Relationship between Achievement and Students’ Acceptance of Evolution or Creation in an Upper-Level Evolution Course

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Abstract: Students often hold strong attitudes regarding topics they encounter during their studies, and many instructors feel that these attitudes can have strong effects on students’ performance. We characterized students’ attitudes toward evolution and investigated the influence of students’ attitudes (pre-course and post-course) regarding evolution on their performance in an evolution course, measured as their final grade. We found our students to hold positive attitudes toward evolution; these attitudes became more positive following the course. The most significant change in attitude occurred in the group of students initially undecided toward evolution. We also found that attitudes prior to the course had little influence on later achievement; however, at the end of the course, students’ attitudes were positively related to final grades, although the effect was small. We argue that pedagogical techniques directly addressing students’ attitudes help reduce the influence of attitudes (especially prior attitudes) on achievement. © 2005 Wiley Periodicals, Inc. J Res Sci Teach 43: 7–24, 2006

Anecdotal evidence from instructors has suggested that students’ attitudes toward the subjects they study influence their performance in those subjects. In his meta-analysis of research investigating relationships between attitude and achievement, Willson (1983) concluded that attitude had a modest effect on later achievement for college students. However, recent research has been equivocal with respect to the relationship between attitude and achievement in science courses. For example, Willson, Akerman, & Malave (2000) found no association between students’ attitudes and their later achievement in a college physics course. Similarly, Nicoll & Francisco (2001) reported that students’ attitudes about math ability and about a particular course did not predict achievement in college-level physical chemistry. In contrast, Freedman (1997) found that attitude was positively and moderately correlated with achievement for high school
physical science students, when both attitude and achievement were measured at the end of a course. Likewise, House (1995) found that initial attitudes toward chemistry were better predictors of achievement for university chemistry students than cognitive factors like admission test scores and mathematics background. Results from the extensive literature on the relationship between attitude and achievement have suggested that attitude does not predict achievement or explains only modest amounts of variation in achievement. Interpretation of these and similar studies has remained difficult due to the multitude of definitions of attitude used by researchers (Koballa, 1988) and the lack of valid and reliable measures of attitude (Gogolin & Swartz, 1992). Yet the conviction persists among practitioners that positive attitude toward science can be critical to later achievement.

Evolution has been recognized as the unifying theme of biology (Dobzhansky, 1973) and a significant portion of most undergraduate biology curricula has been devoted to instruction in evolution. Despite this centrality of evolution and its place in the curriculum, many students have rejected evolution, a situation long recognized by biology educators (dating back at least to Dudycha, 1934). This resistance to evolution has been very well characterized, as has our knowledge of students’ understanding of evolution and alternative conceptions they hold. Researchers have reported students’ acceptance and understanding of evolution with respect to demographic factors such as gender (Grose & Simpson, 1982; Lord & Marino, 1993), academic standing (Dudycha, 1934; Fuerst, 1984; Johnson & Peeples, 1987; Lord & Marino, 1993), and major course of study (Grose & Simpson, 1982; Johnson & Peeples, 1987). Most researchers have found little or no difference among these groups in either acceptance or understanding of evolution. Although this body of work has led to a more robust understanding of the challenges of teaching evolution, few researchers have investigated possible relationships between attitude toward evolution and later achievement. This absence in the literature seems puzzling; because evolution is considered by many to be controversial, attitudes toward evolution are almost certainly influenced by other strong beliefs, and evolution remains a fundamental component of science education. The most basic attitude toward evolution is one of acceptance or rejection of evolutionary principles and conclusions. Other attitudes toward evolution, such as a student’s view of the positive or negative consequences of evolution (Brem, Ranney, & Schindel, 2003), may influence students’ achievement, but are not our focus in this research.

Lawson (1983) found a negative relationship between acceptance of evolution and later achievement in a college-level, nonmajors’ biology course with a laboratory focus. He determined students’ acceptance of evolution by their response to a one-item Likert scale statement: “All living things were created during a short period of time by an act of God” (Lawson, 1983, p. 120). At the beginning of the course, 57% of students agreed with this statement. Achievement then was measured using a ten-item multiple-choice instrument, a problem regarding geologic time, and an essay question about natural selection. Lawson found that students who initially accepted creation or were unsure earned statistically significantly lower scores on the multiple-choice instrument than did students who initially accepted evolution (moderate effect size \( f = 0.3889 \), our calculation). Acceptance of evolution did not influence achievement on the other assessments. In a regression analysis, acceptance of evolution was the best predictor of achievement on the multiple-choice instrument (among other possible influences like prior knowledge and developmental level), explaining 13.3% of variance in scores; prior knowledge was the second best predictor. When all achievement measures were examined collectively, acceptance of evolution explained 11% of variance in achievement, second only to a student’s ability to filter out irrelevant information. To Lawson, these results suggest that cognitive dispositions interfered with subsequent learning, and thus, that teachers should attend to students’ beliefs and attitudes.
Lawson’s results were confirmed recently by McKeachie, Lin, and Strayer (2002). As these authors rightly stated, “...we do not know how students who enter college biology classes believing in creationism will fare” (McKeachie et al., 2002, p. 189). They determined students’ acceptance of evolution using responses to one item from a four-item survey. At the beginning of the course, 17% of students accepted creation and rejected evolution; the majority of the remaining students accepted evolution in some form. They found that students who accepted evolution earned higher final grades than did students who accepted creation, by an average of one full letter grade (a statistically significant difference). This pattern was present whether acceptance of evolution was determined before or after the course. Although most students responded the same before and after the course, all students who changed their responses were more accepting of evolution after the course. Also, they reported that a disproportionately high percentage of students who rejected evolution or were unsure of their attitude toward evolution either dropped the course or did not respond to the questionnaire at the end of the course. McKeachie et al. (2002) interpreted this result as one way that students resolved internal conflict between course content and personal beliefs or attitudes. The conclusions of this study in terms of achievement were clear: rejecting evolution had serious consequences for learning biology. From these two reports, the expected relationship was established between attitude, in terms of acceptance, and achievement for the specific case of evolution—a more favorable attitude toward evolution leads to higher achievement in a course containing evolution content.

