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High School Students' Perceptions of Evolutionary Theory

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> *If we are to be successful in teaching evolution, we must take into account our students' worldviews as well as their individual understandings and misconceptions. It is important to know our students their cultures, personal histories, cognitive abilities, religious beliefs,* [and] *scientific misconceptions.* [It is also important] *to address directly the likely cultural/religious concerns with evolution and to do so early on so as to break down the barriers that keep many students from hearing what you say.* (Smith, 1994, p. 591)

Smith penned these words for a special issue of the *Journal of Research in Science Teaching* which focused on the "Teaching and Learning of Biological Evolution." One inference to be drawn from Smith is that, should we fail to account directly for the needs of our target learners, we are destined to develop curriculum materials and instructional plans that fall far short of the level of scientific literacy we wish to engender. Thus, although the standards they set possess scientific integrity, efforts initiated by the American Association for the Advancement of Science (AAAS, 1993) and National Research Council (NRC, 1996) -- to accurately characterize the foundational importance of evolutionary theory to the discipline of biology -- may not be fully realized. Does the research literature support Smith's contention? The purpose of this study was to examine students' perception about evolutionary theory.

Contextual Background for the Study

Cummins, Demastes, and Hafner (1994) point out the relative paucity of research on evolution education. This fact is not as surprising as it may seem given that evolutionary theory is so badly misunderstood by the general public (National Academy of Sciences, 1999). In other words, it is very difficult to comprehensively research that which sometimes gets left out of or is often only integrated into the biology curriculum in a piecemeal fashion (Skoog, Cielen, Jordan, Lariviere, Scharmann, & Scott, 1998). If we are, as a science education community, to do justice with respect to evolutionary theory, how might we more effectively integrate evolutionary theory within the biology curriculum?

Joseph J. Schwab (1973) offers invaluable insights concerning the proper foci for initiating and/or revising science curricula. Schwab was educated at the University of Chicago (B.S., Physics/English Literature, 1930; Ph.D., Biology, 1939) and performed a post-doctoral fellowship at Teachers College, Columbia University. Schwab, a William Rainey Harper Distinguished Professor of Natural Science and Professor of Education at the University of Chicago (1940-1974), forcefully argued that four commonplaces exist in defensible educational thought in relation to curriculum building: "the learner, the teacher, the milieu, and the subject matter" (pp. 508-509). He further argued that these commonplaces must not just be present but be *equal* in rank in the initiation of new or the revision of existing curricula "coordination, not superordination-subordination is the proper relation of these four commonplaces" (p. 509).

What happens when we apply Schwab's "commonplaces" theory to the inclusion of evolution in the biology curriculum? Given the tortuous history of acceptance, or lack thereof, for evolution and the fact that school board presidents (and consequently public school teachers) remain sensitive to local religious sentiments (Zimmerman, 1991), it is not difficult to note that the cultural or political milieu of the community may quickly become superordinate. In other words, no matter how well versed in the biological sciences teachers may be, how well they may understand their students, or how well they choose appropriate teaching methods, there may not exist an *equality* of rank among the four curriculum commonplaces. Alternately, despite a prevailing negative cultural community milieu, teachers may present evolutionary theory with a great deal of scientific integrity but do so at the expense of the psychological needs of their students. In this situation, subject matter becomes superordinate to the other three commonplaces. It is not that the other three are missing; however, they are not coordinated well enough with subject matter to be considered of *equal* rank.

In a similar fashion, one can conceive of a variety of situations in which, despite our best efforts, evolution is not appropriately represented in the biology curriculum. Schwab warns us that such situations will always occur whenever the four commonplaces are not of *equal* rank. A review of recent research efforts whose focus is evolution education continues to illustrate the explanatory value of Schwab's "commonplaces" curriculum theory. Let's consider a few examples.

<u>Teachers</u>

Two successive years of a National Science Foundation (NSF) funded institute titled, "The Nature of Science and Instructional Role of Scientific Theories," (Scharmann, 1994; Scharmann & Harris, 1992) brought about discussions of a common frustration. Institute teachers remarked that no matter how they approached instruction on the topic of evolution, as soon as the topic was begun, it made instructional matters more difficult. This description was especially the case among those teachers that taught in smaller, more conservative communities. Through further discussion and conversation it became apparent that those teachers reporting the gravest difficulties with the topic of evolution were those who opted to lecture directly on the subject matter.

The application of Schwab's commonplaces curriculum theory might suggest to us that teachers were overtly concerned with their community's dominant cultural milieu. Thus, albeit with full recognition of the existence of several rival explanations, teachers reporting difficulties may have attempted a counterbalance of their milieu by placing an overemphasis on subject matter and teacher-centered instruction. One prominent conclusion from this NSF project is that biology teachers must select teaching methods that more appropriately match the needs of their target learners especially in relation to the curriculum topic of evolution. Such a conclusion is also consistent with recent recommendations for standards-based science education (National Research Council, 1996).

