A History of Teaching Evolution in U. S. Schools: Insights from Teacher Surveys and Textbook Reviews

Paul J Wendel

Paper presented at the MidWestern Educational Research Association

Columbus, Ohio

October 11-14, 2006

A History of Teaching Evolution in U. S. Schools:
Insights from Teacher Surveys and Textbook Reviews

Abstract

The presentation of evolution in the high school classroom is possibly the single most controversial educational issue of the 20th and 21st centuries. Despite the strong feelings evoked by evolutionary education, it is not easy to determine what actually happens behind closed classroom doors. In this paper, I track the history of evolutionary education through an analysis of teacher surveys and textbook studies. Both indicate a gradual increase in evolutionary education throughout the 20th century. To a lesser extent, creationist education has also increased during this time. I finish with a discussion of the assumptions and implications of this study and those upon which it is based.

Introduction

Along with sex education and school-sanctioned prayer, evolutionary theory is one of the most contested curricular issues faced by educators and legislators. Evolutionary theory has motivated numerous public controversies, legislative battles, and judicial trials from the Scopes trial of 1925 to the Dover, PA trial of 2005 ("Kitzmiller v. Dover Schools District," 2005). Yet what have high school biology teachers actually done in the midst of all of this controversy? Have they quietly taught evolution, quietly ignored evolution, or some combination of the two?

Although this question is of interest to both pro- and anti-evolutionary interest groups, it is not easily answered. Education is a public service and most teachers are public employees, but teaching is generally practiced behind closed classroom doors. Therefore determination of what happens in U. S. classrooms is difficult, and it must be inferred from indirect evidence. This difficulty is compounded in the case of evolutionary theory, in which teachers typically wish to avoid involvement in public controversy. However, teacher surveys and biology textbook studies can serve as windows into classroom practices.

In this paper, I review teacher surveys conducted between 1942 and 2004, identifying a general positive trend in teacher-reported evolutionary content. Next, I examine several reviews of textbooks published between 1900 and 1990. Again, I demonstrate an uneven but noticeable increase in evolutionary content over this time. I finish with a discussion of the assumptions and implications of such studies as well as my own assumptions in analyzing the literature in this way.

Surveys

Surveys of biology teachers provide the most direct evidence that teachers are presenting or avoiding evolution, yet they have limitations. First, we will see that most surveys of biology teachers are restricted to a specific geographic area, e. g. a state or a municipality. Second, some respondents answer successive survey items in an apparently self-contradictory way, rendering interpretation difficult. Hence determination of the validity of a survey instrument is a matter of judgment as much as computation. Third, survey return rates tend to be low. In the studies presented below, return rates range from as low as 20% to a high of 80%. Since it is generally unknown whether individuals who complete surveys are representative of the population (see, e. g., Schiltz, 1988; West, 1991), low survey return rates introduce questions of sample bias. Despite all of these difficulties, teacher surveys offer a means of hearing the teachers' voices with respect to the teaching of evolution. Consequently, they are a valuable source of evidence regarding the extent to which evolution has been taught in U. S. secondary schools.

Although numerous surveys regarding secondary-level evolutionary instruction have been conducted since1980, I have been able to identify only a few earlier studies. Fortunately, the first of these was a large-scale nationwide survey of biology teachers conducted by the Union of American Biological Studies under the leadership of Oscar Riddle (Riddle, 1941; Riddle et al., 1942). In the winter of 1939-1940, researchers mailed nearly 16,000 copies of a questionnaire to high school biology teachers. Over 13,000 of these teachers were on a mailing list from a biological supply house and the remainder were taken from the membership list of the National Association of Biology Teachers. Of the original 16,000 surveys, 3,186 (20%) were completed and returned.

Of the 96.6% of respondents who answered the questions on teaching evolution, 53.7% indicated that they taught evolution as a fact or taught it as the principle underlying plant, animal, and human origin. However, about 60 of those who indicated that they taught evolution as a fact also indicated that they excluded humans from evolutionary theory, reducing the percentage of those who taught evolution in an unqualified manner to about 50%. The data also indicates that teachers from parochial schools and/or southern schools were less likely to teach evolution. Riddle et. al. further argued that because teachers from parochial schools and southern areas were under-represented in the survey, their 50% figure was probably inflated:

> When these several facts and indications are considered it may be concluded that evidence obtained from this study indicates that the principle of evolution is now taught in *notably less that half* of the high schools of the United States (Riddle et al., 1942, p. 71, emphasis original).

Despite this negative conclusion, only 0.9% of the respondents indicated that they openly denied evolution in the classroom, 3.8% indicated that they entirely omitted evolution in the classroom, and 14.4% indicated that they teach evolution only by inference. Therefore a total of 19.1% of those who answered this question reported that they avoided or denied the theory of evolution in their biology courses.

Although our second early study is of a much smaller scale than the Riddle et. al. survey, it reaches similar conclusions. In the late 1940s, Estelle Laba and Eugene Gross mailed surveys to all of the 64 biology teachers in Essex County, NJ (Laba & Gross, 1950). Twenty-nine of these (45%) responded. Eight of these 29 teachers (28%) reported that they did not discuss evolution as a regular part of their courses, while 72% reported that they include evolution. Eighteen of the 21 teachers who presented evolution (62% of all teachers surveyed) included human evolution in their courses.

