Scientists and educators generally view “intelligent design” (ID) theory as the latest initiative by creationists to force the teaching of creationism alongside evolution in schools (Alters and Nelson 2002, Moore 2003, Alberts and Labov 2004, Cracraft 2004). ID posits an undefined “designer” to explain the appearance of putatively “irreducibly complex” biological structures and biochemical pathways. Because they claim the designer need not be considered a traditional deity, ID advocates assert that the teaching of ID does not violate the establishment clause of the First Amendment to the US Constitution. Meanwhile, creationists and social conservatives are attempting to lay the legal foundation to survive an eventual court challenge to that interpretation (see, e.g., Beckwith 2003).

Proponents of ID have made initial headway toward ID’s inclusion in the K–12 science curricula in numerous states by emphasizing the provisional nature of science. Such arguments generally assert that evolution “hasn’t been proven,” and often call for “fairness,” “equal time,” and “teaching the controversy” (Moore 2002, Bishop 2003). These arguments often resonate with the lay public and with school boards (Bishop 2003). As a result, state standards continue to be threatened with mandates to include ID in K–12 school curricula, and at least one school district has enacted such a requirement.

Even before recent widespread reporting about ID-related controversies, polling data showed that the US public had little understanding or acceptance of evolution. In 1982, 45 percent of Americans agreed with the statement, “God created man pretty much in his present form at one time within the last 10,000 years.” In 1997, 44 percent agreed with the statement. In a poll conducted in late 2004, 55 percent agreed with the statement, “God created human beings in their present form” (NYT/CBS 2004). During the time period 1982–2004, the percentage of survey participants with less than a high school education declined from 26 percent to 8 percent, while the percentage with some exposure to college rose from 35 percent to 59 percent (Bishop 1998, NYT/CBS 2004).

Since before the advent of “creation science,” the previous attempt by creationists to force the teaching of creationism in schools, science educators have been engaged in research on effective evolution pedagogy. In response to the need for more effective evolution education, several national organizations, including the National Academies and the National Center for Science Education, have produced books and pamphlets aimed at providing the general public, as well as educators, with information about evolution education (Alberts and Labov 2004). In general, advice to educators comes in two forms: educators are advised to provide students

Keywords: undergraduate, evolution, creationism, prior learning, critical thinking
with ample evidence supporting evolution, and educators are encouraged to use modern pedagogy (Alters and Nelson 2002, Alberts and Labov 2004). Alters and Nelson (2002) also propose several research questions, including the exploration of which student misconceptions are most influential and how to help students overcome them, of how to elicit higher levels of critical thinking in science classes, and of how much intervention is necessary to help students progress in their understanding of evolution.

The importance of prior learning
As a result of these efforts, information on effective pedagogy is becoming more accessible to science faculty, and research on pedagogy is becoming an accepted pursuit outside of colleges of education. One key pedagogical insight is that students arrive in classrooms with deeply held (if sometimes erroneous) ideas based on their prior learning about various topics (Bransford et al. 2003). Unless students are engaged at the level of their initial understanding and helped to come to terms with the new information, they often simply memorize the new information for the duration of the class (or until the next test) and then go back to their old way of thinking. In other words, students must "unlearn" before they can learn. Even if their prior learning is correct but shallow, it is necessary for students to be able to connect the new information with the old, or the new information is at risk of failing to be incorporated in the student's worldview (Bransford et al. 2003).

Writing specifically about evolution education, Scharmann (1990) noted that "the factual content taught is potentially less important than the development of learner attitudes regarding biology and the application of biological concepts on both a personal and social level."

