

The Influence of Religion and High School Biology Courses on Students' Knowledge of Evolution When They Enter College

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Abstract

Students whose high school biology course included evolution but not creationism knew more about evolution when they entered college than did students whose courses included evolution plus creationism or whose courses included neither evolution nor creationism. Similarly, students who believed that their high school biology classes were the primary source of their views of evolution knew more about evolution than did students who claimed that religion was the primary source of their views about evolution. Students who described their religious views as conservative or middle-of-the-road knew less about evolution than did nonreligious students or those who described their religious views as liberal/progressive. To our knowledge, this is the first measure of how students' experiences in high school biology courses affect their knowledge of evolution when they enter college.

Keywords: Evolution, teaching, religion, high school biology.

For several decades, numerous surveys conducted throughout the United States have documented the surprisingly large percentage of biology teachers who are creationists (Moore & Cotner, 2009, and references therein). Indeed, 20-35% of biology teachers include creationism in their courses, and fully one-sixth of biology teachers are young-Earth creationists who reject many of the tenets of biology and other sciences (Berkman, Pacheco, & Plutzer, 2008). The popularity of creationism among biology teachers continues despite decades of science education reform, numerous statements by professional scientific organizations supporting evolution and rejecting creationism, state science-education standards requiring the teaching of evolution, and numerous court decisions declaring that the teaching of creationism (e.g., creation science, intelligent design) in public schools is unconstitutional. Some of these court decisions have involved biology teachers who have taught creationism (Moore, 2002). Other such teachers have also made headlines; for example, Ohio biology teacher John Freshwater taught creationism, prayed, and held "healing sessions" in his classes for more than a decade, but was fired only after he used an electrical device to brand a cross into a student's arm (Demartini, 2008). Although the studies cited above have often lamented the occurrence of creationism in high school biology courses, few have measured the impact of including creationism in the curriculum. Does it matter if biology teachers teach creationism in their high school courses?

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We have previously reported that students whose high school biology courses included evolution (but not creationism) are significantly more likely to accept evolution than are students whose high school biology courses did not include evolution (Moore & Cotner, 2009). Similarly, students whose high school biology courses included creationism (with or without evolution) are significantly more likely to accept creationism and reject evolution than are students whose high school biology classes included only evolution. These studies involved students' responses to the Measure of Acceptance of the Theory of Evolution (MATE) survey, which measures students' acceptance of broad statements about evolution (e.g., age of Earth, fixity of species; Rutledge & Sadler, 2007). Although the MATE survey is informative about the acceptance of evolution, it does not measure students' factual *knowledge of* evolution. Knowledge of evolution is not synonymous with acceptance of evolution; as Cavallo and McCall (2008) have noted, biology students have "little scientific understanding of evolutionary processes, but hold many beliefs about the theory" (p. 522).

In this study, we examined the relationship of students' high school biology courses to their knowledge of evolution. Although several studies have examined whether college biology courses alter students' views of evolution (Hoyakem & BouJaode, 2008; Cavallo & McCall, 2008), we wanted to know how students' high school biology courses are associated with students' knowledge of evolution. We wanted to answer several questions. For example,

- Do students whose high school biology courses included evolution (but not creationism) know more about evolution when they enter college than students whose high school biology courses included creationism?
- Do students whose high school biology courses included evolution or creationism know more about evolution than students whose biology classes included neither evolution nor creationism?
- From what source do students believe they got the most information about evolution and creationism? Their high school biology course? Their family? Their religion?
- Do students' evaluations of the evolution-related content of their high school biology courses reflect their actual knowledge of evolution?

Methods

Study population. During the week before classes, we surveyed students enrolled in several sections of an introductory biology course at the Twin Cities campus of the University of Minnesota. All of the students in this study had taken a biology course in a public high school. Students in this course had an average high school graduation-percentile of $84 \pm 12\%$ and an average ACT composite score of 25 ± 4 .

The survey instrument. We designed our survey to assess students' background in, and knowledge of, the theory of evolution. First, we asked students to tell us whether their high school biology course included evolution but not creationism, creationism but not evolution, both evolution and creationism, or neither evolution nor creationism (Table 1).