The U. S. Federal Security Agency's Office of Education conducted a second nationwide study of secondary biology teaching in the 1949-1950 school year (Martin, 1952). The sample included 1,072 public high schools, of which 786 usable surveys (73.3%) were returned. Although this survey included no specific questions regarding the teaching of evolution, 540 schools (68.7%) responded to the question: "List the important areas such as health, conservation, heredity, classification, etc., on which most emphasis is placed in the course, and estimate the number of days of instruction devoted to each." Seventy-five of the 540 schools (13.9%) who answered the question wrote some variant of "modification of species" (Martin, 1952, p. 21). Note that the format of this survey is different from all of the of the other surveys--instead of choosing items from a checklist, the respondents generate answers in a "fill-in-the-blank" style. Also, the survey included no specific questions about teaching evolution. Consequently, I will not be able to meaningfully compare these results to the results of the other surveys.

Unfortunately, no relevant surveys were conducted between 1950 and 1981, when William Ellis surveyed teachers in Kentucky, Indiana, and Tennessee (Ellis, 1983, 1986). In 1981, Ellis mailed surveys to all of the nearly 800 high school biology teachers in Kentucky, of which 44% were returned. He found that 59.6% of the teachers placed moderate or strong emphasis on evolution in their biology classes, while 40.3% placed little or no emphasis on evolution. Because the latter figure was lower than he expected, Ellis added parenthetical descriptors to three survey items (e. g. "No emphasis: I never initiate and avoid the use of the theory of evolution whenever possible," and "Little emphasis: I rarely mention evolution except in response to student inquiry or a general textbook assignment") and sent the revised 3-question survey to a 20% sub-sample of respondents. He found that only 23.6% of the sub-sample

reported little or no emphasis on evolution, and 73.5% reported moderate or strong emphasis on evolution. Thus contrary to Ellis's expectations, the parenthetical descriptors tended to increase the teachers' reported emphasis on evolution in their classrooms.

In 1982, Ellis mailed the complete survey (with the parenthetical annotations to the three survey items mentioned above) to a 25% random sample of Indiana biology teachers and a 20% random sample of Tennessee biology teachers. He received a response rate of 50% in Indiana and 53% in Tennessee. The results were similar to those in Kentucky: 77.2% of Indiana teachers and 67.9% of Tennessee teachers reported a moderate or strong emphasis on evolution.

Four years later, Michael Zimmerman surveyed Ohio biology teachers (Zimmerman, 1987). In February of 1986, Zimmerman mailed three copies of a 19-item questionnaire to each of the 1,013 accredited high schools in Ohio. He received responses from 296 high schools (29.2%) representing 404 biology teachers and 472 courses. Zimmerman found that 87.7% of the courses included evolution and that there was no significant difference between public and private schools. Zimmerman also found that 18.9% of the public school courses included a section on creationism, as did 39.7% of courses in private sectarian schools and 66.7% of the courses in private nonsectarian schools. After subtracting those who teach creationism in an unfavorable light, Zimmerman found that 15.3% of Ohio biology courses contained a creationism component which treated the topic favorably.

Robert Tatina conducted a similar study in South Dakota (Tatina, 1989). In January of 1988, he mailed numerous copies of a 23-item questionnaire (based on Zimmerman's) to a biology teacher at each of South Dakota's 200 high schools. He received responses from 93 high schools (46.5%) representing 99 biology teachers and 129 biology courses. Tatina found that 72.7% of the high school biology courses included evolution and that there was no significant

difference between public and private schools. Tatina found that 16.3% of the South Dakota courses included a section on creationism.

Ganga Shankar and Gerald Skoog surveyed a random sample of the 2,238 Texas biology teachers listed in the 1988 NSTA directory (Shankar & Skoog, 1993). Of the 634 surveys that were successfully mailed, 307 (48%) were completed and returned. Shankar and Skoog found that 87% of Texas biology teachers included evolution in their courses, although only 31% of the teachers devoted more than 30 minutes of class time to human evolution. Fifty-six percent of Texas biology teachers presented creationism, although no more than half of these (28% of the total) presented creationism in a positive light.

Shankar and Skoog's finding that a fairly high percentage (87%) of Texas biology teachers included evolution in their courses is roughly confirmed by Kenneth Feder's 1985 survey of Texas college students (Feder, 1995). Of the 443 students surveyed (409 at the University of Texas at Arlington and 34 at Texas Christian University), 75.6% reported that they were taught evolution in high school, although 43.8% of these (33.1% of the total) reported that creationism was taught along with evolution.

Donald Aguillard surveyed Louisiana public high school biology teachers in the 1997-1998 school year (Aguillard, 1999). Sixty-four percent of the 605 mailed surveys were completed. Aquillard found that 77% of survey respondents reported moderate or strong emphasis on evolution instruction, and 23% reported little or no emphasis on evolution. Aguillard found that 14% of Louisiana biology teachers indicated moderate to strong emphasis on creationism instruction, 69% reported little or no emphasis, and 17% reported a counter-creationist emphasis. In all, Aguillard found that 15 to 20% of Louisiana high school biology teachers presented creationism favorably.

Jeffrey Weld and Jill McNew randomly selected 462 of the 840 public high school life science teachers in Oklahoma (Weld & McNew, 1999). Of these, 224 surveys were completed (48.8%), representing 26.7% of all life science teachers in Oklahoma. They found that about two thirds of Oklahoma life science teachers placed moderate or strong emphasis on evolution, while nearly one third placed little, no, or counter emphasis on evolution. They also found that about one fourth of Oklahoma public life science teachers placed moderate or strong emphasis on creationism.

Of the 989 surveys which Michael Rutledge and Melissa Mitchell mailed to Indiana public high school biology teachers, 552 (56%) were completed (Rutledge & Mitchell, 2002). Of these, 66% reported that they allocate four or more days to evolutionary instruction. Seven percent of the total report that they avoid evolutionary theory and 36% report that they briefly mention evolutionary theory.