Subject Matter

Representative studies were examined that dealt with student understanding of evolutionary concepts. Lawson, for example, initiated a series of investigations to determine students' conceptions with respect to evolutionary theory. Lawson and Thompson (1988) determined that reasoning ability (Piaget & Inhelder, 1969) was the only variable related to the number of misconceptions held by seventh grade students with respect to genetics and natural selection. In a related study with undergraduate students enrolled in a beginning biology class, Lawson and Weser (1990) were able confirm that less skilled reasoners were more likely to hold initial nonscientific beliefs and less likely to change those beliefs. Finally, working with high school aged students Lawson and Worsnop (1992) found that systematic instruction did not promote a group-wide shift away from special creation toward evolution. Lawson noted that, after systematic instruction in evolutionary concepts, just as many students who began as "unsure" shifted toward creationism (n=13) as did those who shifted toward evolution (n=12). The vast majority of students, in addition, remained committed to their initial positions (n=64).

While unstated, it is clear from reading each of the Lawson studies that only two curriculum commmonplaces were considered: subject matter and teacher. Conspicuously absent, although briefly acknowledged, was a consideration of milieus and learners with respect to the instructional decisions described in each study.

In a more recent study, Demastes, Settlage, and Good (1995) determined that students were able to understand and apply evolutionary concepts in situations where teachers emphasized an inquiry model of instruction. These researchers suggest that, "future studies should give as much attention to instructors' conceptual frameworks as to the students' in science learning" (p. 549). Finally, Jensen and Finley (1996) concluded that student understanding of evolution was enhanced through the use of a paired problem-solving instructional strategy. Both of these studies provide corroborative evidence for the explanatory capacity of Schwab's theory: the greater the number of curriculum commonplaces for which the teacher accounts, the greater the opportunity to achieve a desired student learning outcome.

<u>Milieus</u>

The milieu within which evolution education takes place is an interwoven fabric possessing cultural, political, personal, theological, epistemological, and scientific influences. The media often refers to this fabric (milieu) as the evolution/creation debate. But, must a consideration of evolution/creation and science/theology result in a debate in which there exists a winner and a loser? Outstanding books richly describe the complexity of this fabric (Gould, 1999; Larson, 1997; Miller, 1999; Nelkin, 1982).

Edward J. Larson (1997), for example, provides a brilliant and scholarly treatment of the Scopes trial. He deftly captures the historical moments leading up to the trial, recognizes the public's misunderstanding of the nature of science and scientific theories during the trial and its' aftermath, and carefully illustrates the cyclical nature of America's continuing debate over science and religion.

Stephen J. Gould (1999), on the other hand, delineates a position that advances scientific integrity without severely compromising theological sanctity. In Gould's view, science and religion possess non-overlapping magesteria -- or NOMA -- in which questions to be answered might be addressed from a scientific, theological, or both scientific and theological points of view. In other words, science informs us about the heavens, while theology tells us how to get to heaven. NOMA, in Gould's view, attempts to help individuals find a simple way to understand this complex fabric, accepting scientific advancement without a risk to one's religious values.

Finally, in full complement to Gould's view, Kenneth R. Miller (1999) tackles contemporary criticisms of evolution, including "Intelligent Design," while simultaneously searching for common ground between theology and evolution. Miller's writings delve into the political, cultural, theological, and scientific realms, all filtered through the lens of a personal worldview that accepts both scientific and theological premises. Suffice it to say, nonetheless, that when a milieu is as unwieldy and as complex as is this one, it is tempting to ignore or subordinate it. Schwab, however, warns us against both of these temptations.

With respect to evolution education research, Cummins, Demastes, and Hafner (1994) validate Schwab's admonition when they write:

> *We intended to de-emphasize the evolution/creationism debate. By this position, we did not intend to discount the importance of religious belief in the learning of evolution. However, for many individuals investigation and research have progressed no further than outlining the many positions within this debate. For that reason we chose to focus away from the creationism debate and on learning and teaching. It is evident, however, that no clear picture of the teaching and learning of evolution can be constructed without incorporating this facet.* (Cummins, Demastes, & Hafner, 1994, p. 446)

Learners

Demastes, Good, and Peeples (1995) investigated students' conceptual ecologies as they related to the learning of evolutionary theory. They identified prior conceptions, scientific and religious orientations, overall view of the biological world, and acceptance of evolutionary theory as critical aspects of students' conceptual ecologies. They conclude that individual students vary greatly in their priorities concerning the use/importance of these aspects. They also recognize that, although evolutionary theory may conflict with students' cultural beliefs, students can progress toward an understanding of the scientific conception of evolution.

When students perceive that an issue is controversial or in conflict with their personal values, they simply may not be ready to adopt a position on evolution that is consistent with one held by a practicing biologist. Rather than attempt to either push students too far too soon (teaching evolution as fact, accept it or not) or ignore their need to struggle with a healthy intellectual challenge (by sidestepping the issue), teachers should provide students with opportunities to "get part of the way there" (Scharmann, 1990, 1993; Mead & Scharmann, 1994). Scharmann (1993) further recommends that teachers use a small-group, peer discussion strategy, one that encourages students to openly relate their knowledge and attitudes concerning science and religion, as the teaching method to initiate these opportunities. Smith (1994) prompts that such a strategy should be initiated early on in a unit of study on evolution. Dagher and BouJaoude (1997) concur when they suggest that "teaching students about the nature of scientific facts, theories, and evidence is more likely to enhance understanding of evolutionary theory, if students are given the opportunity to discuss their values and beliefs in relation to scientific knowledge" (p. 429).