Our study further investigated the relationship between acceptance of evolution and achievement. Our work and that of Lawson (1983) and McKeachie et al. (2002) differed in that we studied students in an upper-level, semester-long evolution course, as opposed to the introductory nonmajors’ settings with short evolution units used by these other authors. We focused our study on three questions: (1) Do students accept evolution as science? (2) Does instruction influence students’ acceptance of evolution? (3) Is students’ achievement related to their acceptance of evolution in an evolution course? Each question is addressed in greater depth in what follows.

1) Do students accept evolution as science? Researchers have found that, in most college student populations, at least 50% of students accept evolution (Bishop & Anderson, 1990; Fuerst, 1984; Grose & Simpson, 1982; Lord & Marino, 1993). We therefore expected that at least half of our student population would initially accept evolution (i.e., respond to pre-course survey items in a manner consistent with evolutionary science).

2) Does instruction influence students’ acceptance of evolution? We anticipated (and hoped) that instruction in evolution would affect positively students’ acceptance of evolution. This expectation was consistent with other research on students’ acceptance of evolution (Lawson & Weser, 1990), particularly among studies in which curricular strategies were investigated (e.g., Scharmann, 1990). However, other researchers have found no change in students’ acceptance of evolution after an evolution unit (Bishop & Anderson, 1990). By directly addressing many alternative conceptions about evolution (e.g., the perceived conflict between science and religion; see Methods section), we hoped to find increased acceptance of evolution among our students following the course.

3) Is students’ achievement related to their acceptance of evolution in an evolution course? In keeping with prior research (Lawson, 1983; McKeachie et al., 2002), we hypothesized that students who were more accepting of evolution would earn higher grades than those rejecting evolution. We expected this result regardless of whether acceptance was determined at the beginning or end of the course. In fact, we expected to find a stronger effect of acceptance of evolution on achievement in our course than that found in the introductory nonmajors’ courses cited previously, because our course was a semester-long, upper-level, majors’ course focused specifically on evolution. If acceptance of evolution affected achievement, we expected the effect
to be very strong in a course that can be entirely in conflict with a student’s worldview (as suggested by Cobern, 1994).

Before our investigation we made three important decisions regarding terminology. First, we chose very specifically the words acceptance, accept, reject, and rejection to describe students’ attitudes toward evolution and creation both in class and in this report (Smith, 1994; Southerland, Sinatra, & Matthews, 2001). We contrast these choices with the word believe, also often used in studies on students’ acceptance or conceptions of evolution. For example, McKeachie et al. (2002) stated in the opening line of their study, “Evolution—To believe it or not to believe?” (p. 189), and Lawson and colleagues used belief in several publication titles (Lawson, 1983; Lawson & Weser, 1990; Lawson & Worsnop, 1992). Our use of accept reinforced the scientific evaluation of evolution (Cooper, 2001; Smith, 1994; see Nelson [2000] for further description of nonscientific yet legitimate evaluations of evolution). Second, we defined creation as young-earth creation; that is, a literal reading of the Bible’s Book of Genesis regarding the origins of all life (including humans), the age of the Earth, and explanations for fossil remains (Scott, 1999). Students did not have to accept all tenets of this framework to reject evolution; in fact, many creationists have claimed a more moderate view of creation (Brem et al., 2003). However, as the most vigorous and vociferous counter-evolution arguments have come from young-earth creationists and our survey instrument strongly modeled these claims, we settled on the young-earth definition of creation. This definition also encompassed some claims of the intelligent design movement, and it was consistent with Muslim and Jewish literalist conceptions of creation. Finally, we distinguished between acceptance of evolution and understanding of evolution, in that neither was a prerequisite nor necessary condition of the other. This assertion has been supported by numerous studies that report high levels of student acceptance of evolution but also a poor ability to define, describe, or solve problems in evolution as would be expected from students with a strong understanding of evolution (Bishop & Anderson, 1990; Lord & Marino, 1993; Sinatra, Southerland, McConaughy, & Demastes, 2003). In our study, acceptance equated with attitude and understanding was measured by achievement. These decisions regarding terminology clarified our research and simplified its communication.

Methods

We surveyed students enrolled in an upper-level evolution course at a large Midwestern university for their acceptance or rejection of creation and evolution during three semesters (Spring 2000, Fall 2001, and Spring 2002—hereafter S00, F01, and S02, respectively). Our survey was administered on the first day (pre-course survey) and at the end of the course (post-course survey) by an individual not involved in the research; responses were used in our subsequent analyses if we could match pre-course survey, post-course survey, and final grade (S00: n = 91; F01: n = 110; S02: n = 54). Most enrolled students participated in the study, and attrition from this required majors’ course was low, so we did not expect bias in our results due to nonparticipation or dropping the course as was found in McKeachie et al. (2002). We used final course grade in percent as our measure of achievement (mean final grades and standard deviations: S00, 89.46 ± 6.71; F01, 89.18 ± 8.03; S02, 83.19 ± 9.14).

The student populations were similar among the three semesters. Most students were junior or senior biology/medicine/health-care professional majors. As our evolution course was the capstone of the biology major, nearly all students had filled most requirements of the biology major already, including a genetics course, and had taken several other science courses (mostly chemistry and physics). Many students reported being somewhat religious, although we
found considerable variation in strength of religious identification and faith practiced (data not shown).