In his survey of 80 randomly selected Oregon public high schools, Randy Trani's response rate was 66% (Trani, 2004). He found that evolution plays a major role in Oregon biology courses and creationism plays a minor role. He found that 16% of Oregon biology teachers do not present evolution.

In 1994, Karen Kraemer surveyed 203 randomly selected public school biology teachers in Minnesota (R. Moore & Kraemer, 2005). Ninety-one (45%) of the surveys were returned. In 2003, Kraemer and Randy Moore repeated the survey. They randomly selected a sample of 132 of the Minnesota biology teachers who had attended the 2003 National Science Teachers Convention in Minneapolis and the 2003 Tenth Annual Biology-Life Sciences Teachers Conference. Of these, 107 teachers returned the survey (82%). As Moore and Kraemer note, Weld & McNew(1999) found that members of professional science teacher organization are

more likely to accept and teach evolution. Consequently, it is not surprising that Moore & Kraemer found that in the 1995 survey of Minnesota biology teachers, 69% of biology teachers reported that they included evolution in their courses and 31% reported that they excluded evolution, while in the 2003 survey of Minnesota biology teachers who are members of professional organizations, 88% reported that they included evolution in their courses and 12% reported that they excluded evolution from their courses. Given the difference between the survey populations, neither of these results in surprising. Yet despite the population difference, 16% of biology teachers reported that creationism was part of their biology curriculum in 1995, whereas this figure had grown to 20% in 2003. Unfortunately, Moore and Kraemer's survey does not reveal whether creationism was presented in a positive, negative, or neutral manner.

Consulting Table I, a trend can be observed. Beginning with Riddle's 1939-1940 survey, we see a nationwide trend toward a greater emphasis on evolution in high school biology courses, although the percentage avoiding evolution has held steady at about 20%. Yet we also see a sharp rise in the percentage of teachers who present creationism. Unfortunately, few of the studies distinguished between teachers who presented creationism favorably and those who presented it unfavorably. Yet the three studies which made this distinction (Aguillard, Zimmerman, and Shankar & Skoog) indicate that about half of teachers who present creationism do so favorably. If this result is generalized, the percentage of teachers presenting creationism rises from about 1% in 1940 to about 10% today.

Consulting Table II, we can see that these national trends are approximately reproduced regionally. In the South, the percentage of teachers presenting evolution increased from about 40% in 1940 to an average of about 73% between 1981 and 1998. In the Central states, this percentage increased from about 64% in 1940 to an average of 75% between 1982-2003. In the

Western states, the percentage increased from about 74% in 1940 to an average of 80% between 1993-2004. Thus since 1940, the strongest gains in evolutionary teaching have occurred in the South, but other regions have experienced significant gains in evolutionary teaching as well.

Table I: Evolutionary Teaching Survey Results

Region	Author(s)	Year of Survey	Percent Teaching Evolution	Percent Avoiding Evolution	Percent Denying Evolution/ Teaching Creationism
U. S.	Riddle et. al.	1939-40	53.7	18.2	0.9
Southern U. S.	Riddle et. al.	1939-40	40.1	29.7	1.3
Central U. S.	Riddle et. al.	1939-40	63.9	18.9	0.6
Western U. S.	Riddle et. al.	1939-40	73.5	14.9	1.0
Essex Co, NJ	Laba & Gross	~1950	72	28	------
Kentucky	Ellis	1981	59.6/73.5	40.3/23.6	------
Tennessee	Ellis	1982	67.9	32.1	------
Indiana	Ellis	1982	77.2	22.8	------
Ohio	Zimmerman	1986	87.7	12.3	21.8 (15.3 favorably)
South Dakota	Tatina	1988	72.9	27.1	16.3
Texas	Shankar & Skoog	~1993	87	------	56 (< 28 favorably)
Minnesota	(Moore &) Kraemer	1995	69	31	16
Louisiana	Aguillard	1997-98	77	------	33 (15-20 favorably)
Oklahoma	Weld & McNew	~1999	~70	------	------
Indiana	Rutledge & Mitchell	~2002	58	7	~25
Minnesota	Moore & Kraemer	2003	88	12	20
Oregon	Trani	~2004	84	16	------

Table II:Evolutionary Teaching Survey Results by Region

Region	Author(s)	Year of Survey	Percent Teaching Evolution	Percent Avoiding Evolution	Percent Denying Evolution/ Teaching Creationism
Southern U. S.	**Riddle et. al.**	**1939-40**	**40.1**	**29.7**	**1.3**
Kentucky	Ellis	1981	59.6/73.5	40.3/23.6	------
Tennessee	Ellis	1982	67.9	32.1	------
Louisiana	Aguillard	1997-98	77	------	33 (15-20 favorably)
Mean		**1981-98**	**73**	**28**	
Central U. S.	**Riddle et. al.**	**1939-40**	**63.9**	**18.9**	**0.6**
Indiana	Ellis	1982	77.2	22.8	------
Ohio	Zimmerman	1986	87.7	12.3	21.8 (15.3 favorably)
South Dakota	Tatina	1988	72.9	27.1	16.3
Minnesota	(Moore &) Kraemer	1995	69	31	16
Indiana	Rutledge & Mitchell	~2002	58	7	~25
Minnesota	Moore & Kraemer	2003	88	12	20
Mean		**1982-2003**	**75**	**19**	**20**
Western U. S.	**Riddle et. al.**	**1939-40**	**73.5**	**14.9**	**1.0**
Texas	Shankar & Skoog	~1993	87	------	56 (< 28 favorably)
Oklahoma	Weld & McNew	~1999	~70	------	------
Oregon	Trani	~2004	84	16	------
Mean		**1993-2004**	**80**		
U. S.	**Riddle et. al.**	**1939-40**	**53.7**	**18.2**	**0.8**
Mean		1981-2004	76	20	

Textbooks

The nature of high school biology teaching encourages reliance on the textbook. As Arnold Grobman noted in 1969:

> Unlike his collegiate colleague, the typical high school [biology] teacher has an assigned work load so overwhelming and time-consuming that, regardless of his honest intentions, he usually must depend very heavily upon textbooks for determining the content of his courses. Theoretically he is able to prescribe the content of his courses with considerable freedom but in actual practice his teaching is influenced largely by the textbooks he uses (Grobman, 1969, p. 300).

