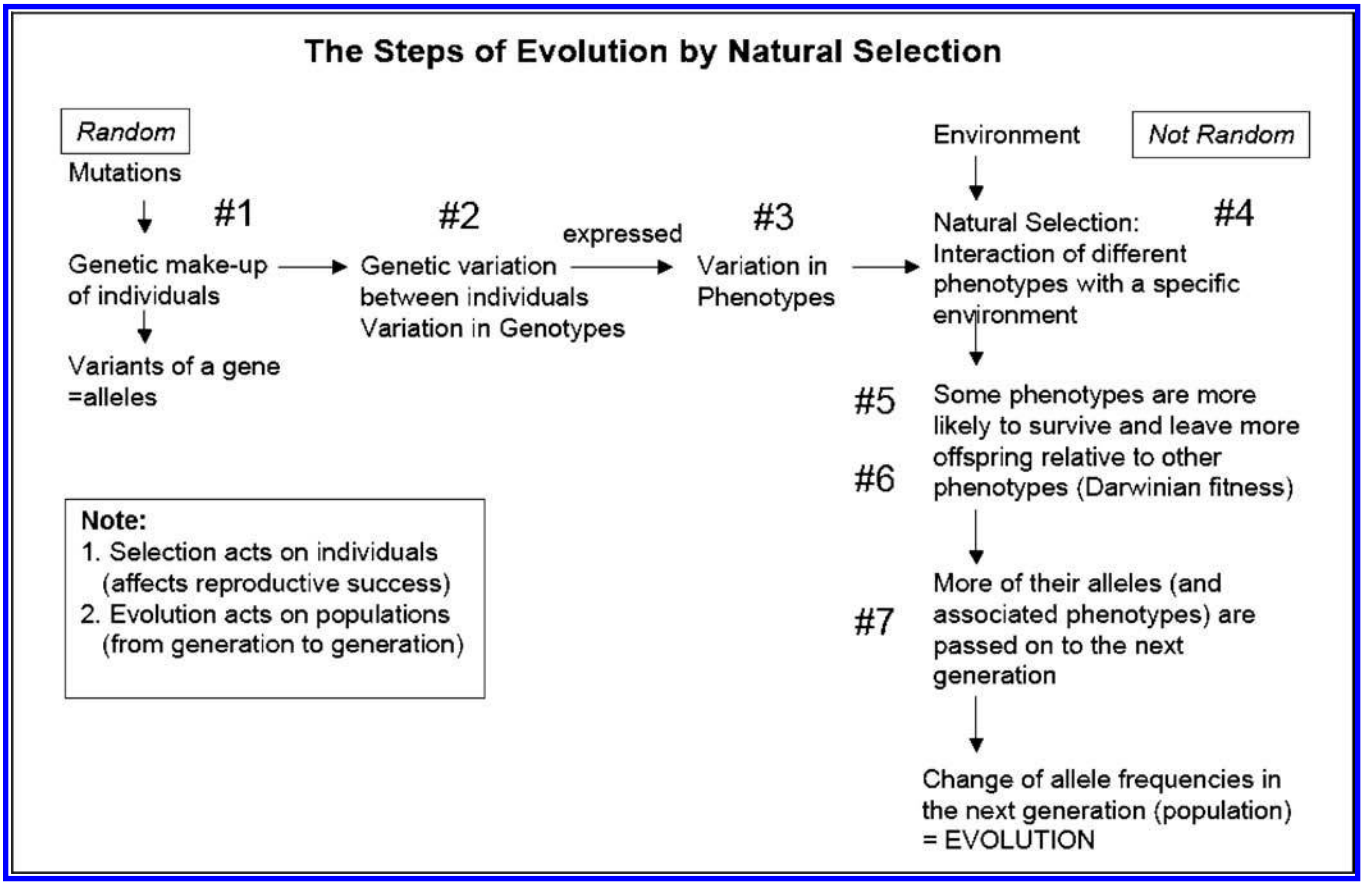

Figure 2. Flow chart: evolution by natural selection.

EVOLUTION OF HIGH SPEED IN CHEETAHS: CODING RUBRICS (BASED ON STUDENT ANSWERS)

Correct Steps

1. Mutations lead to genetic variation.
2. [Heritable] genetic variation in cheetahs (genotype).
3. Variation in speed among cheetahs (phenotypes).
4. Natural selection/"survival of the fittest" (generic use of the phrase), or faster cheetahs are more likely to catch food, escape from predators.
5. Faster cheetahs survive better (general statement).
6. Faster cheetahs leave more offspring than others.
7. Each successive generation has more fast cheetahs in the population.