Cognitive development. Perry's (1970) scheme of cognitive growth is another important contribution to the understanding of effective pedagogy. Nelson (1999) provides an excellent description of Perry's four cognitive modes, through which learners progress as their thinking becomes more sophisticated. The Perry mode in which most students enter college is dualism. Dualists view the world in terms of black/white or right/wrong. Students find this mode comforting, and some dualists may even be attracted to science because they imagine that it provides certainty. Learners in this mode often react with distress, even disillusionment or hostility, when confronted with uncertainty. In order to progress to the next phase, learners need to accept that uncertainty is real and unavoidable. This realization leads them to the next mode, called multiplicity. Most college graduates have multiplicity as their most highly developed approach to complex problems (King and Kitchner 1994, Nelson 1999). Multiplicity is only a slight improvement over dualism, however: in this mode, learners either rely on authority figures to shape their views or, absent acceptable external opinion, view all positions as equally valid (Nelson 1999). When confronted with new or challenging situations, students may temporarily regress by one or more Perry stages, and students may occupy different Perry modes for different topics at the same time.

These observations about how people learn, combined with the evolution–creationism duality and the assertions of ID supporters that evolution and ID are equally valid approaches to the same issues, clearly have enormous implications for biology education. In order for learners to arrive at mature views of the role of evolution in biology and other fields, they must be helped from dualism, through multiplicity, and through Perry’s next two modes, contextual relativism and commitment. Students in the contextual relativism mode are able to form their own considered opinions but are unwilling to defend them, and thus often give answers they think their teachers want to hear. In Perry's final mode, commitment, students are willing to defend their own considered opinions. Transitions from dualism or multiplicity and through contextual relativism and beyond are nontrivial, as evidenced by the continued high level of public confusion about evolution, even among college graduates (Bishop 1998). Indeed, one could argue that the evidence suggests most high school graduates, and even most college graduates, are cognitively unprepared to think effectively about evolution.

Engaging prior learning. The prior learning of most American college students includes creationism, so it is reasonable to consider ways to connect new college-level information to students’ earlier understanding. One way to attempt this might be to explicitly include biblical or other creation stories in an introductory biology course, as was done by Matthews (2001). Given the necessity of engaging prior learning, this or a similar approach is arguably pedagogically sound, but such approaches are controversial. Perhaps because the approach is so controversial, Matthews’s (2001) is the only published report on any strategy aimed at engaging prior creationist learning in college biology education.

Here I describe another approach to engaging prior learning, in which students read and discussed an ID text in parallel with a critique of the book and a well-known defense of evolution, in the context of a biology class that included deliberate support for the learners’ transitions through Perry’s modes. Support for Perry transitions included information about the history and philosophy of science, rhetoric, modern cosmology, the role of uncertainty in science, and the value of inductive reasoning, and required a more interdisciplinary approach than is traditional in introductory biology classes.

In addition to the deliberate engagement of students’ prior learning with respect to creationism, students were presented with significant information about the nature of science (NOS). McComas and colleagues (1998) and Nelson and colleagues (1998), among others, have noted that addressing information about NOS rather than simply factual recall of content in science classes helps students toward a fuller understanding of science.

Some of the topics involved in the intervention described here are covered in the first chapter of at least one evolution textbook intended for advanced undergraduates (Strick-
berger 2000). The first chapter of most introductory biology textbooks is typically devoted to an overview of the “unity and diversity of life,” the central role of evolution, and the process of science, with a focus on the hypothetico-deductive method (cf. Campbell and Reece 2002, Purves et al. 2002, Raven and Johnson 2002). McComas (1998) observes that the presentation of NOS in many science textbooks is limited and, as in the case of the hypothetico-deductive method, sometimes erroneous. McComas lists 14 “myths” relating to the presentation of NOS in textbooks, but these could just as easily be called “icons” (McComas 1998, cf. Wells 2002).

Course composition
In the fall quarter of 2003, three different instructors at Central Washington University (CWU) taught four sections (A, B, C, and D) of Biology 110, the first course in the introductory biology sequence for majors. The university registrar’s office randomly assigned students to the four sections. While the instructors’ approaches varied, the students enrolled in the sections were generally similar in terms of gender, amount of college experience, and college grade point average; the sections contained similar numbers of students (about 25). Sections A and B were taught by the same instructor using the same approach in both, and are treated as replicates here. Sections C and D were taught by different instructors using nearly identical syllabi, and are also treated as replicates. Table 1 summarizes similarities and differences in materials, organization, and students in each of the four sections.