Research Focus

Our intention in writing the section above is not to criticize the research efforts of others for their failure(s) to consider the four commonplaces of Schwab's curriculum theory. Instead, it is to make three points. First, when an area of research is under-represented, additional insights into each of the four commonplaces are necessary before quality curriculum synthesis can occur. Second, acceptance of evolutionary theory will continue to engender frustration in the United States as long as the cultural and/or political milieu dictates that it must be so. Finally, biology teachers attempting to deal with evolution in a proactive manner need to create classroom environments in which the four curriculum commonplaces are both *equal* and integrated.[1]

The remainder of this paper is consistent with these intentions. This will be followed by an examination of perceptions concerning evolutionary theory held by high school students. Finally, after providing a summary discussion, implications for science instruction will be delineated.

Methods

Setting

The formal study took place at a high school located in the West-Central Great Plains of the continental United States. The school is located in a town of approximately 21,000 residents. A nearby military installation adds approximately 30,000 people to the immediate area. The presence of this military base, one of the largest in the United States, has a substantial impact on the community and school district. Given the transient nature of military personnel, many of the district students have attended several high schools in many different states; some even in countries outside of the United States. This unique circumstance gives the school characteristics that would be found at larger schools found in urban or metropolitan settings.

The four-year high school serves grades nine through twelve, possessing a total population of over 1500 students. The overall student to teacher ratio is 18 to 1; the average class size is 25. Consistent with the nature of the military, the school has a higher than normal transient rate and, being the only high school in the district, its students exhibit a wide range of lifestyles and tremendous cultural and ethnic diversity. The high school thus possesses demographics, characteristics, qualities, and problems more representative of a large urban high school than a more typical small town Mid-West school. According to school records, of the school's approximately 1500 students, 48% are minority. The racial make-up of the student body is 34% African American, 5.7% Asian American, 8.2% Hispanic American, 0.1% Native American and 52% European American. The student gender ratio is evenly balanced with 765 females and 752 males.

Based on free and reduced lunch participation and estimations of family income, approximately five percent of the high school students are from the upper, 66% from the middle, and 29% from the lower socioeconomic bracket. Students range in age from 14 to 47. The high school serves more than twenty students over the age of 25 years. Almost all of these non-traditional students are Asian American women who are military spouses. These factors were important and had the potential to influence any data collected in this setting. As recent years have shown with other controversial issues in the media and popular culture of the

United States, attitudes on some issues have the potential to differ across racial and ethnic lines. Socioeconomic status and level of education can also be divisive factors.

Participants

The population for this study consists of 518 students enrolled in at least one science class, grades nine through twelve. Among this population, 53% are female and 47% are male. With respect to race/ethnicity, 48% are European American, 24% African American, 14% classified themselves as biracial, 7% Hispanic American, 5% Asian American and 2% Native American. In terms of grade level, 52% are enrolled in 9^{th} grade, 26% in 10^{th} grade, 16% in 11^{th} grade, and 5% in 12^{th} grade.

Design

Data were collected using both quantitative and qualitative methods. A causal-comparative or *ex post facto* design was used to examine quantitative data sources, which consisted of subjects' responses to a questionnaire set. The questionnaire set consisted of 3 instruments, the Grouped Assessment of Logical Thought (GALT), the Locus of Control in Science (LOCIS) and theWoods-Scharmann Evolution Inventory (AE). The source of qualitative data was a short post-questionnaire interview protocol.

Quantitative Data Sources

The causal-comparative method is aimed at the discovery of possible causes and effects of a behavior pattern or personal characteristic by comparing subjects in whom it is absent or present to a lesser degree. Essentially this is experimentation in reverse: instead of taking groups that are equivalent and exposing them to different treatments with a view to promoting differences to be measured, the experiment begins with a given effect and seeks the experimental factor that brought it about (Mouly, 1970). In this study, the pattern to be investigated is student acceptance of evolutionary theory within a population of representative 518 high school students. The independent variables are science locus of control, logical reasoning ability, race/ethnicity, gender, grade level, and teacher. The dependent variable is an acceptance of evolutionary theory.

The Group Assessment of Logical Thinking (GALT) was chosen to measure logical reasoning ability (Roadrangka, Yeany, & Padilla, 1983). Other instruments have been designed to measure logical thinking; however, the GALT is easier to administer, score and was a better fit for the population under study. This instrument is designed to assess six logical operations: conservation, controlling variables, and four forms of reasoning combinatorial, probabilistic, proportional, and correlational reasoning. Construct validity was established via convergent validation and factor analysis. Science locus of control orientation was assessed using the Locus of Control in Science (LOCIS) scale developed by Haury (1989). The LOCIS scale is an 18-item forced choice instrument possessing an internal reliability consistency coefficient of 0.73. Finally, to measure subjects' understanding and acceptance of scientific theories, a 20-item forced choice questionnaire developed and validated by the authors was administered. Internal consistency reliability was measured to range from 0.71 for high school students to 0.80 for college undergraduates; construct validity was assessed through the technique of known group differences (Anastasi, 1982). More information on these three instruments is available in a dissertation by Author (1995).

