

REFLECTION ON THE DIFFICULTIES OF TEACHING  
EVOLUTION IN HIGH SCHOOL BIOLOGY

by

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(Under the Direction of Norman Thomson)

ABSTRACT

From the time Darwin first published his book, *The Origin of Species*, there has been conflict. Casualties of the conflict are, perhaps, most highly noticed in terms of edification in our schools, but the consequences expand to a much larger scale. While most school systems claim to support national and state mandated science standards and accept the principles of evolution there are many schools, and certainly individual teachers, who limit their instruction of evolution or do not teach it at all. There is evidence to support a lack of understanding of evolution as well as a lack of understanding of the nature of science on the part of teachers.

This study is designed to investigate the level of acceptance of evolution as a topic to be taught and to determine why there is delineation at a point where it is not accepted. Of great interest is the relationship between the acceptance of evolution and understanding of the nature of science by the teacher. More specifically, this study looks at (a) how understanding the nature of science affects a teacher's acceptance of evolution; (b) how understanding the nature of evolution affects a teacher's acceptance of evolution; (c) how a change in the understanding of the nature of science affects a teacher's acceptance of evolution; (d) to what extent teachers understand evolution and the nature of science; (e) how understanding the nature of science affects a teacher's willingness to teach evolution. This study is a product of personal interest and professional concern for a documented problem in science education. There have been studies directed at measuring the understanding of the nature of science as well as those measuring acceptance of evolution. This study combines the two concerns using both quantitative and qualitative data to illustrate that further understanding of the nature of science contributes to understanding and acceptance of evolution and willingness to teach evolution and it makes available some reasons why.

INDEX WORDS: Evolution, Nature of science, Standards, Teacher, Darwin, Science, School, Willingness, Acceptance.

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## DEDICATION

I dedicate this dissertation to my wife Celita for her patience, support, and encouragement throughout this project. She, Emily, and Anna have been and continue to be the foundation for the successes in my life.

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## CHAPTER 1: INTRODUCTION

### Personal Perspective

In reading the Bible, there are often stories told that contain miraculous events that give credit to the “will of God” and offer no scientific explanation. As a “good Baptist” those things are accepted as true and accurate because “the Bible tells us so”. The foundation of religion seems to be built on such faith. If it were not for faith in unscientific things there would be no religion because faith is what religion is about. On the other hand, from the objectivist’s epistemology and the positivist’s theoretical framework, science is about quantification in description. Science is based on measurable, reproducible facts. As I grew up I knew little about the nature of science and how or why science was different than religion. After all it seemed that there was one version of how time and life began versus another and there were books to describe both, so you just look at the information presented by both and make a decision. From a scientific standpoint, the story of man seemed to have as many questions and problems as the religious point of view. After all, over and over again I had learned that nothing in science is absolutely certain. Much of science was uncertain and because the scientific community was uncertain it seemed fair to choose the religious side since I was made to feel that a choice had to be made. Not only did I have to make a decision, but also, if I made the “wrong” decision I would pay the ultimate, eternal penalty. Now the idea of going to hell hardly seemed to fit the Baptist description of a loving, caring God, none-the-less if you made the choice for science, you were going to hell for eternity. As a result, evolution was not talked about much as I grew up, nor was it supported as I began

to teach. In fact, in my first year teaching, I was told not to talk about evolution because the trouble that it would cause was not worth trying to teach it. This directive was administered because on the first day of class as I read through the syllabus, I mentioned evolution as part of the curriculum. One of the students took the syllabus home and showed his mom. She called the principal to say that she didn't want her son taught that he came from monkeys. For ten more years evolution in my class was given very low priority. This was in part because of the experience with that first parent, but also because of an internal conflict. The conflict was between the postulated inadequacies of science and evolution and the literal interpretation of the Bible.

As I began to do more and more research, and as I learned more and more about what science is and how it works, I found answers. The answers did not directly fulfill religious or even scientific doubts, instead the answers were more centered on how science was different from religion and why the two did not completely oppose one another. There are particulars that conflict with one another in certain religions, but even at that, I found that science and religion are not a one or the other choice. If there is inconsistency in either it doesn't call for its dismissal. In this discovery came a peace of mind or resolution that allows me a peaceful coexistence of both.