Survey of student attitudes. At the end of the term, students in all four sections were invited to participate in an optional, anonymous survey aimed at gauging their attitudes and prior learning with respect to creationism. The survey was introduced using a consent script read by a CWU Biology Department staff person who was not associated with any of the sections. None of the instructors was in the room when the survey was administered, and the survey instrument and consent script were approved by the CWU Human Subjects Review Board.

The creation–evolution continuum. In the survey, students were offered the choice of six descriptions of attitudes toward creationism and evolution, based generally on Nelson’s (1986) creation–evolution continuum. The choices ranged from highly nonrationalist to highly rationalist (as used here, the term “rationalism” means the rejection of supernatural explanations for natural phenomena). The choices were described to the students as follows:

- Christian literalist (CL): The Bible literally describes history; God created the world 6000–10,000 years ago, just as we see it today, in 6 days.

- Young-Earth creationist (YE): The Earth is 6000–10,000 years old; God created life, including humans—Eve from Adam’s rib—in 6 days; some evolution may have happened, but only at the family level or below.

- Progressive creationist/intelligent design (PC/ID): The universe is about 15 billion years old; the major taxa were created by an intelligent designer, possibly just before each appears in the fossil record; evolution commonly occurs.

- Theistic evolutionist (TE): Evolution is God’s way of creating life; once the universe was formed, God generally took a hands-off approach.

- Nontheistic evolutionist (NTE): Maybe God has been involved, maybe not; science can and should explore natural explanations, separate from religious beliefs.

- Atheistic evolutionist (AE): The supernatural does not exist; philosophical materialism tells us God does not exist; the origin and evolution of the universe was and is entirely natural.

Students were asked to recall their position along the scale at the time when they entered the class and to identify their position after the class, and were also asked whether their views had changed to any degree over the course of the class. In addition, students were asked about their prior learning regarding creationism and evolution. This is the only time students were surveyed regarding this matter. This study was designed on the basis of the assumption that students at the end of an 11-week class would have no trouble recalling their earlier views on these issues. There was also reason for concern that a pretest would have needlessly influenced student attitudes during the course. McKeachie and colleagues (2002) found that creationist-oriented students disproportionately dropped an introductory biology course that had included an evolution—creationism attitude assessment at the beginning of the term.

Section similarities and differences. Chapter coverage in the primary text (Campbell and Reece 2002), which was used in all sections, varied slightly depending on the instructors’ preferences but generally included at least part of five of the eight units of the book, including most of “The Chemistry of Life” (unit 1), parts of “The Cell” (unit 2), the classical genetics portion of “Genetics” (unit 3), most of “Mechanisms of Evolution” (unit 4), and part of “The Evolutionary History of Biological Diversity” (unit 5). All sections covered similar textbook material related to evolution, except that section C covered one more of the chapters in unit 5, and section D covered two more, than did sections A and B. Table 1 summarizes some similarities and differences between the sections.

None of the sections was taught entirely using a strictly traditional lecture–lab approach: all sections included weekly formal seminar discussions of additional readings. Seminar texts and seminar formats varied between the sections.
Seminar reading assignments. Sections A and B used The Blind Watchmaker (Dawkins 1996) and Icons of Evolution (Wells 2002) for seminar discussions. Icons of Evolution is an ID-oriented book; students also read Icons of Obfuscation (Tamzek 2004), an online rebuttal of Wells (2002). Readings from these books were discussed in seminars as follows: week 2, Dawkins, front matter and chapter 1; week 3, Dawkins, chapter 2; week 4, Wells, chapters 1 and 2; week 5, Dawkins, chapter 3; week 6, Wells, chapters 3 and 4; week 7, no seminar; week 8, Dawkins, chapter 4; week 9, Wells, chapters 11 and 12; weeks 10 and 11, no seminar. The Web page of the Discovery Institute, a leading ID-promoting organization, was made available via a link on the class Web page. Seminar discussions were generally conducted as outlined by Harnish (1995).