The course centered around three themes, with only minor modifications across semesters. The main themes were a brief history of life, evolution as patterns (including evidence for evolution such as fossil and molecular records, adaptations and limits on adaptation, and patterns of diversity), and evolution as processes (including explanations of evolution such as inheritance and variation, speciation and macroevolution, and extinction). We integrated a considerable focus on the nature and limits of scientific knowledge into the main themes, particularly scientific and general critical thinking and the application of critical thinking to controversies involving science. The course included twice-weekly combined lecture and discussion sessions and once-weekly learning-group periods. During learning groups, students engaged in various critical thinking exercises, such as comparing hominoid skulls, simulating population genetics dynamics, evaluating different religious and scientific conceptions of the evolution/creation controversy, and constructing phylogenies from molecular sequences. We emphasized the compassionate analysis of the perceived conflict between evolution and some religious beliefs, mostly during class discussions of pertinent readings (consistent with the recommendations of Jackson, Doster, Meadows, & Wood, 1995; Nelson, 2000, and others cited therein). A student’s final grade in the course was based on learning-group participation and grades from three exams, occasional quizzes, and learning-group worksheets. The content of the course was substantially the same across semesters.

We used Brian Alters’s unpublished survey measuring student acceptance of evolution to assess students’ attitudes toward creation and evolution. We used this unpublished instrument because we were unaware of a suitable instrument that assessed students’ attitudes toward evolution, including acceptance of evolution, and the nature of scientific knowledge. Participants responded to a full survey containing 21 Likert-scaled statements, several short essay questions, and numerous demographic questions in S00. After preliminary analysis of the data, we reduced the survey to 12 Likert-scale statements that appeared particularly informative for determining whether acceptance of evolution influenced achievement and that students could complete rapidly (see Appendix). We used only these 12 statements in our analyses of data from each semester (hereafter, survey refers to the 12-item survey). Data from S00 were retained for the analyses described in what follows. These statements were scored on a five-point scale such that the evolutionarily consistent response was scored as 5 regardless of whether the response was strongly agree or strongly disagree. Because most of the statements invited students to accept creationist claims, we felt that the survey was not biased against the creation worldview. Although this survey instrument has not been published, there were strong reasons to accept it as a reliable and valid mechanism for quantifying students’ attitudes toward evolution. A reliability analysis of the survey when given prior to instruction in evolution resulted in a Cronbach’s alpha of 0.865 (n = 255); when measured for post-course surveys, Cronbach’s alpha was 0.878 (n = 255). In both cases, the reliability of the survey exceeded the general minimal acceptable reliability for Cronbach’s alpha of 0.7. Furthermore, our consistency analysis, described subsequently, indicates that students’ responses were similar for similar survey items. Therefore, this survey was reliable. In addition, our survey paralleled the Measure of Acceptance of the Theory of Evolution (MATE, designed to quantify biology teachers’ acceptance or rejection of evolution) (Rutledge & Warden, 1999); some statements on our survey were virtually identical to several on the MATE. When we administered the MATE and our instrument to a class not participating in this study, we found a highly positive and statistically significant correlation between MATE score and our pre-course survey score (see below; \( r = 0.879, p < 0.001, n = 63 \)). The high and statistically significant correlation between MATE score and
pre-course survey score supported the validity of our survey, because these two surveys were
designed to measure the same construct (i.e., acceptance of evolutionary concepts). Several
science educators and biologists judged the face validity of the survey as high. Most statements
(although framed in a creationist light) mirrored primary themes of the course textbook (Freeman
& Herron, 1998/2001) and reflected basic tenets of evolution that are frequently questioned by
creationists.

From the survey responses we generated four scores for each student: a pre-course
score; a post-course score; a raw gain score; and a normalized gain score (\( <g > \) as in Hake, 1998;
although note that we were assessing attitude, not knowledge). Because the normalized gain score
[raw gain score/(maximum possible – pre-course score)] scaled for the pre-course score, we
avoided the constraint of pre-course score exhibited by raw gain score (e.g., students with high pre-
course scores could only have low raw gain scores but a full range of normalized gain scores).
These expected relationships were reflected in correlations between pre-course scores and the
change scores: pre-course score was negatively correlated with raw gain score (\( r = -0.300, p < 0.001 \)), but uncorrelated with normalized gain score (\( r = 0.037, p = 0.558 \)). Although these
two measures of change were not independent, they provided different information. Each score in
every semester (except final grade in F01) fit a normal distribution by the Kolmogorov–Smirnov
goodness-of-fit test; therefore, we used parametric tests to analyze these data. Effect size of the raw
gain was calculated using Cohen’s \( d \) (Cohen, 1988); an effect size of 0.5 is generally considered to
indicate a medium effect. These four scores characterized students’ acceptance of evolution and
changes in that acceptance during the course.

We used matched \( t \)-tests to assess change in students’ acceptance of evolution or creation
between the pre-course survey and the post-course survey. To determine the relationship between
acceptance of evolution and achievement, we performed four separate simple regression analyses
using final grade as the dependent variable, with either pre-course score, or post-course score, or
raw gain score, or normalized gain score individually as the predictor variable. For the \( t \)-tests and
regression, we examined the three semesters individually, because the mean scores and variation
around these means differed among semesters, and to avoid claiming that final grades were
equivalent among semesters. In addition, we used the chi-square test to determine whether
instruction influenced students’ acceptance of evolution, using a null hypothesis of no expected
change (comparing pre-course survey responses to post-course survey responses). For this
analysis we pooled the data from the three semesters to avoid small sample sizes. Analyses were
performed using the Statistical Package for the Social Sciences (SPSS, 2002), or calculated by
hand. Our criterion for statistical significance was set at \( p < 0.05 \).