Evolution is supported by unrequited facts. These facts are used as measures of accuracy of past as well as future proclamations. If they don't fit, they are not used. Religion on the other hand is based on faith, love, emotions, and spiritual needs. All these things are real parts of everyday life, but unlike science they are not based on quantifiable, testable facts. Science is used to explain things based on very few rules or laws. Each of these laws describes relationships that are measurable and are supported

by facts. The facts that support these laws are pieces of information that are repeatedly supported by evidence. Religion is not based on evidence that is quantified. Religion is taught on faith and the stronger the faith, the stronger the religion. It does not depend on scientific facts.

The understanding of the nature of religion and the nature of science are critical to my ability to not only teach the theory of evolution, but also to have conviction when promoting the idea that evolution is a real process. It is a process that has validity and should not be compared to religious representations for changes in life forms over time. This personal revelation has been a source of inspiration for me to research the relationships other teachers have between their understanding of the nature of science and their acceptance of evolution.

#### Significance of the Problem

When asked his opinion of the (1925) Tennessee law denying the teaching of evolution in the high school classroom, Albert Einstein replied, “Any restriction of academic freedom heaps coals of shame upon the community” (Kuh, 1925, p.10).

The fundamental validity and significance of evolution is not subject to debate among the vast majority of mainstream scientists (Gross and Levitt, 1994). Despite this fact, less than one-half of American adults believe that humans evolved from earlier species (National Academy of Sciences, 1998a). As recently as September 2002, Cobb County’s (Georgia) school board chose unanimously to allow science teachers to teach alternative propositions for the origin of ‘man’. “Thirteen science books used in Cobb middle schools and high schools already carry stickers that tell students that evolution is a theory, not a fact, and should be critically considered” (McDonald, 2002).

The declaration for evolution was first postulated by Charles Darwin over 100 years ago and since supported through research evidence “from astronomy, physics, biochemistry, geochronology, geology, biology, anthropology, and other sciences” (National Research Council, 1996, p. 125). More than one-half of Americans say they would like to have creationism taught in public school classrooms (Rensenberger, 1994). This is notwithstanding the fact that the United States Supreme Court has ruled, in *Edwards vs. Aguillard*, 1987, that creation science is a religious idea that cannot be part of a public school curriculum (Berra, 1990). There is, therefore, a need to address this incongruence between science, education, and religion in order that science education will be allowed to provide the best possible scientific information.

The inability to designate distinct parameters for each of the aforementioned factors--science, education, and religion--is of great concern from a biology education standpoint because a lack of distinction promotes not only incognizance, but also resistance to learning. This conflict, in-fact, deteriorates the very base of biology education by denouncing the foundation of biology - the evolutionary theory: “Nothing in biology makes sense except in the light of evolution” (Dobzhansky, 1973, p. 125).

Much opposition to evolutionary theory is grounded in metaphysical or religious beliefs; however, it seems that many individuals associated with religious groups in the United States are unaware of position statements offered by their religion. This is evidenced by the number of people mentioned earlier who advocate creationism be taught in the public schools. Matsumura reports in *Voices for Evolution* (1995), that Roman Catholics, Jews, Episcopalians, Methodists and many other religious groups have declared that either creationism should not be taught in the high schools or that evolution

is not in conflict with their mission, or in some cases, both. Yet as stated earlier, a large number of people in the country still, ironically, refuse to accept or allow the tenets of evolution be taught in public schools because of a perceived conflict with their religious beliefs.

Law or no law, many teachers in the South (1925) were forbidden from teaching evolution. Most others simply ignored the topic.... After the Scopes trial (1925) no other lawsuits to revoke anti-evolution were filed until Susan Epperson of Arkansas challenged the ban on evolution in 1965.... After the Scopes trial there were some defeats for the anti-evolutionists such as the Education Association of Southern Methodists opposed 'all legislation that would interfere with the proper teaching of science in American schools and colleges' (Moore 1998a, p. 573).