Sections C and D used as their seminar book The Red Queen (Ridley 1995), reading approximately one chapter a week. The seminar structure for sections C and D was different from that of sections A and B: before each seminar meeting, a group of two or three students was expected to prepare a brief quiz on the reading assignment. This group was also expected to lead the discussion. The quality of each group’s quizzes and discussions was graded.

Support for Perry transitions; engaging prior learning. In addition to the use of an ID book as a foil for an evolutionist book for seminar reading, sections A and B included deliberate support for Perry transitions and a focus on NOS. Some readings and other activities in sections A and B provided background to support lectures and discussions that replaced chapter 1 of Campbell and Reece (2002). For example, students were given access, via the class online syllabus, to Internet-based information about pre-Socratic philosophers, Aristotle, the recognition and avoidance of fallacious arguments, and modern cosmology. The pre-Socratics were introduced as the founders of rationalist inquiry. Several of Aristotle’s contributions to modern science were emphasized, including his acceptance of the inevitability of uncertainty, his recognition that different fields involve different inherent levels of uncertainty, and his use of inductive reasoning.

Connection to prior creationist learning included an assignment to write a reflection paper on nonrationalist explanations for the local natural landscape; the assignment explicitly asked students to ignore rationalist or scientific explanations. While emphasizing the varying levels of uncertainty involved, a variety of alternative cosmogonies were presented, along with the current scientific understanding of the origin of the universe, the origin of the elements, and the origin of life on Earth. During the discussion of alternative cosmogonies, students were shown The Creation (Gratz 1981), a short animated art film recounting the CL creation myth.

Statistical analysis of the results involved one-way analysis of variance (ANOVA) using yes-no contingency tables (yes = 1, no = 0) to test the significance of differences in prior learning and changes in creation–evolution attitudes between the four sections. In cases where ANOVA indicated the existence of statistically significant differences (that is, $p \leq 0.05$) between sections, the differences were further analyzed using chi-square analysis. Differences were examined both section by section (not shown) and after pooling of data from sections A–B and sections C–D.

Prior exposure to creationism. Of a total enrollment of 103 students, 66 (64 percent) completed the survey. Survey participation in the sections ranged between 63 percent and 78 percent, except in section D, where 43 percent of registered students participated.

Figure 1 illustrates student prior learning in each section. An average of 73 percent of Biology 110 students reported having been exposed to both evolution and creationism in their prior learning, with all sections except section D reporting roughly similar percentages. In section D, 90 percent of students reported both creationism and evolution as their prior

Table 1. Similarities and differences between materials, organization, students, and faculty in sections A, B, C, and D of Biology 110, the first course in an introductory biology sequence for majors.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Section A</th>
<th>Section B</th>
<th>Section C</th>
<th>Section D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading assignments (chapter numbers)</td>
<td>2–5, 7, 12–14, 22–24, 26 (12 total)</td>
<td>Same as section A</td>
<td>Same as section A, plus 1, 8, 15, 27 (16 total)</td>
<td>Same as section A, plus 8, 15, 27, 28 (16 total)</td>
</tr>
<tr>
<td>Supplemental texts</td>
<td>Dawkins 1996, Wells 2002, Web sites including Tamzek 2004</td>
<td>Same as section A</td>
<td>Ridley 1995</td>
<td>Same as section C</td>
</tr>
<tr>
<td>Typical weekly schedule</td>
<td>3 hours lecture, 1 hour seminar, 2 hours laboratory</td>
<td>Same as section A</td>
<td>Same as section A</td>
<td>Same as section A</td>
</tr>
<tr>
<td>Average student course GPA (A = 4.0)</td>
<td>3.06</td>
<td>3.22</td>
<td>2.64</td>
<td>3.35</td>
</tr>
<tr>
<td>Average student college GPA (A = 4.0)</td>
<td>3.03</td>
<td>2.98</td>
<td>2.97</td>
<td>3.02</td>
</tr>
<tr>
<td>Student gender (percentage female)</td>
<td>57</td>
<td>67</td>
<td>64</td>
<td>57</td>
</tr>
<tr>
<td>Instructor gender</td>
<td>Male</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
</tbody>
</table>

Note: Data shown are for all registered students. Not all students participated in the survey.

a. Reading assignments were from Campbell and Reece (2002). Some assignments included partial chapters.
learning. Only 5 percent of all Biology 110 students reported creationism as their only form of prior learning, while 15 percent reported evolution only, and 6 percent reported having been exposed only to origin stories other than evolution or Judeo-Christian creationism. One-way between-subjects ANOVA indicated that differences in prior learning between sections were not significant ($F = 0.8092, p = 0.494$).