Misconceptions

8. Purpose-driven (in order to… or they needed… or they had to…).
9. Religious explanation (God made them that way…).
10. Interbreeding with another species (they mated with another animal that was already fast…).
11. Focuses purely on change in body structure/behavior in individuals (their muscular structure has changed to reduce drag… or they developed stronger lungs…).
12. Use of terms without knowing what the term means (…passing on this useful genome).
13. Effect is cumulative within each line (grandchildren are faster than children, who are faster than the parents).

Figure 3. Coding rubrics (based on student answers) for the cheetah evolution essay.

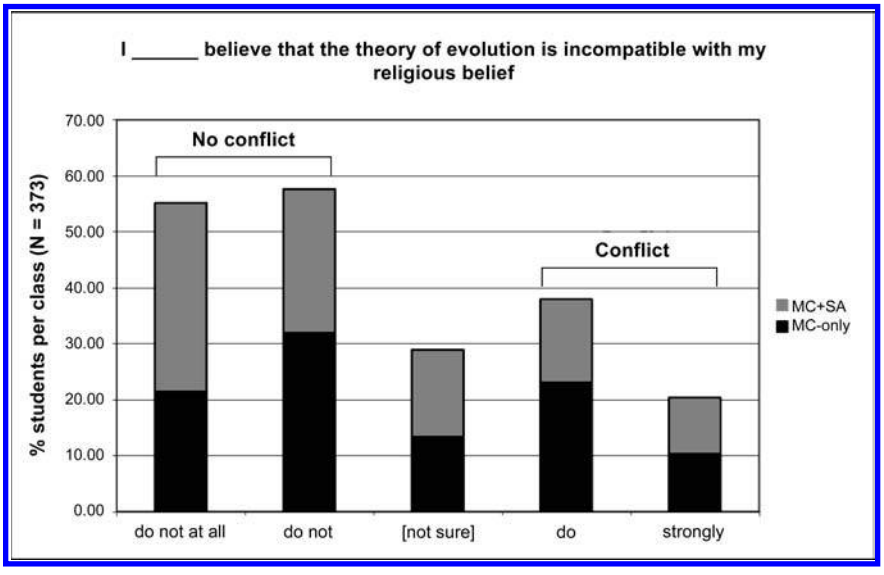

Figure 4. Student self-reports of religious conflict with the theory of evolution in an introductory biology class for majors. Shown are distributions of students (for each class section) across the five answer categories (sample sizes: total in class, N = 373; MC-only, N = 225; MC+CR, N = 148).

theory of evolution, N = 208 students (55.76%) reported no conflict, and N = 53 students (14.21%) were undecided (for a breakdown of individual categories, see Figure 4). Below, we present the results for the MC-only section, the MC+CR section, and a comparison between sections (i.e., the effect of exam format).

MC-Only Section

Of the 242 consenting students in this section, 225 students took the pretest, and 215 students reported their start-of-semester GPA. Of the 225 students, 75 (33.3%) reported a religious conflict with the theory of evolution, and 120 (53.3%) reported no conflict (13.4% were undecided). There was no significant difference between students who reported a conflict and those who did not in terms of prior academic achievement (as measured by GPA; Table 1).

MC Performance on Final Exam and Posttest. Students with a conflict scored significantly lower on the 18 evolution-related questions than students who did not report a conflict, and also on the 117 questions not directly related to evolution (Table 1).

Pretest and Posttest Essays. At the beginning of the semester, there was no significant difference (with or without conflict) on how well students could apply the concept of evolution by natural selection to the cheetah evolution essay, and no significant difference in misconceptions (Table 1). By the end of the semester, there was still no significant difference in how well students could apply the concept of evolution by natural selection to the giraffe posttest, or in their misconceptions (Table 1). Students without a conflict showed an average normalized percent gain of 2.0% between the pretest and posttest, whereas students with a conflict showed an average gain of 1.7%. This was not significantly different.

MC+CR Section

Of the 162 students in this section, 148 took the pretest and 141 reported their start-of-semester GPA. Of the 148 students, 37 (25%) reported a religious conflict with the theory of evolution and 88 (59.46%) reported no conflict (15.5% were undecided). There was no significant difference between students with and without reported conflict in terms of prior academic achievement (as measured by GPA; Table 1).

Final Exam Performance on MC Questions. On the final exam/posttest, there was no significant difference in scores on the 11 evolution-related MC questions or the 84 non-evolution MC questions (Table 1).

Pretest and Posttest Essays. At the beginning of the semester, there was no significant difference (with or without conflict) in how well students could apply the concept of evolution by natural selection to the cheetah evolution essay, and no significant difference in misconceptions (Table 1). By the end of the semester, there was still no significant difference on how well students could apply the concept of evolution to the giraffe essay, and no significant difference in misconceptions (Table 1).