Teachers reportedly fail to cover evolution for a number of individual reasons. Teachers run out of time (Nickels, 1987), or they lack the knowledge or understanding of the topic (Lawton, 1998). Some of these teachers lack the ability to scientifically differentiate facts, theories and laws, and/or they lack the understanding of scientific inquiry (Linhart, 1997; Osif, 1997; Tatina, 1989). Other restrictions on the way evolution is taught might be traced a little further back to include restrictive Board of Education policies, opposition of religious groups, pressure from local school administration, community member protests, and/or inadequate texts (Eglin, 1983; Roelfs 1987; Shankar & Skoog, 1993; Skoog, 1970; Tatina, 1989; Troost, 1967; Zimmerman, 1987). Further complicating the issue, we must consider a common lack of understanding of the nature of science by many teachers. Without an adequate understanding of the nature of science it could be very difficult to defend ones' position. In *The Teaching of Evolution and the*

*Nature of Science* (National Academy of Sciences [NAS], 1998a) there are questions that are identified as arguments likely to be made from the creationists' perspective. The responses to these arguments can be more easily explained by understanding the nature of science. It follows that if teachers do not know the nature of science, they will have difficulties explaining why one explanation is used in the science classroom while another is unacceptable. Perhaps understanding the nature of science would allow for delineation between religion and science (NAS, 1998a).

### Research Questions

Teachers are guided to teach evolution as a part of their science curriculum. The National Science Standards (NAS, 1998b) were established to provide a framework of minimal information that students should be proficient in before moving on to the next level. According to these standards there are unifying concepts and processes that should be present from kindergarten through grade 12.

Unifying concepts and processes include:

- Systems, order, and organization.
- Evidence, models, and explanation.
- Change, constancy, and measurement.
- Evolution and equilibrium.
- Form and function (NAS, 1998b, p. 104).

The Georgia Department of Education has developed the Quality Core Curriculum [QCC]. Part of this curriculum for biology is *Theories of Origin* in which there are three standards that are specifically tied to evolution and natural selection.

Theories of Origins:

Standard: Describes and applies concepts of origins.

- Explains historical and current theories of origins. i.e. Big Bang, evolution, etc.
- Compares micro and macroevolution.
- Explains natural selection and how it is affected by environmental change (Georgia Department of Education, 2003).

Despite the fact that these are part of not only national, but also state standards, teachers still have numerous reasons for not covering some, if not all, evolution topics. Of interest, with regard to this subject, are a number of possibilities for why all aspects of evolution are not taught to all students.

#### Statement of the Problem

The purpose of this study is to compare high school teachers' willingness to teach evolution before they were taught a unit on the nature of science with their willingness to teach evolution after the unit taught on the nature of science. Also of interest are the teachers' noted problems associated with teaching evolution and ways they have dealt with them in the past.

#### Questions

1. How does understanding the nature of science affect a teacher's acceptance of evolution?
2. How does understanding the nature of evolution affect the teacher's acceptance of evolution?
3. Does a change in understanding of the "nature of science" affect a teacher's acceptance of evolution? (Acceptance was measured as a score on the Likert scale on the MATE Plus.)

4. To what extent do teachers understand evolution and the nature of science?
5. How does a change in understanding of the nature of science affect a teacher's willingness to teach evolution?

The researcher determined willingness of the participants by analyzing the transcripts of the interviews and by a description of the concepts the participants would teach as indicated on the MATE Plus. Willingness is described by the researcher based on the following ascribed tenets of evolution:

1. An old earth means the earth is over 4 billion years old.
2. Evolution means the lineage of organisms' changes over time.
3. Gradualism means differences between organisms accumulate by a series of small innumerable steps through intermediate forms.
4. Common descent means species diverge from common ancestors.
5. Evolution is a scientific process.

## CHAPTER 2: LITERATURE REVIEW

### Why is Teaching Evolution Important?

Rutledge and Warden (1999) write, “Evolutionary theory is the central and unifying theme of the discipline of biology. Its broad explanatory power allows for the investigation of a wide range of intriguing biological questions and provides an underlying framework to the discipline, bringing meaning to the tremendous array of life’s traits and behaviors” (p. 13). Because of the evolutionary theory’s explanatory and unifying powers, scientific and educational organizations have formally recognized it as the organizational framework of biology and have called for instruction in evolution to be converse to its station in biology (American Association for the Advancement of Science, 1989; National Association of Biology Teachers, 2003; NAS 1998b). Results from several studies, however, suggest that instruction in evolutionary biology at the high school level has been absent, cursory, or fraught with misinformation (Eglin, 1983; Roelfs, 1987; Shankar & Skoog, 1993).