**Changes in student attitudes**

Some students in each of the four sections reported having changed their attitude toward creationism and evolution at the end of the class. As shown in table 2, the most change was reported by students in pooled sections A and B, in which 61 percent of students (23 of 38) reported some change. The amount of change was nearly identical in each of the two sections: 59 percent (10 of 17) in section A and 62 percent (13 of 21) in section B. The average amount of change in pooled sections C and D was 21 percent (6 of 28). Students in sections C and D reported total changes of 28 percent and 10 percent, respectively. One-way between-subjects ANOVA indicated that differences between the four groups were significant ($F = 3.314, p = 0.028$). Figure 2 illustrates the degree of change in the pooled sections A–B and C–D. Chi-square analysis indicated that the total differences between A–B and C–D were significant at $p \leq 0.01$ ($\chi^2 = 10.632, df = 1$).

Figure 2 also illustrates the degree of attitude change among those students who reported that their attitudes changed, but by less than one CL–AE category. Twenty-nine percent of students in pooled sections A–B reported that their attitudes changed by less than one CL–AE category, compared with 14 percent of students in pooled sections C–D. These differences are significant at $p \leq 0.05$ ($\chi^2 = 4.591, df = 1$). Changes of one or more CL–AE category were 32 percent in sections A–B and 7 percent in sections C–D. These differences were significant at $p \leq 0.05$ ($\chi^2 = 4.591, df = 1$).

Figure 3 illustrates students’ attitudes toward evolution at the beginning and at the end of the course, and changes along the CL–AE spectrum. Sections A and B were the only sections in which any CL students changed their views: 67 percent (4 of 6) of the students who entered sections A and B as CL creationists changed their views to more rationalist views. None of the CL students in any of the other sections reported modifying their views. The number of YE creationists who changed their views in sections A and B (40 percent, or 4 of 10) was also greater than in section C (25 percent, or 1 of 4) or section D (0 of 1).

Among the 12 section A and section B students for whom direction of change could be distinguished, 9 students moved toward the rationalist end of the spectrum and 3 moved toward the nonrationalist end of the spectrum. None of the 5 students in the other sections whose direction of change could be determined moved toward the nonrationalist end of the spectrum. Students in sections A and B whose views became less rationalist included one who entered the class in the AE mode and left in the PC/ID mode (a three-unit change), and two who changed from TE to PC/ID (a one-unit change). Seven of the 9 students in sections A and B who reported changes in the rationalist direction reported changes of two or more units. The direction of change for the remaining 14 students who reported that their views had changed cannot be determined because they reported that their views had changed to some extent, but not enough to cause them to switch categories on the CL–AE spectrum.
Discussion
A majority (73 percent) of students in all sections reported prior learning that had included both creationism and evolution. There were no significant differences in prior learning between sections. Students had been randomly assigned to each section, and the composition of the sections, based on a variety of metrics, was quite similar. The sections were all structured similarly with respect to content and general classroom activities, but an effort was made to emphasize NOS, to support Perry mode transitions, and to engage the prior creationist learning of students in sections A and B.

Students in sections A and B reported an approximately twofold greater overall rate of change in attitude toward evolution and creationism relative to students in either of the other sections of Biology 110 in the fall quarter of 2003. This supports the hypothesis that in this case, engaging prior learning and addressing NOS while supporting student progress through Perry’s cognitive modes was an effective approach to evolution education.