Table 1. Student performance (points) for MC-only (top) and MC+CR (bottom) sections on final exam and evolution essays.

Student Performance in MC-only Class Section		Conflict (N = 75) Mean ± SD	No conflict (N = 120) Mean ± SD	P
GPA (N = 73 and N = 113)		3.29 ± 0.35	3.36 ± 0.42	ns
Final Exam & Posttest	MC without evolution (N = 117 questions)	78.33 ± 14.48	84.99 ± 13.73	**
	Evolution MC (N = 18 questions)	7.09 ± 1.47	7.83 ± 1.34	***
Pretest	Cheetah correct (of 7)	1.48 ± 0.81	1.72 ± 0.91	ns
	Cheetah misconceptions	0.39 ± 0.54	0.25 ± 0.47	ns
Posttest	Giraffe correct (of 7)	1.68 ± 0.84	1.93 ± 1.06	ns
	Giraffe misconceptions	0.39 ± 0.52	0.30 ± 0.5	ns
Student Performance in MC+CR Class Section		**Conflict (N = 37) Mean ± SD**	**No conflict (N = 88) Mean ± SD**	**P**
GPA (N = 35 and N = 83)		3.24 ± 0.49	3.23 ± 0.42	ns
Final Exam & Posttest	MC without evolution (N = 84 questions)	56.54 ± 9.76	57.3 ± 9.58	ns
	Evolution MC (N = 11 questions)	8.19 ± 1.6	8.08 ± 1.76	ns
Pretest	Cheetah correct (of 7)	1.30 ± 0.85	1.55 ± 0.82	ns
	Cheetah misconceptions	0.38 ± 0.55	0.28 ± 0.45	ns
Posttest	Giraffe correct (of 7)	2.64 ± 1.42	2.43 ± 1.29	ns
	Giraffe misconceptions	0.27 ± 0.45	0.16 ± 0.4	ns

Notes: Total possible points on final exam/posttest = 1 point per question. Significance levels of comparisons: ns = nonsignificant ($P > 0.05$), *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Students without a conflict showed an average normalized gain of 17.6% between the pretest and posttest evolution essays, whereas students with a conflict showed an average gain of 21.9%. This was not significantly different.

Influence of Exam Format on the Learning of Evolution

To compare student performance between the two class sections (exam formats), we analyzed the pretest and posttest essay questions, and the common MC questions on the final exam and posttest (N = 95 total, N = 11 evolution questions, and N = 84 questions not directly related to evolution). To distinguish between the effects of exam format and reported conflict, we analyzed students with and without reported conflict separately for the two class sections. This allowed us to evaluate how students with and without a self-reported conflict performed in this introductory biology class when assessed with MC-only or MC+CR exam formats, specifically whether exam format made a difference.

Students with Reported Conflict. There was no significant difference between students with conflict in their start-of-semester GPA between the two class sections (exam formats; Table 2). However, the students who reported a religious conflict and were assessed with MC-only questions on their class exams scored significantly lower on all final-exam and posttest MC measures than the students with a conflict in the MC+CR section of the class (Table 2).

At the beginning of the semester, students with a conflict in the two class sections did not differ from each other significantly in their performance on the pretest (cheetah essay; Table 2). However, by the end of the semester, students who were assessed with the MC+CR exam format significantly outperformed the students who were assessed with MC-only on correct elements of the posttest giraffe evolution essay (Table 2). This resulted in a significantly lower average normalized percent gain (1.7%) between the pretest and posttest evolution essays for students in the MC-only section, compared with students in the MC+CR section (21.9%; $P < 0.001$; Figure 5, top panel).

Students without Reported Conflict. There was a significant difference between students without conflict in their start-of-semester GPA between the two class sections (exam formats). Students in the MC-only section reported a significantly higher start-of-semester GPA than the students in the MC+CR section (see Table 2).

Exam format had no influence on the final-exam performance of students without religious conflict: students in the two class sections did not perform significantly differently from each other on the final exam and posttest MC measures (Table 2).

At the beginning of the semester, the students without conflict in the two sections did not differ from each other significantly in their performance on the pretest (cheetah essay; Table 2). However, by the end of the semester, the students who were assessed with the MC+CR exam format significantly outperformed the students who were assessed with MC-only on the posttest (giraffe evolution essay), and stated significantly fewer misconceptions (Table 2).

This resulted in a significantly lower average normalized percent gain (2%) between the pretest and posttest evolution essays for

Table 2. Performance of students with (top) and without (bottom) a reported conflict by class section (exam format). Shown are points earned for the common questions between the two sections (exam formats) only.