Results

(1) Do students accept evolution as science? Overall, students were accepting of evolution
before the course. In the three semesters, the percentages of these junior and senior biology majors
who initially accepted evolution (Statement 1) were 65%, 67%, and 61%, respectively (Table 1).
Outright acceptance of creationism was initially 23%, 34%, and 30%, respectively, in the three
semesters (Statement 2, Table 1). For most of the other statements, the majority of students
responded in a manner consistent with evolutionary science on the pre-course survey. However,
for Statements 9 and 12 (Probability of Life and Second Law of Thermodynamics, respectively),
a large percentage of students were undecided, a circumstance that might have reflected
their unfamiliarity with the concepts. Almost all students accepted that mutations can be
beneficial (Statement 11), most likely reflecting their learning from a prerequisite genetics
course. Also, we found that more students accepted individual tenets of evolution than accepted the
general statement of evolution in each semester. For example, in S00, 64.8% of students accepted evolution as written in Statement 1, yet a higher percentage of students responded in an evolutionarily consistent manner to most of the remaining statements (Table 1). In sum, the majority of students initially accepted evolution and various tenets of evolutionary theory. Generally, students held internally consistent views of evolution at the beginning of the course. Fewer than 15% of students responded inconsistently for any pair of statements we examined (Table 2). We found greater consistency (i.e., fewer inconsistencies) in responses between the two generalized statements of evolution and creation than between comparisons involving human evolution (e.g., Statements 3 and 6), but the difference between these levels of inconsistency was not large. Overall, students responded to related survey items in a similar manner.

(2) Did instruction influence students’ acceptance of evolution? Acceptance of evolution increased between the pre-course survey and the post-course survey. On the post-course survey, the percentages of students who accepted evolution were 77%, 70%, and 74%, respectively, representing on average a 9% increase in number of students accepting evolution, one that was statistically significant in each semester (Table 1; S00, $t = 4.65$; F01, $t = 5.14$; S02, $t = 3.18$).

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<th>Creation</th>
<th>F01 Evolution</th>
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Note. See Appendix for statements. The Evolution column indicates the percentage of students responding consistent with evolutionary conceptions and Creation indicates the percentage of students responding consistent with creationist conceptions. “Strongly agree” and “agree” responses were summed (likewise for “disagree” and “strongly disagree”). Undecided responses are not included. Statistical comparisons are given in Tables 3 and 4.
Outright support for creationism decreased to 13%, 27%, and 17% in the three semesters, a change that was also statistically significant in each semester (Statement 2, Table 1; S00, \( t = 4.95; \) F01, \( t = 2.61; \) S02, \( t = 3.54 \)). For most other statements, more students responded in an evolutionarily consistent manner on the post-course survey than on the pre-course survey (Statements 4 and 11 of S00 are the only exceptions; however, in these two cases we found high initial levels of acceptance and only a small amount of change). Pre-course score and post-course score were significantly positively correlated (\( r^2 = 0.573 \)), but almost half of the variance in post-course score was not associated with pre-course score and thus could be attributed to other factors, such as the influence of instruction. Change toward increased creationist thinking occurred in at most four students in a semester (Statement 4; S00), and most commonly in only one student on any statement. On average, post-course scores were 8% higher than pre-course scores, representing a small but statistically significant change (Table 3), despite the constraints of the initially high levels of acceptance of evolution among our students. More importantly, normalized gain scores

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Statements} & \text{Pre-Course} & \text{Post-Course} & \text{Same} \\
\hline
1 \& 2 & 6.3 & 4.7 & 0.8 \\
1 \& 3 & 9.8 & 7.5 & 3.1 \\
2 \& 3 & 12.9 & 11.8 & 5.1 \\
2 \& 5 & 10.6 & 10.9 & 3.9 \\
3 \& 5 & 7.5 & 6.7 & 1.6 \\
3 \& 6 & 8.2 & 7.1 & 1.2 \\
3 \& 7 & 4.7 & 4.3 & 0.4 \\
\hline
\end{array}
\]

\textbf{Note.} Numbers in pre-course survey and post-course survey columns represent percentages of students accepting one statement but not the other (responses from all semesters tabulated together; \( n = 255 \)). “Same” column indicates the percentage of students who responded inconsistently on both surveys. These statements were chosen for pairwise examination because the special creation of humans is an important tenet of the creationist viewpoint.

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Semester} & \text{S00} & \text{F01} & \text{S02} \\
\hline
\text{Raw gain} & & & \\
\text{Mean} & 4.99 & 4.47 & 4.69 \\
\text{Standard deviation} & 5.24 & 4.60 & 5.74 \\
\text{\( t \)} & 9.08 & 10.20 & 6.00 \\
\text{Percent increase} & 8.31 & 7.45 & 7.82 \\
\text{Cohen’s d} & 0.868 & 0.658 & 0.566 \\
\text{Normalized gain} & & & \\
\text{Mean} & 0.34 & 0.22 & 0.34 \\
\text{Standard deviation} & 0.36 & 0.28 & 0.37 \\
\text{\( t \)} & 9.19 & 8.42 & 6.49 \\
\hline
\end{array}
\]

\textbf{Note.} Raw gain and normalized gain are defined in the text. All means are statistically significantly greater than zero at a significance level of \( p < 0.05, n = 91, 110, \) and 54 for S00, F01, S02, respectively.
averaged 30%, also a statistically significant change (Table 3). That is, the mean post-course score increased by almost one-third of the possible gain, an amount equivalent to a change from 70% to 79% on a 100-point scale. Students were more positive toward evolution after the semester-long course.