Logical thinking is included to verify a conclusion reached by Lawson, who argued that reasoning level is the primary factor influencing acceptance of evolutionary theory (Lawson & Thompson, 1988; Lawson & Weser, 1990; Lawson & Worsnop, 1992). In addition, research involving locus of control which has its origin in social learning theory suggests that locus of control has a significant interaction with science attitudes (Stuessy & Rowland, 1990). Finally, gender, race/ethnicity, and grade level are integrated to account for additional mediating influences. These mediating variables were incorporated consistent with a suggestion by Shymansky and Kyle (1992) that "Gender, ethnicity, and class status are three variables that bear investigation in any research on moderators of curriculum effects" (p. 771).

Table 1

Correlation Matrix for Study Variables: Logical Reasoning (GALT), Acceptance of Evolution (AE), Locus of Control in Science (LOCIS), Grade Level (GRADE), Gender, and Race/Ethnicity (RACE)

	GALT	AE	LOCIS	GRADE	GENDER	RACE
RACE	-0.12*	-0.01	-0.04	-0.01	0.04	-------
GENDER	-0.12*	-0.02	-0.11*	-0.01	--------	
GRADE	0.31**	0.07	0.14	---------		
LOCIS	0.22**	0.20**	---------			
AE	0.31**	---------				
GALT	---------					

* $p < 0.01$ ** $p < 0.001$

Intercorrelations among the six study variables are shown in Table 1. There is a statistically significant correlation between Acceptance of Evolution (AE) scores and both GALT and LOCIS scores. This data was used to determine an order for entry into a forward regression analysis, which is summarized in Table 2. Table 2 provides evidence that logical reasoning accounts for 10% of the common variance ($R^2 = 0.10$; $F = 53.33$; $p < 0.001$) for AE scores. An additional 1% of the common variance for AE scores can be attributed to science locus of control. The remaining variables account for less than 1% of the common variance. Thus combined, logical reasoning and locus of control account for 11% of the common variance of subjects' acceptance of evolutionary theory. This finding, consistent with the assertion made by Lawson concerning logical reasoning, therefore provides insights by which to interpret interview responses.

Table 2

Summary of Forward Regression Analysis Predicting an Acceptance of Evolution (AE scores): Logical Reasoning (GALT), Locus of Control in Science (LOCIS), Grade Level (GRADE), Gender, and Race/Ethnicity (RACE)

Variables in Equation	R2	df	F	p	Beta
GALT	0.1	1,505	53.33	***	0.28
LOCIS	0.11	2,504	32.47	***	0.14

Variables not in Equation (fail to meet minimum criteria for entry)

GRADE
GENDER
RACE
TEACHER

*** $p < 0.001$

Qualitative Data Sources

The source of qualitative data was a short post questionnaire interview. Ten percent of the students completing the GALT, LOCIS, and AE questionnaire set were selected for the interview process. Numbers were randomly chosen at the start of each class period in which interviews were conducted. Students completing and returning their answer sheets at a time that corresponded to one of the random numbers were asked to participate in the interview process. Although nearly sixty students were selected for an interview, only forty-nine actually participated. Interviews were strictly voluntary and some students chose to decline.

The interview questions sought to investigate the following: if the students had studied evolution, if they could define evolution, what factors influenced their attitudes about evolution, and whether they thought evolution should be taught in high school science courses. Interviews were audio taped, transcribed, and word-processed.

The authors assumed in this study that it is impossible to distinguish with confidence between learning based on school science and that derived from out of school experience. Learning experiences that the interviewees encountered in science classes were not monitored. Each interviewee was asked if s/he had studied evolution. Regardless of whether encountered in or out of school, evolution is a subject well covered by the media, particularly television. It is likely that many students developed their own ideas and attitudes about evolution long before it was covered in a high school science course. The interview transcripts provide evidence of knowledge about evolution from out of school sources.

To initiate the interview protocol, it was first determined whether the students felt that they had studied evolutionary theory. To accomplish this, the following question was posed:

Have you studied evolution in class?

Among the forty-nine participating students thirty-nine, or 80%, indicating that they had, while ten responded no. The question was intentionally ambiguous. It was not as important to determine in which class they studied evolution as it was to determine their initial reaction to the question and their perceptions about evolution. It was, in addition, already ascertained from the biology teachers that evolutionary theory had been taught. Other science teachers indicated that evolution had been discussed in all of the science classes. Finally, it was curious to note that students from the same science class gave conflicting answers, indicating that they had studied it in class while others said they had not. If the students responded in the positive they were then asked to define evolution in their own words. Take the following example:

> **Interviewer**: Tell me briefly what evolution is.
>
> **Student**: I think evolution is that all of a sudden the earth was formed by gases coming together and then like cosmic energies came together and then life started and that everything evolved from like this one animal.
>
> If the student responded in the negative to the initial question they were asked if they knew enough about evolutionary theory to answer questions about it.
>
> **Interviewer**: Have you studied evolution before in class?
>
> **Student**: No I haven't.
>
> **Interviewer**: Do you know enough about evolution to answer questions about it?
>
> **Student**: Yes I do.