Surveys bear out a strong connection between biology classroom content and textbook content. For example, in a 1977 nationwide survey, Weis (1978, p. 89) found that 92% of high school science courses used at least one text book. In the nationwide survey conducted by the U. S. Federal Security Agency Office of Education in 1949-1950, 93.6% of schools were found to use a basic textbook in the general biology course (Martin, 1952, p. 32). The same study revealed that sixty-six percent of all biology courses were organized around the textbook (Martin, 1952, p. 20). Shankar and Skoog were able to establish a strong connection between evolutionary content in textbooks and evolutionary content in the classroom, noting that 24%, 50%, and 26% of teachers present respectively more, the same, and less evolutionary content than presented in the textbook (Shankar & Skoog, 1993, p. 226).

Assuming that the biology textbook largely correlates to classroom content, textbook studies provide a second window into the biology classroom. Although textbook evidence is less direct than survey evidence, textbooks provide a lasting record, enabling the comparative study of biology teaching across numerous decades. However, I should note that in the early decades of the 20th century, the general biology course gradually replaced the separate botany, zoology, and physiology courses which had previously dominated secondary school (see, e. g. DeBoer,

1991, p. 93). Consequently, studies which consider only general biology textbooks will miss those schools which had not yet introduced a general biology course. Also, as John Cretzinger noted in his study of 54 biological textbooks published between 1800 and 1933:

> The theory of Evolution was finally formulated by Charles Darwin in 1858, but it . . . was destined to have little acceptance in secondary school books until after 1900 when the convincing evidence of Wallace and Haeckel made that theory acceptable as on the secondary science level (Cretzinger, 1941, p. 312).

Robert Hellman (1968) generally confirmed this delay in the introduction of the theory of evolution at the secondary level, finding the first references to evolution in texts published in 1888 and 1890. Consequently, I will restrict my review to studies of textbooks published after 1900.

Oscar Richards conducted one of the earliest studies of biology textbooks (Richards, 1923). Using a survey, Richards identified the six most commonly used textbooks in the U. S. published between 1911 and 1919, representing 75% of all U. S. schools. Estimating content through word count, he found that 12,217 of the 728,533 words in the six texts (1.68%) was devoted to evolution. However, 7,867 of these (64%) were attributable to two chapters on evolution in a single text (Linville and Kelley's *General Zoology*, 1919).

In a similar study, Knapp (Knapp, 1933, p. 59) identified the five most commonly used textbooks between 1917-1927 (cited in Christy, 1936, pp. 280-281). According to Knapp, only one of these (Moon's *Biology for Beginners*, 1921) devoted more than 20 pages to evolution.

In a detailed study of 17 textbooks published between 1907 and 1935, Christy (1936) concludes that "[s]pace given to heredity and evolution has progressed from a negligible amount in early texts to the quite respectable average of about 8 percent for books of the last decade" (Christy, 1936, p. 278). Although Christy does not separate evolution from heredity, he notes a positive trend in the coverage of evolution after about 1925.

By contrast, Grabiner and Miller (1974) describe the opposite trend for the period following the 1925 Scopes trial. Grabiner and Miller note, as does Skoog (1979), that after the Scopes trial, many publishers removed the words "evolution" and "Darwin" from the indexes of their biology textbooks. They also noted that some publishers cut back on evolutionary content in post-1925 editions. Notable among these are the most widely used textbook of the 1930s, Lewis H. Mills' *Dynamic Biology* (1933), and various editions of Moon's *Biology for Beginners* (1933). However, first editions of three unequivocally evolutionary books were released shortly after 1925, most notably Alfred C. Kinsey's *Introduction to Biology* (1926). Undoubtedly this accounts for the fact that Christy found an increase in evolutionary content after 1925. Grabiner & Miller also report that the most popular book of the 1950s, Moon and Mann's *Biology: A Revision of Biology for Beginners* (1947) had scaled back the treatment of evolution found in Moon's (Truman Moon, 1921) pre-Scopes edition. Yet the second most popular textbook in the 1950s, Smith's *Exploring Biology* (Smith, 1949), included a thorough treatment of evolution. Thus Grabiner and Miller were able to document a reduction in evolutionary content in specific texts, but their evidence does not support the conclusion that the Scopes trail led to an *overall* reduction in evolutionary content.

Despite the evolutionary rollback documented by Grabiner & Miller in pre-Scopes to post-Scopes editions, overall the evolutionary content in biology textbooks continued to grow after the Scopes trial. In his study of the evolutionary content of over 100 secondary biology textbooks published from 1900-1983 Gerald Skoog (1979; 1984) found that an average of 3% of the words were devoted to evolution in the 15 books published in the 1930s, 3.3% for the 15 books published in the 1940s, 3.0% for the 14 books published in the 1950s, 8.1% for the 17 books published in the 1960s, and 7.4% for the 10 books published between 1970 and 1977.