Students with conflict		MC only (N = 75) Mean ± SD	MC+CR (N = 37) Mean ± SD	P
GPA (N = 73 and N = 35)		3.29 ± 0.35	3.24 ± 0.49	ns
Final Exam & Posttest	Shared MC without evolution (N = 84)	51.70 ± 9.15	56.54 ± 9.76	*
	Shared evolution MC (N = 11)	7.24 ± 1.89	8.19 ± 1.60	*
Pretest	Cheetah correct (of 7)	1.48 ± 0.81	1.30 ± 0.85	ns
	Cheetah misconceptions	0.39 ± 0.54	0.38 ± 0.55	ns
Posttest	Giraffe correct (of 7)	1.68 ± 0.84	2.65 ± 1.42	***
	Giraffe misconceptions	0.39 ± 0.52	0.27 ± 0.45	ns
Students without conflict		**MC only (N = 120) Mean ± SD**	**MC+CR (N = 88) Mean ± SD**	**P**
GPA (N = 113 and N = 83)		3.36 ± 0.42	3.23 ± 0.42	*
Final Exam & Posttest	Shared MC without evolution (N = 84)	56.1 ± 8.99	57.3 ± 9.58	ns
	Shared evolution MC (N = 11)	7.9 ± 1.64	8.08 ± 1.76	ns
Pretest	Cheetah correct (of 7)	1.72 ± 0.91	1.55 ± 0.82	ns
	Cheetah misconceptions	0.25 ± 0.47	0.28 ± 0.45	ns
Posttest	Giraffe correct (of 7)	1.93 ± 1.06	2.53 ± 1.29	***
	Giraffe misconceptions	0.30 ± 0.5	0.16 ± 0.4	*

Notes: Total possible points on final exam = 1 point per question. Significance levels of comparisons: ns = nonsignificant (P > 0.05), *P < 0.05, **P < 0.01, ***P < 0.001.

students in the MC-only section, compared with students in the MC+CR section (17.6%; P < 0.001; Figure 5, bottom panel).

Comprehensive Analysis of Conflict, Exam Format, & GPA

Overall, GPA (previous accomplishment) had a significant influence on MC performance (all 95 common MC questions) on the final exam and posttest (F = 86.711, P < 0.001). Exam format also had a significant influence (F = 15.05, P < 0.001), and so did self-reported conflict (F = 5.232, P = 0.023).

○ Discussion

Of the 373 students in the study, 165 students (30%) reported a conflict between their religious belief and the theory of evolution, whereas 208 (55.8%) reported no conflict. These data demonstrate that a perceived conflict could indeed be an issue for student learning in this introductory biology class, and likely for introductory biology classes in other colleges and universities.

Research suggests that the acceptance and/or understanding of evolution can be improved by teaching the nature of science (Martin-Hansen, 2006; Lombrozo et al., 2008), genetic literacy (Miller et al., 2006), and critical-thinking skills (Nelson, 2007; Allmon, 2011). Although these are valuable approaches in their own right and serve important learning objectives for an introductory biology class, our data show that students with a conflict can learn evolution by natural selection equally well as students without a conflict. As expected, students in the two sections did not differ from each other in their previous accomplishments (GPA) or in their performance on the pretest essay (cheetah evolution and misconceptions) at the beginning of the semester. However, how much students learned about evolution, as well as biology in general, was associated with both self-reported conflict (as predicted) and exam format.

Our data show that if students are assessed with MC-only exams, religious conflict with evolutionary theory is, indeed, negatively associated with academic achievement – both on questions that are specific to evolution and on those that are related to other biology topics. Students in the MC-only section who reported a conflict struggled with all aspects of the course, possibly because the MC-only exam format (and associated surface learning: Stanger-Hall, 2012) allowed them to engage less with the class content, including evolution.

By contrast, the MC+CR exam format was associated with no significant performance difference between students with a religious conflict and students without conflict. The benefit of CR questions for student learning is not limited to students with religious conflict. Students without conflict who were assessed with MC+CR questions performed significantly better on the posttest giraffe essay than those who were assessed with MC-only. The positive impact of a mixed exam format on student learning through more cognitively active study behaviors has been shown previously (Stanger-Hall, 2012), but this study extends this benefit to the learning of evolution, even in the presence of a religious conflict.