Instruction had a strong effect on students’ acceptance of evolution for those students who changed their responses between the pre-course survey and the post-course survey. The majority of students were consistent in their responses to both surveys (e.g., a response of 1 or 2 on the pre-course survey and a response of 1 or 2 on the post-course survey were both considered creationist and so no change was recorded). However, for most statements, at least 20% of the participants changed their responses between surveys, although far fewer students changed their responses to Statements 4 and 11. If instruction had no effect on students’ acceptance of evolution, we expected that, of the students whose responses changed meaningfully between surveys, half would respond more positively to evolution and half would respond more positively to creation. More students responded in an evolutionarily consistent manner on the post-course survey than would be expected from the pre-course survey results if instruction did not influence students’ attitudes (Table 4). For 11 of the 12 statements, change toward evolutionary conceptions was statistically significant (Table 4). The one statement for which we did not find a statistically significant change toward evolutionary conceptions (Statement 11) was constrained by the initially high acceptance of this statement, making statistically significant change mathematically impossible. When we performed the same analyses using only those students who responded as undecided to a certain item on the pre-course survey but not on the post-course survey, we found statistically significant change toward evolutionary conceptions for all 12 statements (Table 4). In fact, the deviation from the expectation of equal change in attitudes toward creation and evolution was greater for the undecided students on 8 of the 12 statements than it was for all students whose responses changed. That is, instruction in evolution was

<table>
<thead>
<tr>
<th>Statement</th>
<th>All Students Changing Responses</th>
<th>Undecided Students Changing Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27.60** (67)</td>
<td>19.20** (30)</td>
</tr>
<tr>
<td>2</td>
<td>36.45** (83)</td>
<td>28.49** (43)</td>
</tr>
<tr>
<td>3</td>
<td>23.14** (56)</td>
<td>11.57** (28)</td>
</tr>
<tr>
<td>4</td>
<td>5.44* (36)</td>
<td>16.20** (20)</td>
</tr>
<tr>
<td>5</td>
<td>36.57** (92)</td>
<td>43.22** (65)</td>
</tr>
<tr>
<td>6</td>
<td>40.89** (91)</td>
<td>49.00** (64)</td>
</tr>
<tr>
<td>7</td>
<td>40.11** (81)</td>
<td>38.75** (57)</td>
</tr>
<tr>
<td>8</td>
<td>51.55** (77)</td>
<td>53.07** (57)</td>
</tr>
<tr>
<td>9</td>
<td>4.72* (122)</td>
<td>25.81** (62)</td>
</tr>
<tr>
<td>10</td>
<td>18.85** (65)</td>
<td>31.84** (43)</td>
</tr>
<tr>
<td>11</td>
<td>1.33 (12)</td>
<td>8.00* (8)</td>
</tr>
<tr>
<td>12</td>
<td>57.14** (112)</td>
<td>82.05** (86)</td>
</tr>
</tbody>
</table>

All tests used the null hypothesis of no change expected. Semesters were analyzed together using all students whose responses changed between surveys and then students responding as undecided on the pre-course survey but not on the post-course survey (number of students in parentheses, df = 1 for all tests).

*p < 0.05.

**p < 0.001.
particularly effective at changing acceptance of evolution for those students who were initially undecided toward evolution. Because the change toward evolutionary conceptions was statistically significant for all of the statements where significance was mathematically possible, these results clearly were not an artifact from making multiple comparisons. Not surprisingly, instruction in evolution positively affected students’ attitudes, increasing acceptance of evolution.

Students’ responses were more internally consistent on the post-course survey than on the pre-course survey (Table 2). For every comparison except that between Statements 2 and 5, fewer students responded in an inconsistent manner on the post-course survey than on the pre-course survey. For every comparison, we found that the students who responded inconsistently on the post-course survey were usually different than those who responded inconsistently on the pre-course survey. Most students who were initially inconsistent did not maintain their inconsistent responses throughout the course. Students’ attitudes were more consistent after the semester-long course.

(3) Was students’ achievement related to their acceptance of evolution in an evolution course? Although both pre-course score and post-course score were positively related to final grade in each semester (significantly so for post-course score), the explanatory power of these variables was low (Table 5). Therefore, we found that students’ acceptance of evolution was not strongly related to their achievement in this course. Generally, students who rejected evolution earned only slightly lower final grades than those who accepted evolution. Earning a high grade in our course did not require accepting evolution. For example, in two of the three semesters, the lowest post-course score was for a student earning above 90% in the course. Similarly, students’ changes in their acceptance of evolution were not related to their final grades in two of the three semesters (Table 5). In S00, both raw gain score and normalized gain score were statistically significant predictors of final grade, although the variance explained by these two predictors was low (Table 5). Students’ acceptance of evolution, and its change throughout the semester, was not strongly related to achievement.