Although he did not publish an evolutionary content percentage after 1977, he noted a decrease in the coverage of evolution in the 13 textbooks published between 1977 and 1983. Skoog summarizes his analysis as follows:

> Analysis of the 93 biology textbooks revealed that prior to 1960, evolution was treated in a cursory and generally noncontroversial manner. However, there was a continued increase in the emphasis on evolution in the textbooks from 1900 to 1950. This trend was reversed in the 1950s when the concept was deemphasized slightly. In the 1960s the activities and influence of the Biological Sciences Curriculum Study (BSCS) resulted in several textbooks that gave unprecedented emphasis to evolution. Accordingly, 51% of the total words written on the topics concerned with the study of evolution in the 83 textbooks published between 1900-1968 appeared in 17 textbooks published in the 1960s (Skoog, 1979, p. 622).

As noted above, the evolutionary content in textbooks decreased in the 1970s and 1980s, but they stayed far above pre-BSCS levels.

Skoog also noted that four of the five textbooks published between 1980 and 1983 "mentioned special creation as a possible explanation for the origin of life" (Skoog, 1984, p. 124). This is a notable development, since only 3 of the 68 pre-1968 textbooks mentioned special creation or catastrophism. However, none of these books followed up on creationism; each briefly mentioned and then ignored it.

Dorothy Rosenthal analyzed the content of 22 popular high school biology textbooks published between 1963 and 1983 (Rosenthal, 1985). She found that the average percentage of the texts devoted to evolution was 13.7% for the four textbooks published in 1963, 13.9% for the four textbooks published in 1968-1969, 13.2% for the five textbooks published in 1973 and 1976, and 9.9% for the nine textbooks published between 1979-1983. This generally confirms Skoog's observation of a decrease in evolutionary content in the late 1970s and early 1980s.

A caution regarding the use of page- or word-count can be found in Levin and Lindbeck's analysis of five biology textbooks published between 1970 and 1973. They analyzed

all three of the 1973 BSCS texts, a 1973 non-BSCS text, and a text published by the Creation Research Society entitled *Biology: A Search for Order in Complexity* (J. N. Moore & Slusher, 1970). Surprisingly, they found that Darwinian evolution occupied between 3.0 and 3.5% of all five books. Yet the books differ substantially in quality:

> Although [*Biology; A Search for Order in Complexity*] had one of the higher percentages of page space, important subtopics were omitted and the quality was generally poor. The apparent thrust was to obscure basic concepts of Darwinian evolution which the authors deem incompatible with Biblical creationism (Levin & Lindbeck, 1979, p. 200).

Hence caution is in order regarding reliance on strictly quantitative data.

Arthur Woodward and David Elliot analyzed 15 textbooks published between 1977 and 1983 (Woodward & Elliot, 1984, 1987). They found that two books avoided evolution altogether, six contained "extensive and uncompromising" treatments of evolution, and seven took a "balanced" approach. Like Skoog, Woodward and Elliot found that three of the "balanced" textbooks "discuss alternative theories to evolution." Four others presented an "otherwise excellent" treatment of evolution, but avoided discussion of human evolution.

In order to improve on previous quantitative work in textbook evaluation, David Moody (1996) measured the number of chapters in which fifteen key terms (e. g. "cell," "protein," and "evolution") appeared, the sequence in which each term was introduced, and the number of chapters in which pairs of terms appeared. Moody used the latter as a rough measure of the extent to which the various terms were integrated into the overall structure of the text. He examined two editions of four secondary-level biology textbooks: one edition from the early- or mid-1980s, and the second edition from the early- or mid-1990s. Moody found that in all four textbooks, the frequency and integration of evolution improved markedly in the later (1990s) editions.

The trend in these textbook studies is toward a gradual increase in evolutionary content. Early textbooks included little evolutionary content: Richards (1923) attributed most of the 1.68% of evolutionary coverage from 1911-1919 to just one of the six texts analyzed, while Knapp (1933) judged that only one of five texts published between 1917-1927 included an extensive and uncompromising treatment of evolution. Between about 1925 and 1935, Christy (1936) estimated that about 8% of textbook content was devoted to evolution. Skoog placed the estimate at just over 3% in each decade between 1930 and 1960, followed by a dramatic increase to 8.1% between 1960-1969 and a rollback to 7.4% between 1970-1977. Although Rosenthal's estimates are much higher, she generally confirms Skoog's estimates of substantial evolutionary content between 1963-1976, followed by a rollback between 1979-1983. Yet Woodward and Elliot (1984, 1987) found that 10 of 15 books published between 1977-1983 included extensive evolutionary content. Furthermore, Moody found that any rollbacks of the 1980s were reversed in the 1990s.

Taken together, the biology teacher surveys and the textbook studies indicate a gradual, albeit uneven, increase in evolutionary content from 1900 until the present. Yet nearly all of the authors adopt an alarmist tone. Rutledge & Mitchell, for example, conclude:

> The data from this study suggests that the topic of evolution does not receive appropriate emphasis in the high school biology curriculum . . . Clearly, the status of evolutionary theory as the central and unifying theme of biology is not reflected in the teaching of a disturbing number of Indiana public high school biology teachers. Given the ability of evolutionary theory to bring meaning to the vast array of traits, behaviors and characteristics of life and to promote understanding of biology as a discipline, the overall quality of instruction in a significant number of Indiana public high school biology classes is problematic (Rutledge & Mitchell, 2002, p 25).

The disconnect between such hand-wringing and the gradual progress in introduction of evolutionary content to the classroom could be attributed to simple impatience on the part of visionary academics. However, I suggest that it is, in part, a call to vigilance in the face of

frequent and persistent attempts to introduce creationism into the public schools (R. Moore, 1998a, 1998b, 1998c, 1999a, 1999b, 1999c). Also, Amy Binder has shown that although creationists have been able to acquire *political* power, educators have consistently resisted the introduction of creationism into the public schools through the exercise of *institutional* power (Binder, 2002). I suggest that just as educators utilize institutional power to resist creationism, they also utilize institutional power to enforce a gradual, rather than sudden, introduction of evolutionary theory into the curriculum. Thus I expect that evolutionary content in classrooms will continue to grow, but I doubt that evolutionary biologists will be satisfied anytime soon.