Most of the change in sections A and B was among students on the less rationalist end of the spectrum, including 8 of the 15 self-reported preclass CL and YE creationists. In particular, the only CL students in any section to report that their views had changed were in pooled sections A–B. In section A, 50 percent of CL students (2 of 4) reported change; in section B, all CL students (2 of 2) reported change. These results belie the assumption that the attitudes of this group of students are extremely hard to change (Lawson and Worsnop

Table 2. Numbers and percentages of students in sections A, B, C, and D of a college-level introductory biology course who reported no change, less than one unit of change, or at least one unit of change in attitude concerning creationism and evolution, on a scale of nonrationalist to rationalist thought ranging from Christian literalist through atheistic evolutionist.

<table>
<thead>
<tr>
<th>Amount of reported change</th>
<th>Section A</th>
<th>Section B</th>
<th>Sections A–B</th>
<th>Section C</th>
<th>Section D</th>
<th>Sections C–D</th>
<th>All sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of students reporting no change (n)</td>
<td>41 (7)</td>
<td>38 (8)</td>
<td>39 (15)</td>
<td>72 (13)</td>
<td>90 (9)</td>
<td>76 (22)</td>
<td>56 (37)</td>
</tr>
<tr>
<td>Percentage of students reporting less than one unit change (n)</td>
<td>29 (5)</td>
<td>29 (6)</td>
<td>29 (11)</td>
<td>17 (3)</td>
<td>10 (1)</td>
<td>14 (4)</td>
<td>23 (15)</td>
</tr>
<tr>
<td>Percentage of students reporting at least one unit change (n)</td>
<td>29 (5)</td>
<td>33 (7)</td>
<td>32 (12)</td>
<td>11 (2)</td>
<td>0 (0)</td>
<td>7 (2)</td>
<td>21 (14)</td>
</tr>
</tbody>
</table>

Note: The units on the nonrationalist–rationalist scale are as follows: Christian literalist, young-Earth creationist, progressive creationist/intelligent design, theistic evolutionist, nontheistic evolutionist, atheistic evolutionist (Nelson 1986). Percentages may not total 100 because of rounding.
Students who changed their views could be said to have behaved as if they had entered Perry’s “commitment” stage: they were able to make and express their own informed judgment about evolution and creationism, even if their judgment disagreed with that of their earlier formal and informal teachers or that of their present instructor.

**Alternative explanations.** Although sections A and B were modified in an effort to help students toward a more carefully considered view of creationism and evolution, it is doubtful that the modifications were the cause of all of the change that was observed. For example, it is possible that the simple act of demonstrating respect and tolerance for nonrationalist views while teaching about evolution had the effect of allowing students to open their minds to new ideas. Section A contained more self-reported CL or YE creationists compared with other sections (53 percent in section A, 34 percent in section B, 33 percent in section C, and 8 percent in section D). This may have been an anomaly that resulted from some unrelated factor or factors, or may have resulted because these students felt more comfortable reporting their views honestly. Other studies have reported various proportions of creationist-oriented college students. Brem and colleagues (2003) found that 18 percent of students at a “major, public university in the Western United States” expressed creationist views. McKeachie and colleagues (2002) reported that 17 percent of students in an introductory biology course at a midwestern community college identified themselves as CL creationists. Harrold and Eve (1987) found that 28 percent of students from a Texas university and 19 percent of students from two California universities and one Connecticut university agreed with the statement that “God created man pretty much in his present form within the past 10,000 years or so.” Eve and Dunn (1990) reported that 25 percent of US high school life science teachers agreed with the same statement.

The data of McKeachie and colleagues (2002), while not couched in terms of the Perry model, indicate that “steadfast creationists” differ markedly from more rationalist students in measurements of test anxiety, intrinsic motivation, self-efficacy, and task value. In general, these students “memorized more and thought about ideas less.” These characteristics are consistent with Perry’s first two modes, dualism and multiplicity. McKeachie and colleagues (2002) found that a disproportionate number of students who did not accept evolution either dropped the class or otherwise declined to take the post-test.