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S00 (n = 91)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-course score</td>
<td>0.164</td>
<td>0.122</td>
<td>0.141</td>
<td>0.020</td>
</tr>
<tr>
<td>Post-course score</td>
<td>0.389</td>
<td>0.103</td>
<td>0.372*</td>
<td>0.138</td>
</tr>
<tr>
<td>Raw gain</td>
<td>0.381</td>
<td>0.129</td>
<td>0.299*</td>
<td>0.089</td>
</tr>
<tr>
<td>Normalized gain</td>
<td>6.541</td>
<td>1.889</td>
<td>0.346*</td>
<td>0.120</td>
</tr>
<tr>
<td><strong>F01 (n = 110)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-course score</td>
<td>0.295</td>
<td>0.110</td>
<td>0.250*</td>
<td>0.063</td>
</tr>
<tr>
<td>Post-course score</td>
<td>0.289</td>
<td>0.108</td>
<td>0.249*</td>
<td>0.062</td>
</tr>
<tr>
<td>Raw gain</td>
<td>0.011</td>
<td>0.168</td>
<td>0.006</td>
<td>0.000</td>
</tr>
<tr>
<td>Normalized gain</td>
<td>1.110</td>
<td>2.763</td>
<td>0.039</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>S02 (n = 54)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-course score</td>
<td>0.265</td>
<td>0.149</td>
<td>0.240</td>
<td>0.057</td>
</tr>
<tr>
<td>Post-course score</td>
<td>0.309</td>
<td>0.150</td>
<td>0.275*</td>
<td>0.076</td>
</tr>
<tr>
<td>Raw gain</td>
<td>0.071</td>
<td>0.221</td>
<td>0.044</td>
<td>0.002</td>
</tr>
<tr>
<td>Normalized gain</td>
<td>2.296</td>
<td>3.523</td>
<td>0.093</td>
<td>0.009</td>
</tr>
</tbody>
</table>

* $p < 0.05$.  

---

**Table 5**

Summary of regression analysis for variables separately predicting student achievement.
Discussion

We found that a substantial majority of students in our sample accepted evolution and rejected most claims of creationism, both before and after the course. Both acceptance of evolution and consistency of students’ responses increased after a semester of instruction in evolution. Students who were initially undecided about evolution were more likely to experience a change in their acceptance of evolution than either students initially accepting creation or students initially accepting evolution, and this change was strongly toward evolutionary attitudes. In this course, students’ attitudes prior to the course or change in attitudes during the course had little influence on achievement. Students with creationist and evolutionist pre-course attitudes had both high and low achievement. However, attitudes at the end of the course were moderately but not strongly associated with achievement. Although attitudes before and after instruction were correlated and both attitudes were positively correlated with achievement, students’ attitudes statistically influenced achievement only when measured after the course.

(1) Do students accept evolution as science? Our students are slightly more accepting of evolution than other populations of college students, based only on responses to Statement 1 (Bishop & Anderson, 1990; Grose & Simpson, 1982; Lawson & Weser, 1990). This finding could be due to the population we studied—almost all students who enroll in the course are either juniors or seniors majoring in biology. Although major status (biology major or non-biology major) does not appear to influence acceptance of evolution (Grose & Simpson, 1982; Johnson & Peeples, 1987), higher academic standing has been associated with higher levels of acceptance (Dudycha, 1934; Fuerst, 1984; Lord & Marino, 1993). Our students are predisposed to favor evolution, in that they overwhelmingly reject typical creationist arguments against evolution (the remaining survey statements). This result is consistent with that of Lord and Marino (1993), who found just over 80% of their junior and senior student population answered positively when asked “Do you think the modern theory of evolution has a valid scientific foundation?” (p. 354). Our results are consistent with the literature that suggests upper-division students are more likely to accept evolution.

Students are more positive toward the individual tenets of evolution than to the general statement of evolution. One explanation for this finding is that students may hesitate to self-identify as evolutionists. Other researchers note that scientists who accept evolution are sometimes considered atheistic or amoral by people not accepting evolution (Brem et al., 2003; Jackson et al., 1995). Students, and others, may believe that accepting evolution necessarily means that they reject God. The majority of participants in our study report a religious identification; they might resist evolutionary thinking for fear of renouncing their religious beliefs. Also, if students hold negative opinions of the consequences of evolutionary thought (e.g., that evolution promotes racism or leads to a lack of purpose, as in Brem et al. [2003]), they could consider accepting evolution a moral problem. Students’ overall acceptance of a general statement of evolution is slightly higher following instruction, reflecting changing conceptions about the interface between science and religion, increasing understanding of what it is that evolution explains and does not explain (i.e., the nature of science [Smith, 1994]), or some other factor.

Despite high levels of acceptance of evolution among our students, a small fraction of biology students reject evolution both before and following the course; that is, they reject the general evolution statement and accept the special creation of humans. Far fewer students respond as creationists to the other statements on the survey. We suggest two explanations for this discrepancy. First, the finding that students accept the creation statement but not the other statements may reflect the somewhat strict wording of some statements on the survey. Individuals hold a variety of views on evolution and creation (Brem et al., 2003; Nelson, 2000; Strahler, 1983).
If instead we define creation as naturalistic processes operating at the hand of a supreme being with humans representing a special case of intervention (one version of theistic evolution), then the discrepancy among students’ responses no longer exists because this option and related ideas are not included in the survey in its current form. In this vein, the standard practice of establishing a dichotomy between evolution and creation may ignore the more moderate creationist perspectives many students hold. A second explanation for the discrepancy among responses is that students may respond in an evolutionary-consistent manner to most statements, yet accept the creation statement in an attempt to maintain religious self-identification. As in Jackson et al. (1995), we recognize that students can accept both a creationist view of origins and an evolutionarily consistent view of the rest of biology. Although instructors may consider students holding such inconsistent views to be lacking in critical thinking ability, these somewhat creationist students instead may be exhibiting developmental advancement in their demonstration of learning despite preexisting or long-standing rejection of the content of the course, and may be paralleling or copying more sophisticated theological stances (see Nelson, 1986, 2000). According to McKeachie et al. (2002), students must experience cognitive dissonance in a course that challenges their fundamental beliefs or attitudes, possibly resulting in lower achievement. For students not experiencing conflict regarding evolution, whether they accept or reject the theory, their acceptance may be rote or influenced by an authority figure, rather than carefully reasoned or fully developed (Jackson et al., 1995; Lawson & Weser, 1990). Regardless of the explanation, some students accept creation even after a semester-long course in evolution.