Discussion

The authors of these studies do not operate in a cultural vacuum; both the authors of the studies and the objects of study (the teachers) are cultural products and cultural actors. Consequently, we cannot argue that they have discovered pure facts. Instead, facts and values are so "entangled" that any fact/value dichotomy must be abandoned (Putnam, 2002), particularly within the social sciences (Flyvbjerg, 2001). Of course, I am a cultural product and a cultural actor as well. Therefore any critical analysis of the assumptions and motivations of the authors of the surveys and textbook studies must also apply to me.

Michel Foucault's concept of power and knowledge will be central to my discussion of the survey and textbook studies:

> Perhaps, too, we should abandon a whole tradition that allows us to imagine that knowledge can exist only where the power relations are suspended and that knowledge can develop only outside its injunctions, its demands and its interests. Perhaps we should abandon the belief that power makes mad and that, by the same token, the renunciation of power is one of the conditions of knowledge. We should rather admit that power produces knowledge (and not simply by encouraging it because it serves power or by applying it because it is useful); that power and knowledge directly imply one another; that there is no power relation without the correlative constitution of a field of knowledge, nor any knowledge that does not presuppose and constitute at the same time

> power relations . . . [I]t is not the activity of the subject that produces a corpus of knowledge, useful or resistant to power, but power-knowledge, the processes and struggles that traverse it and of which it is made up, that determines the forms and possible domains of knowledge (Foucault, 1978/1995, pp. 27-28).

Here, Foucault is arguing that power and knowledge are inseparable (hence "power-knowledge"), although the connection between them may be invisible. Note that Foucault is not suggesting that power corrupts knowledge or that knowledge produces power. Instead, power-knowledge is, for Foucault, both amoral and decentralized. Power-knowledge is embedded in all cultures, and no one can utilize knowledge without power or *vise versa*.

How is power embodied in studies of evolutionary content in classrooms? First, as noted above, the authors of all of our studies assume that teaching evolution in schools is a good thing. Increases in volume and integration of evolutionary content are always treated as positive developments, while decreases in such content are treated as negative developments. Yet who benefits from the inclusion of evolutionary content in the public schools, and who loses? For the biologists and educators who conduct the studies, the inclusion of evolutionary content increases both cultural status and cultural influence. For example, an increase in secondary evolutionary content increases the pool of prospective scientists. Furthermore, a scientifically oriented electorate is less likely to interfere with the work of scientists and more likely to fund their research.

Yet we can follow Foucault's concept of power-knowledge far deeper into the culture. Evolution by natural selection furthers the introduction of naturalistic materialism into the world. Its reliance on random, amoral processes de-spiritualizes the world and breaks down the distinction between the living and nonliving. Consequently, evolutionary theory changes our relationships to other living things (human and nonhuman), our view of the physical world, our view of ourselves, and perhaps most importantly, our religious beliefs. In short, the acceptance

of evolutionary theory changes who we are. Such changes in self-concept increase the power and influence of scientists and technologists. These changes also decrease the power of religious leaders and the ability of religious people to feel at home in the world and to preserve a sense of certainty and security. Therefore it is not surprising that recent polls (Nisbet, 2005) document broad public ambivalence toward the teaching of evolution in the public schools together with widespread support for presenting creationism as an alternative. Yet in all of the surveys and textbook studies, such public opinions are viewed as obstacles to be overcome rather than a constituency to be acknowledged. Those on both sides of this disagreement recognize that the ascendancy of evolutionary theory produces losers as well as winners.

Other criticisms of our survey research are derived from epistemological considerations. In quantum physics, Neils Bohr developed the "principle of complementarity" to explain the fact that an electron, for example, exhibits particle-like properties in some experiments and wave-like properties in others. Physicists do not conclude that the electron is a particle or a wave or even both, but rather the electron is an entity which responds to wave questions (i. e. experiments) with wave answers and particle questions (experiments) with particle answers. In the same way, some biology teachers may respond to survey questions with survey answers, and these answers may or may not be interpretable as an accurate indicator of classroom practice. These same teachers may respond to interviews or classroom observations in different ways. Yet these should not be interpreted as more accurate indicators of classroom practice either. Just as the survey is a particular context yielding particular kinds of responses, so interviews or observations are particular contexts and protocols for which certain kinds of results are possible and others are not.

A further criticism of the surveys and textbook studies relates to context. Both types of studies attempt to define and then abstract the concept of "evolutionary content" out of the rich, dynamic practice of school science. Gavriel Salomon refers to such abstraction as the "analytic approach" to educational research, which assumes that

> [c]omplex behaviors, settings, and internal events are additively and interactionally composed of more basic elements, the effects of which can be studied in isolation . . . The underlying and common mental model appears to be one of billiard balls: Each is independent of the other, has its own qualities, but interacts with the others to produce an effect. Thus one can assume that the manipulation of one independent variable leaves all the other variables untouched and unaffected. . . . [A] related assumption is that the quality of an observed, measured, or manipulated variable—whether in the environment or the person—has meaning in and of itself. Amount (or *quality*) of collaboration, perseverance, effort expenditure, satisfaction, and the like are assumed to afford their interpretation as events, states, or processes, the meaning of which are their own qualities (Salomon, 1991, p. 13).