### The Nature of Science and of Change

There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning, endless forms most beautiful and most wonderful have been, and are being evolved (Darwin, 1859, p. 459).

In considering Ptolemy’s model of the universe there were certain inconsistencies. “The movements of the moon and stars, however, are not precisely synchronized with

those of the sun. The moon is slower by about one hour per day. The stars remain almost the same on successive nights...and in fact take a full year for the stars to return to their previous position.” (National Academy of Science [NAS], 1998a, p. 27). According to NAS (1998a), surrounded by the stars there were ‘wanderers’ that did not move in unison with the other stars. This developing intricacy stimulated some of the leading astronomers of the 16<sup>th</sup> and 17<sup>th</sup> centuries, such as Copernicus, Kepler, and Galileo, to make even more precise recordings of and deliberative interpretations of the movements of the heavenly bodies. As a result they were able to replace a complex and confusing explanation with a simple one: the sun, instead of the earth, is at the center of a ‘solar system,’ and the earth revolves around it. This bold departure from past thinking, due mainly to the insights of Copernicus (1473 – 1543), simplistically yet dramatically changed the picture of the then known universe. The view of Christianity over most of its history, based on a literal interpretation of the Bible, was that the earth is the center of the universe around which all heavenly bodies revolve. Because of the commitment to religious dogma, Galileo was told to abandon his beliefs (heliocentrism), and he later was tried by the Inquisition and sentenced to the equivalent of house arrest. The Church held that his views were dangerous to faith. As a result of the steady amassing of evidence, the scripture embedded interpretation of celestial movements gave way to the naturalistic explanation, and it is now accepted that night and day are the consequences of the rotation of the earth on its axis.

“People refused to abandon Aristotle’s purposeful and perfect universe, as well as Ptolemy’s positioning of Earth in the center of the universe, despite Galileo’s evidence against both. The most personal aspect of the secularization of the universe – that is,

Darwin's non-purposeful explanation of life's diversity – has generated the most opposition because it addresses some of our most basic questions: where we came from, how life developed, and how we're related to other organisms" (Moore, 1998c, p. 486).

### Changes in Ideology

Charles Darwin is perhaps the most influential biologist ever. Ernst Mayr (2000) said, "Great minds shape the thinking of successive historical periods. Luther and Calvin inspired the Reformation; Locke, Leibniz, Voltaire and Rousseau, the Enlightenment. Modern thought is most dependent on the influence of Charles Darwin" (p. 79). Over the past 150 years many biological ideas were in discord with what everyone assumed to be true. The acceptance of these ideas required an ideological revolution. Charles Darwin is responsible for such a revolution (Mayr, 2000). Darwin's discoveries and publications not only influenced the way science looked at biology but the way the world looked at science. Mayr (2000) went on to say, "There was a belief in cosmic teleology, with a purpose and predetermined goal ascribed to everything in nature. Modern science, however, is unable to substantiate the existence of any such cosmic teleology" (p. 82).

### The History of Biology

For the science of biology, the theory of evolution provides a unifying framework within which many diverse facts are integrated and explained. For this reason, an understanding of modern biology is incomplete without an understanding of evolution (Bishop and Anderson, 1990).

Prior to 1900, there were four distinct branches of biological sciences. Those branches were Natural History, Zoology, Botany and Physiology. After the beginning of the twentieth century all of these individual branches were combined into one, which was