Table 1. Students' descriptions of their high school biology course and their grades on the knowledge of evolution exam (KEE); $n = 193$.

My high school biology course included	% of Students	KEE Score
Evolution only	62.2	57 \pm 3.9
Creationism only	2.6	44 \pm 4.5
Evolution and creationism	22.3	53 \pm 4.5
Neither evolution nor creationism	12.9	41 \pm 3.3

We then asked students to respond to several statements from the Measure of the Acceptance of the Theory of Evolution (MATE) instrument developed and validated by Rutledge and Sadler (2007). Students could answer “strongly agree,” “agree,” “unsure,” “disagree,” “strongly disagree,” or not answer at all. We also included 10 basic, discriminating questions about evolutionary topics with which we and other biology instructors at our university assumed that entering students would be familiar (e.g., fitness, natural selection, evidence for evolution); these questions, which were developed and tested over a period of several years with students in introductory biology courses, are hereafter known as the Knowledge of Evolution Exam (KEE). Students could answer “strongly agree,” “agree,” “unsure,” “disagree,” “strongly disagree,” or not answer at all. We also asked students to identify their and their classmates' primary source of their views of evolution, and whether their high school biology courses' treatment of evolution was adequate, less than adequate, or more than adequate. Finally, we also asked students to identify their religious beliefs as being conservative, liberal, middle-of-the-road, or nonexistent (i.e., not religious). Copies of the survey and students' responses are available from the authors.

The survey, which was voluntary, anonymous, and approved by the university's Institutional Review Board, was distributed electronically to students one week before classes started. To ensure that students' responses were not influenced by the instructor or course, we closed the survey on the morning that classes began (i.e., before the first meeting of the class). Students' responses were tabulated electronically and had no impact on students' grades. The survey was completed by 193 students.

Results

Students' descriptions of their high school biology course and their grades on the KEE are shown in Table 1. The population averaged 54.2% on the KEE questions. The highest score on a question was 68.7%, and the lowest was 33.9%. Students whose high school biology course included evolution but not creationism scored higher on every question than did students whose high school biology classes included neither evolution nor creationism. The average difference between the scores was 32.7%, with the largest difference (61.8%) occurring on the question about mutation as the ultimate source in variation in populations, and the smallest difference (12.5%) occurring on the question about resistance to insecticides as an adaptation.

A one-way ANOVA revealed a significant effect ($F\text{-stat} = 3.58; p < 0.02$) of high school biology on the KEE score. Students whose high school biology course included evolution but not creationism scored an average of $56.4 \pm 2.0\%$ (s.e.) on the KEE. As indicated with a post-hoc pair-wise t -test, this score was not significantly different from that of students whose high school biology course included both evolution and creationism (i.e., $50.0 \pm 3.3\%$; $p = 0.10$) or creationism only ($48 \pm 9.8\%$; $p = 0.4$), but was significantly different from that of students whose high school biology course included neither evolution nor creationism ($41.6 \pm 4.4\%$; $p < 0.01$). The KEE scores of students whose high school biology course included both evolution and creationism were not significantly higher than those of students whose high school biology course included neither evolution nor creationism ($p = 0.12$).

Table 2 shows students' evaluations of the adequacy of the evolution coverage in their high school biology courses, as well as 1) the evolution content of their high school biology course, and 2) these students' scores on the KEE. Students who evaluated their high school biology course as "adequate" or "more than adequate" had similar high school biology courses; for example, 70-72% of the courses included evolution only, 25-28% included evolution plus creationism, and 0-5% included creationism only or neither evolution nor creationism. Thirty percent of students claimed that their high school biology course did a "less than adequate" job with evolution, despite the fact that 60% of these students' courses included evolution. The KEE scores of students' who evaluated their high school biology course as "adequate" and "more than adequate" were not significantly different. However, the KEE scores of both of these groups of students were significantly different ($p < 0.001$ per a Student's t -test) from those of students who evaluated their high school biology course's treatment of evolution as "less than adequate".