**Section D.** Some aspects of section D are worth further consideration. Section D had the lowest rate of participation in the survey. This section contained the fewest students who reported preclass CL, YE, or PC/ID attitudes relative to the other sections discussed in this article, to nine other sections of Biology 110 surveyed over the course of three years (data not shown), or to published reports concerning student creationist attitudes (Harrold and Eve 1987, McKeachie et al. 2002, Brem et al. 2003). The low level of section D participation in the survey calls to mind McKeachie and colleagues’ (2002) observation that creationist students tend to avoid participating in surveys regarding evolutionist attitudes. Students in section D reported the least attitude change of any of the four sections discussed here or of any of the nine other sections that have been surveyed (data not shown). Yet this section covered the most evolution-oriented material as measured by textbook chapter coverage, and involved the greatest amount of obvious emphasis on evidence for evolution of any of the four sections discussed in this article. For example, the words “evolution” or “evolutionary” appeared eight times in the section D syllabus, including in the stated course title, “Origins and Evolution” (the official title of the course is “Basic Biology”). The words “evolution” or “evolutionary” appear only twice in syllabi of sections A, B, and C. Although the sample size is small, it would be consistent with the pedagogical concepts described in this article and with the Perry scheme of cognitive development if section D students felt that they had been placed on notice from the first day of class that they were expected to display an evolutionist mind-set. It is also worth considering that some section D students may have felt inhibited from participating in the survey.

The presentation in sections A and B of the philosophical foundations of science is consistent with suggestions to include the history of knowledge as an educational tool (Nelson 1999). The approach to the history of knowledge in these sections was different from the one described by Jensen and Finley (1995), in that its emphasis was on the historical foundations of the nature of science: rationalism, the management of uncertainty, and inductive and deductive reasoning, among others. The fact that classical Greek philosophers were active during the time of many of the events described in the Old Testament may have been significant for some students.

As mentioned earlier, 73 percent of the students surveyed reported that their prior learning had included both creationism and evolution. It would be consistent with a typical first-year college student’s cognitive development if he or she expressed genuine, earnest confusion over the validity of both creationism and evolution. The results for pooled sections A–B suggest that acknowledging prior creationist learning, addressing student questions in a respectful, matter-of-fact way (either preemptively or as they arise), and presenting a strong foundation regarding the nature of science had a positive effect on the ability of students to think effectively about creationism and evolution.

Scientists and educators have strongly and consistently resisted ID advocates’ call to “teach the controversy.” The results described here for sections A and B suggest that it may be possible for even some YE and CL creationist students to distinguish rationalist explanations from nonrationalist ones, if they are provided with appropriate support. In contrast, the section D results suggest that presenting the validity of evolution as a foregone conclusion may do little to help such students approach a mature perspective.
Managing uncertainty. It can be stated with a low level of uncertainty that there were qualitative and quantitative differences in the amounts of creationist–evolutionist attitude change between students in sections A–B and sections C–D. There is a higher level of uncertainty concerning the cause or causes of these differences, which most likely include some combination of course content, factors relating specifically to the instructors or their approaches, and a variety of other possibilities. There is even greater uncertainty regarding whether the practices outlined here would have similar effects on student attitudes if applied by different faculty at different institutions. Indeed, from a formal, statistical point of view, the results presented here are not generalizable beyond this case study.

It can also be stated with a low level of uncertainty that current approaches to science education are not very effective in helping typical students to think effectively about evolution and creationism. During the past 20 years, the number of US citizens with at least some college education has nearly doubled, while the fraction reporting nonrationalist beliefs regarding fundamental concepts of biology has held steady and concerns about overall science literacy have increased. Public interest in ID is becoming increasingly widespread, and is spreading beyond the United States. This situation presents a significant challenge: science education is notoriously focused on content and memorization, and introductory science classes for both prospective majors and likely nonmajors are typically large. The approaches outlined here may or may not be more broadly applicable, but they do involve specific attention to student cognitive development, critical thinking skills, and the use of nontraditional interdisciplinary material, in addition to the necessary discipline-specific content.

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