called Biology (Cretzinger, 1941). “Traditions in education are very strong so that change normally meets with great resistance” (Pulliam, and Van Patten, 1995, p. 97). Cretzinger (1941) wrote that in the earlier teaching of biology, prior to 1900, abiogenesis, or the belief that life came from non-life, or for some the idea that God created life as it is in today’s form, out of the dust of the earth; ran through the textbooks as an accepted fact until the latter part of the century. These ideas slowly lost popularity because of the gradual acceptance, by textbook writers, of the germ theory, which was formulated by Wolff in 1759 and later demonstrated by Pasteur in 1861. Around 1910, biogenesis finally began replacing abiogenesis in the textbooks when the work of Pasteur and Wolff was “accepted as valuable information for children of secondary school” (Cretzinger, 1941, p. 312). Some things were accepted rather quickly, such as the Theory of Epigenesis (life from life) which was formulated by Von Baer in 1850 and was of a nature that made it acceptable to secondary school textbook writers as early as 1851 (Cretzinger, 1941). On the other hand “Cell Theory” had been around since Hooke discovered the ‘Little Box’ in 1665 but was not formulated until the work of Schleiden and Schwann came to light in 1838 –1839. “Cell Theory” did not get into the secondary school texts until after Mohl discovered the protoplasmic content of the cell in 1846. “That new discovery made the Cell Theory acceptable to the textbook writers who soon recognized it as valuable for secondary school science content (Cretzinger, 1941, p. 312).

#### Evolution in Science Education

“The ‘Laws of Heredity’ were first formulated by Gregor (Johann) Mendel about 1860, but were kept in the background by textbook writers until about 1900 when De Vries succeeded in demonstrating their value to biology. The theory of evolution was

finally formulated by Charles Darwin in 1858 but it too 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). Within a few years of its formal introduction, evolution was introduced into some textbooks in one form or another, however the presentation of the information was entirely up to the teacher or the community. According to Cretzinger (1941) at the turn of the 20<sup>th</sup> century there was objection to teaching evolution in the public schools. There were two conflicting views. The Vitalists believed life in all forms was planned and created by God while the Mechanists believed movements in animal life are caused by either an outside influence or by chemical content of the cells in animals. “That opposition seemed to have its effect upon textbook writing for various states, particularly in the South” (Cretzinger, 1941, p. 312). Evolution was supported with a great deal of evidence and with the use of anthropomorphic statements, which gave man-like characteristics to organisms, and teleological statements that suggested some sort of design. This could easily allow for the attribution of the changes they represented to God. Teachers were therefore able to teach this new theory if they chose to do so. “There was no law to prevent the theory of evolution from being taught in any state until 1925, when Tennessee took the first legal stand against it. Until that time, those who boldly opposed it did so entirely from the standpoint of their religious beliefs” (Cretzinger, 1941, p. 313).

### The Battle for Evolution

Evolutionary theory postulates that man has evolved over time and shares a common ancestry with all other life on earth. In 1859, Charles Darwin published “The

Origin of Species”. In 1860, just after Darwin’s book was published, he was asked about the theological implications of his book (Larson, 1997). He responded by denouncing the likelihood of a God due to the perceived random and cruel acts involved in natural selection and, nature in general. “For some conservative theologians and pious scientists, this represented the ultimate challenge of Darwinism to a Christian worldview: Beneficial variation was random and natural selection was cruel” (Larson, 1997, p.17). In 1874, Charles Hodge wrote a book titled, *What is Darwinism?* to which he replied, “It is atheism and utterly inconsistent with the scriptures” (Hodge, 1874 p. 173). Hodge and some other church leaders raised an alarm against teaching evolution, particularly within seminaries and denominational colleges (Larson, 1997).

Evolutionary theory, as such, was not of great concern nationally because it did not directly appear in American high school education at the time of the antievolution crusade. It had been incorporated into leading textbooks during the late nineteenth century, but with a theistic or Lamarckian twist that reflected prevailing scientific opinion (Larson, 1997). Textbooks typically became more Darwinian in the new century (1900), especially after the newly organized field of biology began to replace separate courses on botany and zoology in the high school curriculum. Evolution was a way to tie many concepts from individual life science branches into one unifying biological theme.

There were movements that arose from the idea of natural selection. One of these was Eugenics. Eugenics is a theory that science can improve the human race through heredity. By 1935, thirty-five states enacted laws to compel the sexual segregation and sterilization of certain persons viewed as eugenically unfit, particularly the mentally ill and retarded, habitual criminals, and epileptics (Larson, 1997). In Hunter’s *Civic Biology*

(1914), he stated, “If such people were lower animals, we would probably kill them off to keep them from spreading. . . . Humanity will not allow this, but we do have the remedy of separating the sexes in asylums or other places and in various ways preventing intermarriage and the possibility of perpetuating such a low and degenerate race” (p. 263). This attitude fueled the fire of antievolutionists who proclaimed eugenics as “the damnable consequence of Darwinian thinking” (Larson, 1997, p. 27). William Jennings Bryan was one of these fundamentalists who had a recognized voice, a political following and a legal background.