Table 3 shows students' claims of the primary sources of *their* views about evolution and these students' scores on the KEE. Students claimed that the top sources of their views of evolution were their high school biology course (55.1% of students), their family (26.9% of students), the media (14.7% of students), and their religion (3.2% of students). The KEE scores of students who claimed that their high school biology course was their primary source of information were significantly higher than those of students who claimed that their church/religion was the primary source of their views of evolution ($p < 0.04$). There were no significant differences between any of the other groups' scores.

Table 3. The relation of students' KEE scores to their primary sources of information about evolution. All numbers in the table are percentages.

Primary source of views About evolution	% of Students	KEE Score
Church/religion	3.1	32 ± 10.4
Family	26.9	53 ± 3.6
High school biology course	55.1	54 ± 2.5
Media	14.7	47 ± 4.8

Table 2. How students’ evaluations of the evolution-related content of their high school biology courses are related to their KEE scores. All numbers in the table are percentages.

		Emphasis of Students’ High School Biology Course				
Evaluation of Biology Course	% of Students	KEE Score	Evolution only	Creationism only	Evolution + Creationism	Neither evolution nor creationism
More than adequate	13.2*	56 ± 4	72	0	28	0
Adequate	56.6	58 ± 2.4	70	1	24	5
Less than adequate	30.2	42 ± 4.4	43	7	15	33

*For example, 13.2% of students evaluated their high school biology course’s treatment of evolution as “more than adequate.” These students scored 56% on the evolution questions. Seventy-two percent of these students had high school biology courses that included evolution only, 28% had courses that included evolution and creationism, and none had courses that included creationism only or that included neither evolution nor creationism.

The KEE scores of students having different self-described religious beliefs are shown in Table 4. Students who claimed to be middle-of-the-road scored significantly lower on the KEE than did students who described themselves as liberal/progressive ($p < 0.04$).

Table 4. The relationship of students' self-described religious views with their KEE scores. All numbers in the table are percentages.

Religious View	% of Students	KEE Score
Conservative	8.5	46 \pm 5.4
Liberal/progressive	36.0	56 \pm 2.8
Middle-of-the-road	25.0	47 \pm 3.2
Not religious	30.4	55 \pm 3.2

Discussion

Students' knowledge of evolution. Although evolution is a required part of the curriculum in most states' high school curriculum (including Minnesota), students averaged only 54% (i.e., a failing a grade) on the KEE. Students' scores on individual questions varied dramatically, but mean scores on all questions were surprisingly low, and even the highest score on an individual question (i.e., 68.7%) was in the D range. These results indicate that students entering college know relatively little about evolution, despite the fact that they took a high school biology course. Evolution may be the unifying theme in biology, but few high school students learn much about it in their high school biology courses, or at a minimum, few retain much of what they learn about evolution in high school.

How students' high school biology courses are associated with students' knowledge of evolution. Students' KEE scores were strongly associated with the evolution-related content of their high school biology courses. Students who scored highest (i.e., 57%) on the KEE were those whose high school biology course included evolution but not creationism (i.e., as required by state educational standards). Students whose high school biology course included evolution and creationism scored lower (i.e., 53%), and students whose high school biology course included neither evolution nor creationism scored lower still (i.e., 41%). These results indicate that the evolution-related content of students' high school biology courses strongly influences students' knowledge of evolution when they enter college. To our knowledge, this is the first quantitative measure of the impact of evolution-related instruction in high school on students' evolution-related knowledge when they enter college.

Although the teaching of evolution in high school increases students' knowledge of evolution when they enter college, the inclusion of creationism with evolution was associated with lower scores on the KEE. We could not determine if these lower scores were due to a decreased emphasis on evolution (e.g., to make time for the teaching of creationism) or to the incompatibility of many types of creationism with basic tenets of evolution (e.g., young-Earth creationism and the fixity of species), but we suspect that it

is a combination of both. Indeed, a surprising number of biology teachers either cover evolution in a trivial way or discredit evolution when they teach the subject (Bandoli, 2008, and references therein). Similarly, approximately one-sixth of biology teachers are young-Earth creationists (Berkman, Pacheco, and Plutzer, 2008), and a presentation of young-Earth creationism as legitimate science would presumably confuse students about the basic tenets of science in general, and evolution specifically. Regardless, the inclusion of creationism (which occurs in approximately 25% of biology courses; Moore and Cotner, 2009, and references therein) or the exclusion of both evolution and creationism (another 13% of biology courses) is associated with students knowing less about evolution when they enter college. When compared with students whose high school biology courses included evolution only (i.e., as specified by state science standards), students who have been taught creationism or who have been taught neither evolution nor creationism enter college biology classes at a distinct disadvantage.