The majority of students are consistent in their acceptance of evolution. Only about 5% of students responded in an inconsistent manner to both the pre-course survey and the post-course survey, and fewer than 15% of students responded inconsistently on either survey. These results suggest that most students hold a well-formed view of either evolution or creation and that their acceptance of evolution is carefully considered, ideas that are contrary to our suggestion given earlier. Another explanation for inconsistency in students’ responses is that students interpret the survey statements differently than we do. For example, students could logically accept the divine origin of humans on faith but reject the existence of evidence supporting such, if they believe that no evidence exists. Whatever the source, very few students were inconsistent in their attitudes toward evolution as measured by responses to our survey.

(2) Does instruction influence students’ attitudes toward evolution? In this population of students, instruction in evolution resulted in a small increase in acceptance of evolution by students and an overall positive change toward evolutionary conceptions regarding human evolution and other tenets of the theory. This result is clearest for normalized gain and strongest for students who were initially undecided in their acceptance of evolution. We contrast the positive results of our study with the results of both Bishop & Anderson (1990) and Lawson & Worsnop (1992); in both of these studies, students’ acceptance of evolution did not change following an instructional unit on evolution and natural selection. One explanation for our positive results in this respect is that our course was a semester-long course on only evolution. Such exposure to and working with concepts in evolution over many weeks positively influenced students’ acceptance of evolution; either length of time or singularity of focus may account for this.

Although acceptance of evolution was higher among our students at the beginning of the course than other similar populations of college students, the very high acceptance of human evolution on the post-course survey by our students was particularly gratifying as the course is taught with a number of activities that focus specifically on human evolution (see Flammer, Beard, Nelson, & Nickels, 2004). Taken together, the instructional strategies we use are successful in terms of eliciting positive change in acceptance of evolution (and rejecting creationist claims). Some of these strategies specifically address survey items, particularly human evolution, and
student acceptance of evolution based on these items shows the greatest amount of change. For example, in one activity students examine skulls from gorillas, chimpanzees, modern humans, and fossil hominids. From this activity they discover changes in skull morphology in relation to diet and bipedalism. Following such activities, students are more accepting of the basic tenets of human evolution (as in Statements 6 and 7). By addressing misconceptions about human evolution explicitly, instructors may cause greater change in students’ acceptance of human evolution than would otherwise occur.

In the context of this semester-long course, students’ acceptance of evolution changes, even for some students who initially identify themselves as creationists. According to Lawson and Worsnop (1992), “highly religious students are not likely to change their belief in special creation as a consequence of relatively brief lessons on evolution” (p. 165). Our positive results in this respect can be explained by the length of our course (as opposed to “relatively brief lessons”) or by our teaching strategy that allows students to examine some consequences of accepting evolution (e.g., through use of J. Bull’s “Applied Evolution” essay from Flammer et al. [2004]). Most students possess negative interpretations of the consequences of accepting evolution and evolutionary principles, regardless of their initial disposition toward evolution (Brem et al., 2003). According to Brem et al. (2003), a majority of both students accepting creation and students accepting evolution believe that having an evolutionary perspective makes it “easier to consider some races and ethnic groups ‘less advanced’ than others” and “easier to believe that human beings are always looking out for their own best interests” (pp. 193, 201–202). Although we do not address the same consequences of evolution as Brem et al. (2003), students’ consideration of the consequences of accepting evolution in the context of the course material may explain some of the positive gain in acceptance of evolution among religious students.

(3) Is students’ achievement related to their acceptance of evolution in an evolution course? Unlike in Lawson (1983) and McKeachie et al. (2002), students’ initial acceptance or rejection of evolution and of various tenets of evolution does not strongly influence achievement. In other words, students can succeed in an evolution course even if they enter the course rejecting its content. However, acceptance of evolution on the post-course survey positively correlates with higher final grades for each semester, although the explanatory power of this association is low. Combining these results, we suggest that students’ acceptance of evolution only slightly affects their achievement. We were disappointed to find that students’ acceptance of evolution sometimes changed without an accompanying change in demonstrated knowledge; that is, attitudes sometimes shifted toward greater acceptance of evolution even in students eventually earning low final grades. These results confirm the reported disconnection between acceptance of evolution (attitude) and understanding of evolution (achievement) (Bishop & Anderson, 1990; Lord & Marino, 1993). Acceptance or rejection of evolution does not have to be a significant influence on students’ achievement in evolution or biology.

One explanation for why students’ acceptance of evolution, particularly pre-course acceptance, did not strongly predict achievement in our study is our redesigned pedagogy. Our course differs radically from the typical lecture-focused college science pedagogy, and fits the recommendations of Cobern (1994) and Smith (1994) for teaching evolution. Cobern (1994) stated that “Constructivism suggests that belief be allowed a legitimate role in the science classroom” (p. 588), because, in this framework, one’s ability to understand evolution relates to one’s attitude toward evolution. Smith (1994) emphasized that constructivism “does not imply that scientists (and science students) are free to construct any explanations they choose based on idiosyncratic and unsubstantiated beliefs” (p. 594). We encourage students in our course to examine beliefs, attitudes, and knowledge in light of both evidence for evolution and
consequences of accepting evolution, and we expect them to construct well-supported explanations for issues they encounter in the course. In our approach, we explicitly provide opportunities for students to generate and examine alternative solutions to problems, integrate different components of the course, and confront misconceptions through hands-on grappling with data (for examples see Flammer et al. [2004] and Nelson [2000]), and we aim to reduce religious conflict with evolutionary principles without sacrificing scientific rigor (Nelson, 2000). In addition, we make no judgments regarding the veracity or importance of religious beliefs, instead allowing students to examine their beliefs individually. This strategy is consistent with the recommendations of Dagher & BouJaoude (1997). Previous experience suggests that these departures from the normal format of an evolution course result in greater learning, although we have not tested this hypothesis or the question of which specific interventions we use affect students’ learning and acceptance of evolution. However, similar interventions have been shown to be successful in enhancing students’ learning of evolution (Jensen & Finley, 1995; Scharmann, 1990), so we assume that our approaches would yield similar results if examined individually. Therefore, we suggest that our redesigned pedagogy positively affects students’ acceptance of evolution and reduces or eliminates the influence of students’ religious beliefs or prior acceptance of evolution on achievement. Increased use of such strategies should further reduce the influence of overall attitude on achievement we have reported herein (e.g., the small but significant effect of post-course attitudes on performance).