> **Interviewer**: Can you briefly in your own words tell me what evolution is?
>
> **Student**: OK, I do kind of know what it is because I sort of gave a speech on it in class. And its just evolution of man from apes over years gradually.

Some students indicated that they did not know enough information to answer questions about evolution:

> **Interviewer**: Have you studied evolution before in class?
>
> **Student**: No.
>
> **Interviewer**: Do you know what evolution is?
>
> **Student**: No.
>
> **Interviewer**: You don't? Do you know who Charles Darwin is?
>
> **Student**: No.
>
> **Interviewer**: Do you know enough about evolution to answer questions about it?
>
> **Student**: No.
>
> **Interviewer**: OK. Thank you.

When asked: *What are your perceptions about evolution?* Fifteen of the forty-nine students, or 30%, indicated that they did not believe evolution. One student responded in the negative in the following manner:

> Well I really don't believe in evolution, because I don't think it is possible for a whole bunch of everything that is on the earth today to come from just one creature.

Another student simply stated:

I don't believe it.

Among those individuals who indicated that they did not accept evolutionary theory, the previous quote was representative. The students either stated their opinion (with an accompanying reason) or in a very determined manner indicated that they did not believe evolutionary theory.

Fourteen students, 28%, indicated that they were unsure about evolution or were unable to provide opinions due to lack of knowledge. For example, one student asserted bluntly, " I don't know what evolution is." Another student indicated that he could not define evolution and that sometimes he felt evolution could be right:

Interviewer: Can you briefly tell me what evolution is?

Student: No I can't remember.

Interviewer: Just tell me as much as you know about the general concept.

Student: I think it is like the theory of... I don't know.

Sometimes I think it could be right.

Three students stated that they believed evolution with conditions. One student, for example, believes only parts of evolution:

Interviewer: What are your perceptions about evolutionary theory?

Student: Parts of it...I believe in parts of it. Parts of it I don't.

Interviewer: Which parts do you believe? And which parts do you not believe?

Student: I think it is wholly possible that we could have come from apes and the rest of it I just don't believe.

The next planned interview theme focused on students' perception of conflict between evolutionary theory and out of school experiences (i.e., home, Church, et al.). To do this several questions were posed. The first question was:

Does the study of evolutionary theory conflict with what you were raised to believe at home?

Sixteen of the 49 individuals, or 32%, reported a conflict of some sort. Twenty-three individuals or nearly half, said there was no conflict between evolutionary theory and how they were raised. Two of the 49 were unsure if there was a conflict and eight students did not answer the question.

To ascertain whether students merely echoed what they were taught at home or, instead, possessed a perception of evolution different than the one that was introduced at home, individuals were asked the following question:

Does the study of evolution conflict with your personal beliefs?

Nine or 18% of the students reported that evolutionary theory conflicted with their personal beliefs while 24 or 49% reported that it did not. Sixteen individuals or one third did not answer this particular question. The following two exchanges illustrate the range of responses obtained:

Interviewer: Does the study of evolutionary theory conflict with what you were raised to believe at home?

Student: Yeah, I was raised in a Christian background and creation but I just kind of have known what the difference is.

Interviewer: Does the study of evolution conflict with your personal beliefs?

Student: Not really. As I said, I just know there are differences between me and home.

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Interviewer: Does the study of evolutionary theory conflict with what you were raised to believe at home?

Student: Yes.

Interviewer: Does the study of evolution cause conflicts with your personal beliefs?

Student: Well it conflicts with my religious beliefs, which is pretty much my personal belief.

Interviewer: How do you deal with those conflicts when they arise?

Student: Pretty much I just kind of know what the evolution theory is and I know its got to be taught. It doesn't bother me. I study it for the test, but it doesn't change my belief.

Thus, while 16 students indicated a perception that evolutionary theory conflicted with what they were taught to believe at home, only 9 reported a perceived conflict with what they, as individuals, believed for themselves.

The last question posed to students concerned the presence of evolutionary theory in high school science courses. Thirty-three students responded that it should be taught, two responded no, six responded yes, but with conditions of some sort and eight did not answer the question.

Interpretive Framework

For the purpose of interpreting a student's level of acceptance of evolutionary theory, Nelson's (1986) multiple model approach was utilized as a basis to conduct a content analysis of individual student perceptions. Nelson gives a spectrum of possible choices for acceptance of evolution/compatibility with religion and some key points related to each. The spectrum is as follows:

I. Atheistic Evolution

- Atheism on other grounds is often coupled with imperfection in biological systems arguing against a creator.

II. Nontheistic Evolution

- Scientific truth is objective and is (or should be) independent of religious assumptions.
- Arguments for or against God from natural processes are logically flawed and vice versa.