Students who were assessed with a mixed exam format also showed significantly greater learning gains (17–22%) on the evolution

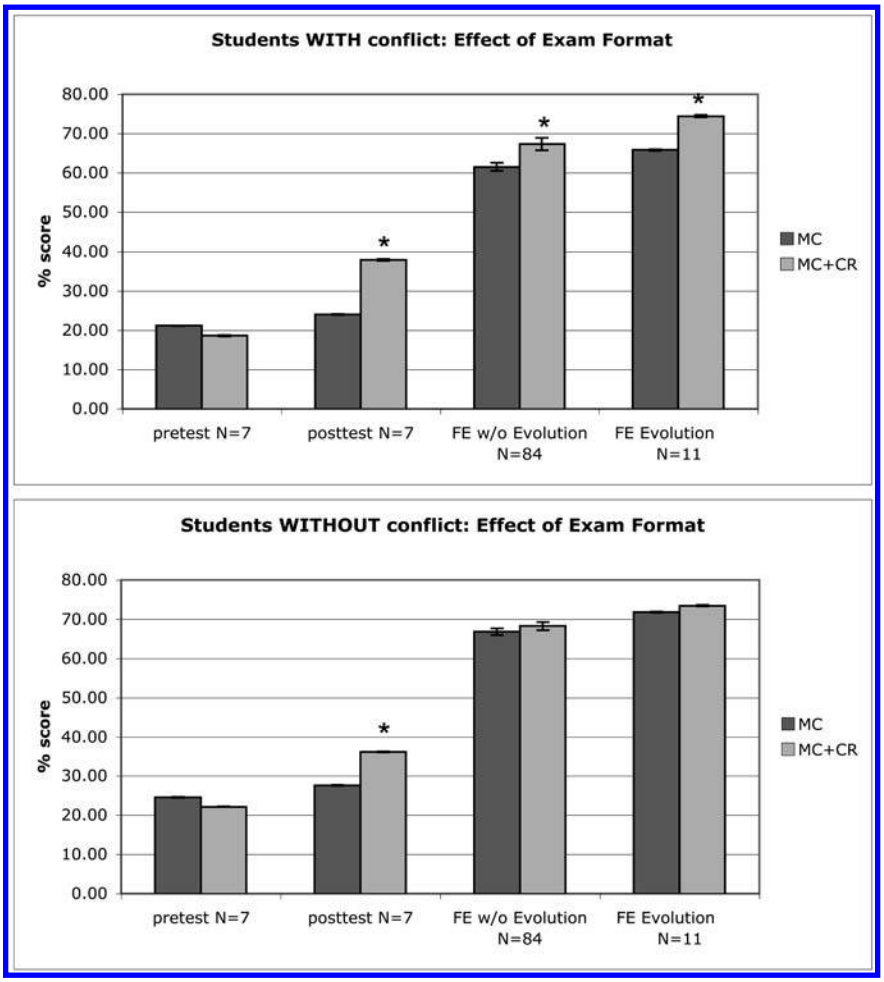

Figure 5. Student performance by conflict and exam format (mean ± SE) based on common exam questions. Asterisk indicates significant difference between exam formats for students with conflict (top panel) and without conflict (bottom panel).

essays than students who were assessed with MC-only questions (1.7–2.0%), whether or not they reported a conflict. Even though the difference is striking, the overall gains were limited. This was likely due to lack of formative application practice and could likely be improved through graded homework assignments (e.g., application tasks for the developed evolution flow chart).

Implications & Recommendations

The potential for exam format to close the performance gap between students with a conflict and those without is an important insight, especially for instructors of large introductory biology classes, which tend to be limited to MC-only exams. By adding grading support to assess students in a mixed exam format, students may learn significantly more (by changing their study behaviors) not only about biology, but also about evolution.

A self-reported conflict was associated with significantly lower performance in the MC-only exam format, but not in the mixed exam format. This raises the possibility that not only the focus on acceptance (along with different definitions of acceptance), but also differences in assessment format, could contribute to the inconsistent research findings in the literature (Cobern, 1994; Meadows et al., 2000; McKeachie et al., 2002; Sinatra et al., 2003; Ingram & Nelson, 2006).

In summary, constructed-response questions are one important support that instructors and their academic institutions can provide for biology students with a religious conflict. It can help them learn both biology and evolution, because, after all, in biology, *nothing* makes sense without the theory of evolution.

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KATHRIN F. STANGER-HALL is Associate Professor of Plant Biology at the University of Georgia, 503 Biological Sciences Bldg., Athens, GA 30602; e-mail: ksh@uga.edu. A doctoral candidate in Mathematics and Science Education at the University of Georgia when this article was accepted (December 2012), JULIANNE A. WENNER is now a Postdoctoral Fellow at the University of Connecticut, Curriculum and Instruction Department, Gentry Bldg., Storrs, CT 06269; e-mail: julianne.wenner@uconn.edu.