#### Evolution in the Courts

“This monkey mythology of Darwin is the cause of permissiveness, promiscuity, pills, prophylactics, perversions, pregnancies, abortions, pornotherapy, pollution, poisoning, and the proliferation of crimes of all types”. -Braswell Dean, Chief Justice of the Georgia Circuit Court of Appeals, 1981 (Moore 1999, p.10).

Bryan warned that, “Darwin’s dreadful law of hate was replacing the Bible’s divine law of love as the origin of humanity” (Bryan, 1909, p. 269). Bryan developed a crusade against evolution and in 1925 was successful in helping outlaw the teaching of evolution in Tennessee public schools. While a recorded victory for fundamentalists, it inspired many evolutionists to pursue a greater agenda and created an even greater division between the two groups.

By 1928, Louisiana, Texas, and Arkansas had banned the mention of evolution in any state-approved textbooks thus taking evolution out of their schools. Then, in 1948, religious instruction was barred from public school and in 1963 compulsory Bible reading was barred which took religion out of the schools. In Arkansas:

As recently as 1968 in *Epperson vs. Arkansas* the Court ruled that an anti-evolution statute was unconstitutional since evolution is a science not a secular religion and students cannot be restricted from such information. Thirteen years later, on March 19, 1981, Governor Frank White signed the Balanced Treatment for Creation Science and Evolution Science Act into law. In 1982 a Federal court ruled it unconstitutional on grounds that it passed to advance religion. (Pulliam and Patten, 1995, p. 159).

In *Edwards vs. Aguillard* (1987), a Louisiana statute was rejected on similar grounds (Pulliam and Patten, 1995, p. 159).

According to Moore (1999) in 1970 there was the first lawsuit initiated by creationists. In that case, a mother sued the Houston Independent School District, claiming that the schools had violated her daughter's constitutional right by teaching evolution "without critical analysis and without reference to other theories which purport to explain the origin of the human species" (p. 10). The judge responded by saying, "Teachers of science in the public schools should not be expected to avoid the discussion of every scientific issue on which some religions claim expertise" (Moore, 1999, p.10).

#### What is Science?

During the late classical and medieval periods, thinkers preferred to rely on the authority of ancient writers such as Aristotle and Euclid rather than modifying or correcting earlier theories with further observations of their own (Killheffer, 1993).

According to Zitzewitz and Neff (1995):

One of the first European scientists to claim publicly that knowledge must be based on observations and experiments rather than ancient books was Galileo Galilei

(1564-1642). He questioned the belief that Earth is the center of the universe. He doubted Aristotle's views on Physics, especially the idea that objects of large mass fall faster than objects of small mass.

In describing science, Mayr (1997a) claims that one of the most characteristic features is its openness to challenge. Science itself is not final form. Whatever science says is the result of an accumulation of observed confirmable data, but it is not the final answer.

Rather than speaking of governing "rules," science educators most often use the phrase "nature of science" (NOS) to describe the interplay of disciplines informing science education about what science is and how it works (Clough 2000 p. 13). Clough (2000) also says,

Students' and teachers' admirable belief in fair play sometimes spills over to how they feel science should work. However, fair play doesn't mean giving credence to all ideas. Discredited ideas such as Aristotelian physics, astrology, flat-earth, geocentricity and a young Earth are not taught today, even though a significant portion of the public may believe those ideas. Fairness is not a criterion for selecting what science content is accepted as good knowledge. The scientific community interpreting the best available evidence, not public opinion polls, decides what is good science! The public certainly has a say in technological applications that may affect society, but it is not in a position to judge the validity of scientific knowledge (p. 14).