III. Gradual Creation (theistic evolution)

- Evolution is God's way of creation (just as gravitation is God's way of controlling the Earth's movement).
- Creation is the ultimate origin of the universe and continuous at each moment in its maintenance.

IV. Progressive Creation (limited evolution)

- The great age of the universe, earth and life are accepted, as is the existence of as much evolutionary change as is directly shown by fossils.
- New lineages (including humans) are regarded as separate acts of special creation. The complexity of the new forms when created increases progressively through time.

V. Quick Creation ("scientific creationist")

- The earth is only a few thousand years (up to 10,000 years) old.
- The geological column was formed in a yearlong global flood.
- Evolutionary change is only within "kind".

To this scale the researchers added a category VI.

VI. Lacks Knowledge of Evolution (or no response)

Based on definitions of evolutionary theory and answers to other questions, the students were grouped into an individual category on Nelson's spectrum.

<u>Atheistic Evolution</u>:

Two students were assigned to this category based on their definition of evolution and other interview responses. Both of these students negated God, speaking only of science as a truth or the only way of knowing. The following dialogue with a student is shown to illustrate this:

Interviewer: Have you studied evolution before in class?

Student: Yeah, one time we talked about it, but the only thing he said was he like… he asked us how do you think all this stuff got here… I said it started from apes like that… and he tried to tell me different and all that then we had words and he never tried to correct me again.

Interviewer: What are your perceptions about evolution?

Student: That, that, that we came from apes because when I watch Natural Geographic about the apes and all that…

Interviewer: What factors influence your attitudes about evolution?

Student: There is none really.

Interviewer: Do you feel that the study of evolution conflicts with what you were raised to believe at home?

Student: No, because they told me believe what I want to believe because we don't worry about religion at home.

Interviewer: Does the study of evolution cause conflict with your personal belief system?

Student: No.

Interviewer: Do you feel that evolution should be taught in high school biology classes?

Student: I think it should be taught more because some people have like they have opinions that they got from their friends and the teacher never told them how to back it up.

From this interaction it is clear that this student accepts evolutionary theory while excluding any possibility for a creator or higher being. This student also seems to become belligerent whenever his views are challenged.

<u>Nontheistic Evolution</u>:

The second category on the spectrum is characterized by an understanding that individuals can explain natural events independent of invoking a deity but without directly denying one. Three students were assigned to this group. The following section of dialogue illustrates such a student:

Interviewer: Have you studied evolution before in class?

Student: In this class I haven't.

Interviewer: Do you know what evolution is?

Student: Yes

Interviewer: Can you please define it in your own terms?

Student: In my own words its basically when a creature starts out as a lesser life form and works their way up into something that's more intelligent.

Interviewer: What are your own perceptions about evolution?

Student: How do I feel about it?

Interviewer: Yes.

Student: I think it is a pretty good theory and that it actually happened, that science can explain it.

Interviewer: What factors influence your attitudes about evolution?

Student: Class, the way it is presented by teachers and things like that.

Interviewer: Do you feel that the study of evolution conflicts with what you were raised to believe at home?

Student: No.

Interviewer: Does the study of evolution conflict with your personal belief system?

Student: No.

Interviewer: Do you feel that evolution should be taught in high school biology courses?

Student: Yes.

Interviewer: Can you tell me why?

Student: Because I feel that since its just an option nobody can say...guarantee this is what really happened but since it is a way it possibly happened everybody should know the different ways and means that people came about.

<u>Theistic Evolution or Gradual Creation</u>:

This region of the spectrum is categorized by the belief that evolution is the mechanism by which God works and that creation is the ultimate origin of the universe. Twelve students were classified in this category. One student's interview follows:

Interviewer: Have you studied evolution before in class?

Student: Yes.

Interviewer: Can you briefly tell me what evolution is?

Student: It's like starting out with a single cell organism and they kept on developing until they branched off into different kingdoms and ... natural selection and stuff like that.

Interviewer: What are your perceptions about evolution?

Student: I think it's ...um, I go to church and stuff and I believe in the Bible and stuff like that so.

Interviewer: What factors influence your attitudes about evolution?

Student: Religion.

Interviewer: Do you feel that the study of evolution contradicts or conflicts with anything you were raised or taught to believe at home?

Student: Some of it.

Interviewer: Can you explain a little bit?

Student: Like the Bible never said that the world started out with people starting out, it never said that man and women started it out. It could have been two single celled organisms, which represent man and women.

Interviewer: Does the study of evolution conflict with your personal belief system?

Student: Not that much.

Interviewer: When it does conflict how do you deal with that?

Student: I just learn it, I don't have to accept it. I just learn it.

Interviewer: Do you feel that evolution should be taught in high school biology courses?

Student: They should have a survey of who believes and who doesn't and split up the entire class into two groups.

This student attempts to connect his knowledge of evolution with his Christian understanding. He inadvertently attempts to bridge the Darwinian theory of common descent (all organisms ultimately go back to a single origin of life on Earth) and creation as told in the book of Genesis. In doing so, this student implies that regardless of how life started on Earth it was God's will.