The obvious objection to this approach is that people are nothing like billiard balls. Yet the analytic approach enables the identification (or definition) of variables which can be statistically manipulated, so such abstractions lend an aura of objectivity to the research. The price for this "objectivity" is distance from the phenomena of interest and a loss of detail. Citing Clifford Geertz, Flyvbjerg notes that

> [t]he problem with an approach, which extracts the general from the particular and then sets the particular aside as detail, illustration, background, or qualification, is that "it leaves us helpless in the face of the very difference we need to explore," Geertz says. "[I]t does indeed simplify matters. It is less certain that it clarifies them" (Flyvbjerg, 2001, p. 133; Geertz, 1995, p. 40).

Thus survey and textbook studies may ignore contextual information that is essential for understanding evolutionary teaching in classrooms. They may trade understanding for simplicity. And as Joseph Maxwell (2004) argues, such distance and isolation of variables enables the determination of correlation between variables, but disallows investigation of cause.

For Maxwell, only direct observation can establish causal relationships, and surveys are far from direct observation.

Specifically, the survey and textbook studies cited above assume that the meaning of "teaching evolution" has the same meaning from teacher to teacher and classroom to classroom. Yet most educated Americans would agree that different teachers can spend the same amount of time on a topic, but lead to radically different results. Even more problematically, my analysis of the studies assumes that "teaching evolution" bears the same meaning in the year 1942 as in 2004. I assume that I have discovered an increase in the teaching of evolution, but perhaps I have merely discovered a cultural trend in the interpretation of "teaching evolution." Adopting an "analytic framework," perhaps classroom behavior is more or less constant, while the culture in which classrooms are embedded is variable. As Kenneth Howe expresses it:

> Lee Cronbach permanently diminished Campbell and Stanley's vision (a vision he once shared) with his famous observation that "generalizations decay": the fact that the social contexts that interact with and help shape the subject matter of generalizations constantly changes imposes a serious limitation on the idea of a cumulative education science in any but the most modest sense (Howe, 2005, p. 310).

"Teaching evolution" as a generalization is open to considerable decay across the course of a century. Thus humility about my results is in order.

Conclusion

In this paper, I attempted to answer a fairly straightforward question: How has the teaching of evolution changed in U. S. schools? The answer turned out to be anything but straightforward. On the one hand, there appears to be an overall increase in evolutionary content in U. S. classrooms, although this trend has been characterized by fits and starts more than steady progress. On the other hand, I identified numerous practical and philosophical difficulties in my

attempt to answer this question, including the connection between the studies and issues of power, the fact that survey research serves as its own rather uncommon context, and the difficulties involved in meaningfully abstracting "evolutionary teaching" from biology classrooms, together with the suppression of context. Despite these difficulties, however, my analysis still "rings true" in my mind: I am persuaded that evolutionary instruction has gradually increased over the course of the 20th century. Thus I do not conclude that the questions raised in the discussion invalidate the research, nor do I conclude that the strengths of this survey analysis render it the "last word" on the subject. Instead, I follow Margaret Eisenhart (2005) and Bent Flyvberg (2001, p. 87) in noting that different tools in educational research serve different purposes, and each has its strengths and weaknesses.

References

Aguillard, D. (1999). Evolution education in Louisiana publis schools: A decade following *Edwards v Aguillard*. *The American Biology Teacher, 61*(3), 182-188.

Binder, A. J. (2002). *Contentious curricula: Afrocentrism and creationism in American public schools*. Princeton, NJ: Princeton University Press.

Christy, O. B. (1936). The development of the teaching of general biology in the secondary schools. *Journal of the Tennessee Academy of Science, 12*(3), 170-350.

Cretzinger, J. I. (1941). An analysis of principles or generalities appearing in biological textbooks used in the secondary schools of the united states from 1800 to 1933. *Science Education, 25*(6), 310-313.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice*. New York: Teachers College Press.

Eisenhart, M. (2005). Hammers and saws for the improvement of educational research. *Educational Theory, 55*(3), 245-261.

Ellis, W. E. (1983). Biology teachers and border state beliefs. *Society, 20*(2), 26-30.

Ellis, W. E. (1986). Creationism in Kentucky: The response of high school biology teachers. In R. W. Hanson (Ed.), *Science and creation: Geological, theological, and educational perspectives* (pp. 72-91). New York: MacMillan Publishing Company.

Feder, K. L. (1995). Cult archaeology and creationism: A coordinated research project. In F. B. Harrold & R. A. Eve (Eds.), *Cult archaeology and creationism: Understanding pseudoscientific beliefs about the past* (Expanded ed., pp. 34-48). Iowa City: University of Iowa Press.

Flyvbjerg, B. (2001). *Making social science matter: Why social inquiry fails and how it can succeed again* (S. Sampson, Trans.). Cambridge, UK: Cambridge University Press.

Foucault, M. (1978/1995). *Discipline and punish: The birth of the prison* (A. Sheridan, Trans. 2nd ed.). New York: Vintage Books.

Geertz, C. (1995). *After the fact: Two countries, four decades, one anthropologist*. Cambridge, MA: Harvard University Press.

Grabiner, J. V., & Miller, P. D. (1974). Effects of the Scopes trial: Was it a victory for evolutionists? *Science, 185*, 832-837.

Grobman, A. B. (1969). *The changing classroom: The role of the Biological Sciences Curriculum Study* (Vol. 4). Garden City: Doubleday & Co., Inc.

Hellman, R. A. (1968). Evolution in American school biology books from the late nineteenth century until the 1930s. *The American Biology Teacher, 27*, 778-780.

Howe, K. R. (2005). The question of education science: Experimentism versus experimentalism. *Educational Theory, 55*(3), 307-321.

Kinsey, A. C. (1926). *Introduction to biology*. New York: Lippincott.

Kitzmiller et. al. v. Dover Area School District (United States District Court for the Middle District of Pennsylvania 2005).