Students' evaluations of the adequacy of their high school biology course. Although all groups of students scored poorly (i.e., < 60%) on the KEE, students' knowledge of evolution was strongly associated with their evaluations of the evolution-related content of their high school biology course. Almost 70% of students claimed that the evolution-related content of their high school biology course was adequate or more than adequate; these students' scores on the KEE (58 and 55%, respectively) were not significantly different, but were both significantly higher than those of students who claimed that the evolution-related content of their high school biology course was less than adequate (43%). Whereas students who evaluated their high school biology course as adequate or more than adequate had similar experiences in high school (e.g., 70-72% had evolution-only biology courses; 25-28% had courses that included evolution and creationism), students who viewed their high school biology course's coverage of evolution as inadequate were much less likely to have taken high school biology courses that included evolution only or evolution plus creationism, and much more likely to have taken courses that included creationism only or neither evolution nor creationism. These results support our claim that the evolution-related content of high school biology courses is strongly associated with college students' knowledge of evolution.

Almost 60% of the students who claimed that their high school biology course's coverage of evolution was inadequate had taken high school biology courses that included evolution. These results indicate that students' claims of the academic inadequacy of their high school biology course (and the reduced knowledge of evolution that is associated with these claims; see above) are usually not due to evolution being excluded from their courses. Although we did not measure the quality of the evolution-related instruction given to any of our students, and do not dispute the claim by Alters and Nelson (2002) that "many students have had ample formal and informal educational opportunities to misunderstand evolution," our results were not due to an increase in creation-related instruction, for the percentage of students in this group who were taught creationism (22%) was similar to that of students who evaluated their biology course as adequate (25%) and more than adequate (28%). Indeed, students who claimed that their high school biology course included an inadequate coverage of evolution were dramatically less likely to have had biology courses that included neither evolution nor creationism

(Table 2). These data are consistent with the claim that the evolution-related content of high school biology courses is strongly associated with college students' knowledge of evolution. Students having less or no exposure to evolution in high school biology classes did not learn about evolution from other sources (e.g., family, media, religion).

Our data show that students' knowledge of evolution is strongly associated with the evolution-related content of their high school biology course. Students know this; more than half (i.e., 55%) of students agreed that their high school biology course was their primary source of information about evolution. Students who claimed that their biology course was their primary source of information about evolution scored higher on the KEE (i.e. 54%) than did students who claimed that their primary source of information was the media (47%) or family (53%), and scored significantly higher than those who attributed their views about evolution primarily to their religion (i.e., 32%).

Students' religiosity. Students whose views of evolution were based primarily on religion scored lower on the KEE than all other groups of students. This is consistent with reports elsewhere about the importance of religion in people's views of evolution (Barnes, Keilholtz, & Albertstadt, 2008). Students who described their religious views as conservative and middle-of-the-road scored significantly lower than those who described their views as liberal and those who said they were not religious. These results 1) are consistent with the report that students' views of evolution are strongly associated with their religious beliefs (Dagher & BouJaode, 1997), and 2) indicate that among entering college students, those who have conservative religious beliefs know less about evolution than do religiously liberal or non-religious students.

Students' perceptions and prior knowledge of a topic strongly influence students' learning about that topic. This is especially important for evolution, because many students perceive an "overlap of some ideas that the theory [of evolution] advocates with other social, epistemological, and religious beliefs" (Hakoyem & BouJaode, 2008). Indeed, many college students view the consequences of accepting evolution as negative and undesirable (e.g., as increased selfishness, increased racism, reduced spirituality, and a diminished sense of purpose and self-esteem; Brem, Ranney, & Schindel, 2003). Until the teaching of evolution improves in high schools, college instructors should expect large percentages of students to continue to question, reject, and misunderstand the topic.

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