Limited Evolution or Progressive Creation:

This region of the spectrum, as its name implies, combines limited evolutionary theory with separate special acts of creation to account for any perceived differences between evolution and creation. In other words, when a conflict is perceived, the science is wrong. There were three students assigned to this category. The following interview transcript provides an illustration:

Interviewer: Have you studied evolution before?

Student: No.

Interviewer: What is your personal opinion of evolution?

Student: I don't believe in evolution because, um, what I believe is that God created the world and they [scientists] are just trying to think of an excuse for what God created and trying to think of an explanation.

Interviewer: Do you think that the study of evolution conflicts with what you were raised to believe?

Student: Yes, um, because, what I basically believe is that, well okay, God created the world and that when you, um, God created the world for us to live on in one way or form. People when they think of evolution are concentrating on what God gave us and not on God.

Interviewer: Do you know what natural selection is?

Student: Kind of, but, um, it is when Darwin...about when he went to the different islands to find different plants and animals.

Interviewer: Do you think that natural selection occurs on a day to day or daily basis and could that have resulted in some of the species diversity that we see?

Student: I think that some new species have been created but I think that they all started out that way. I don't think that apes could mutate to birds. But I think that a type of bird starts and then some different species of the bird can..and I think that we can have different types of people like we do.

Interviewer: Okay. Thanks.

Quick Creation ("Scientific Creationism")

This position on the continuum has received much attention in the past 25 years. There have been numerous attempts to incorporate "scientific creationism," "intelligent design," "sudden appearance theory," etc. into the science curriculum. Quick creationists are Biblical literalists who accept evolutionary change only within "kind," account for geological change through the "great flood," and view the Earth as being very young. Fifteen students were categorized here. An example interview transcript is provided below:

Interviewer: Have you studied evolution before in class?

Student: No.

Interviewer: Not even in biology?

Student: Yeah, in biology yeah.

Interviewer: What are your perceptions about evolution?

Student: I don't believe in it.

Interviewer: What factors influence your attitudes about evolution?

Student: I don't have any.

Interviewer: Does the study of evolution conflict with what you were taught to believe at home?

Student: Yes.

Interviewer: How?

Student: Well, by what we were taught at home, God was the almighty creator. So evolution doesn't make sense at all.

Interviewer: Does the study of evolution conflict with your personal belief system?

Student: Yes.

Interviewer: And how do you cope with that when you are studying evolution?

Student: I pay attention but then I just don't believe what they say even although they have theories.

Interviewer: Do you feel that evolution should be taught in high school science classes?

Student: Yeah.

Interviewer: Can you explain to me why?

Student: Well because most people believe in evolution and they want to learn more about it. So they can be taught earlier, instead of so late.

Interviewer: Thank you.

Lacks Knowledge:

The final position is used to categorize students who claim to know so little about evolution that they choose not to voice an opinion. Fourteen students were classified in this category. An example interview is:

Interviewer: Have you studied evolution before in class?

Student: I don't know what evolution is.

Interviewer: You don't know what evolution is?

Student: No.

Interviewer: Natural selection, the origin of species does any of that ring a bell for you?

Student: No.

Interviewer: It doesn't?

Student: No.

Interviewer: Have you ever heard of Charles Darwin?

Student: Yes.

Interviewer: He talked about the study of evolution and a lot of the work he did was on evolution. Do you remember any of that from biology?

Student: No, I don't.

Interviewer: Thank you.

Summary and Discussion

Overall the students who participated in this study did not comprehend the full scope of evolutionary theory (e.g., natural selection, common ancestry/descent, multiplication of species, gradualism, and change over time). When the students defined evolutionary theory, they most commonly focused their responses on common descent and/or human evolution. This is evident because sixteen students defined evolutionary theory using the phrase "man evolved from monkey or ape." There is also a tendency for students to use anthropomorphic terms, teleology, vitalism, etc. in their definitions (e.g., evolution as a conscious process based on the needs of the organism).

Students' overall perceptions of evolutionary theory are varied. Of those interviewed, 35% generally accept evolutionary theory as a scientific concept (categories I-III), 31% indicated they did not accept any part of it (category V), 6% accepted it with conditions (category IV), while 29% lacked knowledge or were unsure of their level of acceptance (category VI). Those individuals who accepted evolutionary theory with conditions indicated they did not believe all of the theory. In spite of the fact that only 35% of the students accepted evolutionary theory, nearly 80% of the students indicate that it should be taught in high school (67% with no additional commentary; 13% with specific conditions) and 4% (only two students) indicated that it should not be taught. Several of the students, among those expressing conditions under which evolution should be taught, said that evolution should not be taught as fact. Another individual said that students should be separated and taught differently based of their acceptance of evolutionary theory. Sixteen percent of the students did not have an opinion on whether it should/should not be taught.

Despite their perceptions and apprehensions, the students in this study clearly indicated that it was important to study evolutionary theory. The most frequent reasons given for studying it were: a) it is important to know because it is part of science, b) for future use, and c) because it shows how we might have gotten here.