Knapp, R. A. (1933). *Trends in secondary school science in the state of California*. Claremont College.

Laba, E. R., & Gross, E. W. (1950). Evolution slighted in high-school biology. *The Clearing House, 24*, 396-399.

Levin, F. S., & Lindbeck, J. S. (1979). An analysis of selected biology textbooks for the treatment of controversial issues and biosocial problems. *Journal of Research in Science Teaching, 16*(3), 199-203.

Martin, W. E. (1952). *The teaching of general biology in the public high schools of the United States: An inquiry into offerings, enrollments, course organization, facilities, equipment, and expenditures, 1949-1950* (No. 9). Washington, DC: United States Government Printing Office.

Maxwell, J. A. (2004). Causal explanation, qualitative research, and scientific inquiry in education. *Educational Researcher, 33*(2), 3-11.

Mills, L. H. (1933). *Dynamic biology*. New York: Rand McNally.

Moody, D. E. (1996). Evolution and the textbook structure of biology. *Science Education, 80*(4), 395-418.

Moon, T. (1921). *Biology for beginners*. New York: Holt.

Moon, T. (1933). *Biology for beginners*. New York: Holt.

Moon, T., & Mann, P. (1947). *Biology: A revision of biology for beginners*. New York: Holt.

Moore, J. N., & Slusher, H. D. (Eds.). (1970). *Biology, a search for order in complexity*. Grand Rapids: Zondervan.

Moore, R. (1998a). Creationism in the United States: I. Banning evolution from the classroom. *The American Biology Teacher, 60*(7), 486-507.

Moore, R. (1998b). Creationism in the United States: II. The aftermath of the Scopes trial. *The American Biology Teacher, 60*(8), 568-575.

Moore, R. (1998c). Creationism in the United States: III. The ban on the teaching of evolution reaches the U. S. Supreme Court. *The American Biology Teacher, 60*(9), 650-661.

Moore, R. (1999a). Creationism in the United States: IV. The aftermath of *Epperson v. Arkansas*. *The American Biology Teacher, 61*(1), 10-16.

Moore, R. (1999b). Creationism in the United States: V. The *McLean* decision destroys the credibility of "creation science". *The American Biology Teacher, 61*(2), 92-101.

Moore, R. (1999c). Creationism in the United States: VI. Demanding "balanced treatment". *The American Biology Teacher, 61*(4), 175-180.

Moore, R., & Kraemer, K. (2005). The teaching of evolution and creationism in Minnesota. *The American Biology Teacher, 67*(8), 457-466.

Nisbet, M. (2005). *Polling opinion about evolution: Low information public underscores importance of communication strategy*. Retrieved April 14, 2006, from http://www.csicop.org/scienceandmedia/evolution/

Putnam, H. (2002). *The collapse of the fact/value dichotomy*. Cambridge, MA: Harvard University Press.

Richards, O. W. (1923). The present content of biology in the secondary schools. *School Science and Mathematics, 23*(5), 409-414.

Riddle, O. (1941). Preliminary impressions and facts from a questionnaire on secondary school biology. *The American Biology Teacher, 3*(5), 151-159.

Riddle, O., Fitzpatrick, F. L., Glass, H. B., Gruenberg, B. C., Miller, D. F., & Sinnott, E. W. (1942). *The teaching of biology in secondary schools of the united states: A report of results from a questionnaire*: Union of American Biological Societies, Committee on the Teaching of Biology.

Rosenthal, D. B. (1985). Evolution in high school biology textbooks: 1963-1983. *Science Education, 69*(5), 637-648.

Rutledge, M. L., & Mitchell, M. A. (2002). High school biology teachers' knowledge structure, acceptance, and teaching of evolution. *The American Biology Teacher, 64*(1), 21-28.

Salomon, G. (1991). Transcending the qualitative-quantitative debate: The analytic and systemic approaches to educational research. *Educational Researcher, 20*, 10-18.

Schiltz, M. E. (1988). Professional standards for survey research. *Research in Higher Education, 28*(1), 67-75.

Shankar, G., & Skoog, G. D. (1993). Emphasis given evolution and creationism by Texas high school biology teachers. *Science Education, 77*(2), 221-223.

Skoog, G. D. (1979). Topic of evolution in secondary school biology textbooks: 1900-1977. *Science Education, 63*(5), 621-640.

Skoog, G. D. (1984). The coverage of evolution in high school biology textbooks published in the 1980s. *Science Education, 68*, 117-128.

Smith, F. (1949). *Exploring Biology*. New York: Harcourt, Brace.

Tatina, R. (1989). South Dakota high school biology teachers and the teaching of evolution and creationism. *The American Biology Teacher, 51*(5), 275-279.

Trani, R. (2004). I won't teach evolution; it's against my religion: And now for the rest of the story. *The American Biology Teacher, 66*(6), 419-427.

Weiss, I. R. (1978). *Report of the 1977 national survey of science, mathematics, and social studies education*. Washington, DC: U. S. Government Printing Office.

Weld, J., & McNew, J. C. (1999). Attitudes toward evolution. *The Science Teacher, 66*(9), 27-31.

West, L. J. (1991). A frequently violated requirement in survey research. *Journal of Education for Business, 66*, 134-135.

Woodward, A., & Elliot, D. L. (1984). Evolution, creationism, and textbooks: A study of publishers' perceptions of their markets. *Educational Resources Information Center*.

Woodward, A., & Elliot, D. L. (1987). Evolution and creationism in high school textbooks. *The American Biology Teacher, 49*(3), 164-170.

Zimmerman, M. (1987). The evolution-creation controversy: Opinions of Ohio high school biology teachers. *Ohio Journal of Science, 87*(4), 115-125.