This research demonstrates that students’ initial acceptance of evolution does not have to influence their subsequent learning of evolution. In contrast to McKeachie et al. (2002), we believe that understanding evolution is more important than accepting evolution, and indeed that, ethically, we should ask students to strive for understanding prior to making decisions regarding acceptance of any theory. We believe students should be equipped to make reasonable, scientifically based decisions about evolutionary issues of personal interest (what medicine should one choose, what impacts will certain environmental proposals probably have, etc.). Regardless of individual attitudes, we expect that students who understand evolutionary principles often will make more appropriate choices in biologically questionable situations than those who accept evolution but do not understand it. Understanding can be achieved despite a negative attitude toward evolution.

Other factors influence achievement in college science classrooms, particularly prior knowledge. Lawson (1983) found that prior knowledge was second only to acceptance of evolution in predicting achievement when both prior knowledge and achievement were measured using the same instrument. We are extending the study reported here with the Conceptual Inventory of Natural Selection (CINS) (Anderson, Fisher, & Norman, 2002) to examine the influence of prior knowledge on learning evolution, and look forward to other researchers using this tool to examine different curricular strategies and questions similar to those we have addressed. Lawson (1983) stated that instructors must know if students lack essential prior declarative knowledge; the CINS and tools from the forthcoming Bioliteracy project (Klymkowsky, Garvin-Doxas, & Zeilik, 2003) will provide instructors with standardized devices for quantifying prior knowledge, similar to those available for physics and astronomy (e.g., Hestenes, Wells, & Swackhammer, 1992; Hufnagel, 2002, respectively).

Evolution represents one of the most socially controversial topics in the college science curriculum. Students may come to courses containing evolution with negative attitudes toward the theory, and instructors may believe that such attitudes will be detrimental to learning. Yet initial negative attitudes toward evolution, particularly rejecting evolution, need not automatically lower achievement. We encourage instructors teaching evolution and other controversial science topics to address students’ concerns and prior attitudes in a constructive and empathetic
manner (Alters & Nelson, 2002; Cobern, 1994; Dagher & BouJaoude, 1997, Nelson, 2000). Strategies that accomplish such treatment of evolution have been described and in the many sources available to evolution educators (e.g., Alters & Alters, 2001; Alters & Nelson, 2002; Bybee, 2003; Nelson, 2000; Olson, 2004; UC Berkeley’s Understanding Evolution online exhibit [http://evolution.berkeley.edu/]). Because evolution is so widely accepted in the science community, instructors can use evolution to demonstrate how scientists practice critical thinking and to encourage the development of critical thinking skills (particularly evaluating evidence) in students (Nelson, 2000). Because it is so argued over publicly, instructors can use evolution to demonstrate how science guides or is guided by society and that scientific decisions can have moral or ethical components. When students’ attitudes are treated respectfully and are addressed in a nonconfrontational manner, we assert that students’ prior attitudes are not a detriment to learning evolution.

Acknowledgments

The authors thank Deborah Hanuscin for assistance with data entry, and Kelly Polacek, Maxine Watson, John Staver, Larry Scharmann, and three anonymous reviewers for comments that greatly improved this manuscript.

Appendix

Evolution Attitudes Survey

Instructions: For the following statements, choose undecided if you neither agree nor disagree, or if you are unsure. The responses are abbreviated SA (strongly agree), A (agree), U (undecided), D (disagree), and SD (strongly disagree) (record all responses on the scantron form provided)

<table>
<thead>
<tr>
<th>Statement</th>
<th>SA</th>
<th>A</th>
<th>U</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Over billions of years all plants and animals on Earth (including</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>humans) descended (evolved) from a common ancestor (e.g., a one-celled</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>organism).</td>
<td>A*</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
</tr>
<tr>
<td>2. A supreme being (e.g., God) created humans pretty much in their</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>present form; humans did not evolve from other forms of life (e.g.,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fish and/or reptiles).</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E*</td>
</tr>
<tr>
<td>3. There is no real evidence that humans evolved from other animals.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Scientists who believe in evolution do so mainly because they want</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>to, not because of any evidence.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E*</td>
</tr>
<tr>
<td>5. There is scientific evidence supporting that humans were</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>supernaturally created.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E*</td>
</tr>
<tr>
<td>6. There is fossil evidence supporting that animals, including humans,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>did not evolve.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E*</td>
</tr>
<tr>
<td>7. There is no fossil evidence supporting that humans and apes evolved</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>from a common ancestor.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E*</td>
</tr>
<tr>
<td>8. The methods used to determine the age of fossils and rocks are not</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>accurate.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E*</td>
</tr>
<tr>
<td>9. It is statistically impossible that life arose by chance.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. The Earth is not old enough for evolution to have taken place.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Mutations are never beneficial to animals.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. The Second Law of Thermodynamics shows that evolution could</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>not have happened.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E*</td>
</tr>
</tbody>
</table>

*Note. Asterisks indicate the evolutionarily consistent response.
References


SPSS, Inc. (2002). SPSS Base 11.5 user’s guide. Chicago: SPSS.