Numerous factors shape students' attitudes about evolutionary theory. The most frequently mentioned factor was theological the Bible, God, religion, and church. The second most frequently mentioned factor was personal relationships parents, teachers, friends, and school itself. Other factors mentioned were the media, evidence for evolutionary theory, and flaws or lack of proof for evolution.

Several conclusions can be made about the students in this study. A majority of the students do not accept evolutionary theory or know very little about it. The students are willing to take a stand, nonetheless, on whether evolutionary theory should be taught with little or no knowledge about what it is or is not. Students generally express a desire to learn more about scientific theories. Finally, religious belief is a factor that strongly shapes students' attitudes and acceptance of evolutionary theory.

Content analysis of the students' interview data revealed that many students view evolutionary theory in dualistic terms (Perry, 1970) the theory is either accepted or rejected based on an appeal to authority (God, church parents, teachers, etc.). This inference is consistent with findings reported by Demastes, Good, and Peeples (1995). Students categorized as gradual creationists (theistic evolutionists) and progressive evolutionists (limited evolutionists) are, however, beginning to transform their dualistic view of evolutionary theory. The transformation in question is away from a dualistic view (right-wrong) toward an attempt to bridge religious beliefs with their knowledge/understanding of the logic of science in other words, students begin to use more logical approaches. This is a very important step for students in their cognitive development. In taking this step students gain the ability to examine two seemingly opposing views, evolutionary theory and religious beliefs, gain knowledge about one without finding it a necessity to reject the other. This inference is consistent with the views expressed by Smith and Scharmann (1999), Scharmann and Block (1992) and Nelson (1986).

Lawson, Drake, Johnson, Kwon, and Scarpone (1997) further suggest that even among individuals classified as formal reasoners in Piaget's classic four-stage theory (Piaget and Inhelder, 1969) there may exist a sub-continuum of individuals. Lawson et al. (1997) assert a possible continuum running from individuals capable of performing hypothetico-deductive reasoning but not possessing a capacity to comprehend the abstractions often necessary to understand science theories to those who possess true theoretical reasoning ability. This line of inquiry holds promise to potentially delineate the nuances required to move students past simple knowledge of science to a richer understanding of the power and limits of those tools we call scientific theories.

Implications for Instruction

When dealing with a potentially volatile topic such as evolutionary theory, teachers should take great care not to alienate students (Smith, 1994; Smith & Scharmann, 1999). An alienated student will not learn. It is evident from this study (and others) that students already possess many different views of evolutionary theory that potentially impede rather than facilitate their acquisition of scientifically literate information. In addition to activities that increase logical reasoning skills (consistent with the Lawson studies), students should be provided with inquiry- based activities (consistent with the "Teacher" curriculum commonplace) that challenge their prior knowledge of evolutionary theory (National Academy of Sciences, 1998; Mead & Scharmann, 1994; Jensen & Finley, 1996). Such activities coupled with accurate conceptual information on evolution (consistent with the "Subject Matter" curriculum commonplace) may enable students to begin to reconstruct their own knowledge of evolutionary theory. This non-alienating approach will include students and give them some ownership in their education while allowing them to begin to question their attitudes about a topic. Such a suggestion is consistent with the "Learner" curriculum commonplace as delineated by Schwab (1973).

Once the topic of evolutionary theory is initiated, activities should be included that encourage students to develop and share their personal perceptions and scientific explanations with classmates (Dagher & BouJaoude, 1997; Scharmann, 1990; Scharmann, 1993). This can be achieved with periodic group discussions in which all participants are allowed to present their views and compare them to both other students' as well as professional scientists' views. This approach does not seek, as a learning outcome, to change students' beliefs; instead, it aims to prepare students for future science courses and future dealings with evolutionary theory. Acquisition of knowledge is not a one step process rather it is long term.

During this entire process teachers should keep in mind that they are educating the "whole " student (consistent with the "Milieu" commonplace); consequently, not only are they dealing with students' prior knowledge they are also dealing with students' emotional states and community pressures factors that influence everything students do. Therefore, the ultimate goal of high school instruction involving evolutionary theory might be to challenge dualistic views and allow students to bridge their cognitive and social-personal realms including their religious beliefs.

In other words, we need to strive to provide learning opportunities that encourage high school students to find their own 'place to stand' between what many of them perceive to be an 'evolution vs. creation' choice. This 'place to stand' is similar to "positioning the learner for the next step" (Duschl & Gitomer, 1991). Positioning learners to take that next step is crucial if we are to promote a more adequate understanding of the nature of evolutionary theory and why biologists consider it to be a powerful unifying theme for study in the biological sciences. If we fail to do this, at best we risk students memorizing what they think we want to hear. Worse still, we risk alienating their future study of the biological sciences. Finally, worst of all, we continue to perpetuate a public misunderstanding of evolutionary theory among future adults.

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Note:

[1] Schwab is careful to note (pp. 504-505) that equal but still separate commonplaces can fall just as short of the synthesis necessary to achieve desired curricular outcomes as would the omission of any one of the critical four commonplaces.

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