As man has categorized and grouped all things in the world, and even out of this world, he has made them fit his order. Even in the time of the Pythagoreans and Plato,

the general concept of the diversity of the world emphasized its invariance and stability. “This viewpoint is called typology, or essentialism” (Mayr 2000, p. 81). Many people are unaware of the way science really works and as a result, Clough (2000) says,

Perhaps the most counterintuitive notion from the nature of science is the well-supported view that unsolved puzzles and seemingly refuting evidence do not always result in rejection of an idea.... Many historical examples can be found where contradictory data did not result in abandonment of ideas that we today accept as good science (Chalmers 1982; Kuhn 1996). This confidence, rather than seeing the anomaly as falsifying a well-supported idea, was key in the prediction and discovery of Neptune in 1846 (p. 15).

#### Studying the Past

According to Mayr (1997b) biologists try to answer questions about unique past events, such as ‘Why are there currently no hummingbirds in the Old World?’ or ‘Where did species *Homo sapiens* originate?’ and these events cannot be investigated using our universal laws. Biologists study all the known facts relating to the particular problem, infer all sorts of consequences from the reconstructed constellations of factors, and then attempt to construct a scenario to explain the observed facts of this particular case. “In other words, they construct a historical narrative” (Mayr, 1997b, p. 11). Historical narratives have explanatory value because earlier events usually make a causal contribution to later events. For example, as the dinosaurs at the end of the Cretaceous became extinct they left many opportunities for a large number of ecological niches to develop and as a result provided circumstances that allowed proliferation of the mammals during the Paleocene and Eocene. “The most important objective of a historical narrative

is to discover causal factors that contributed to later events in a historical sequence” (Mayr, 1997b, p. 12). In keeping with what we know about the nature of science, we know that proving categorically that a historical narrative is ‘true’ is never possible. The more complicated a system was, and the more interactions there were within the parts of a system the less likely interactions are to be determined by observation and the more likely they will be inferred. “The nature of such inference is likely to depend on the background and the previous experience of the interpreter; therefore, not surprisingly, controversies over the ‘best’ explanation frequently occur. Yet every narrative is open to falsification and can be tested again and again” (Mayr, 1997b, p. 11).

#### Evolution Exemplifies The “Nature of Science”

According to McComas, Clough, and Almazroa (1998), a better understanding of scientists and the scientific community will enhance an understanding of science’s strengths and limitations; interest in science and science classes; social decision making’ instructional delivery; and the learning of science content. Science teachers have an inaccurate view of the nature of science (Carey & Strauss 1970) and when students and teachers are compared, they both seem to score equally poorly on nature of science assessments (Miller 1963, Schmidt 1967). For over 30 years research on the nature of science has found that regardless of how it was measured science teachers do not appear to have adequate conceptions of the nature of science and the best way to advance their understanding is either through instructing on the historical aspects of the scientific knowledge or by giving NOS direct attention (Lederman, Wade, & Bell 1998).

“Scientific literacy is a primary aim for science education in the 1980’s. An important component of scientific literacy is an adequate conception of the nature of

science” (Lederman, 1990, p.1). Mayr (2000) explains why evolution exemplifies NOS. He says,

The truly outstanding achievement of the principle of natural selection is that it makes unnecessary the invocation of ‘final causes’ – that is, any teleological forces leading to a particular end. In fact, nothing is predetermined. Furthermore, the objective of selection even may change from one generation to the next, as environmental circumstances vary (p. 80).

Mayr (2000) goes on to say that there are many biologists and philosophers that deny the existence of universal laws in biology. All regularities should be stated in probabilistic terms, as nearly all so-called biological laws have exceptions.

Susan Epperson gave an account for science and religion that was similar to Mayr’s. Epperson is responsible for an official challenge to Arkansas anti-evolution laws in 1968. Hers was the first legal challenge to the anti-evolutionist since the Scopes’ trial of 1925. The result of her case was a change in the law in Arkansas that opened the door for other states to change their policies. In an interview with Randy Moore, Susan Epperson said,

Though they refer to their arguments as science, it seems to me that the creationists have a dogma already in place and are willing to see only evidence to support that, while ignoring evidence to the contrary. Science, on the other hand, seeks answers from the physical world and lets the evidence lead where it may, without having to prove preconceived notions. Creation science does not seem to have much to do with searching out the evidence or with real science. I find their denial of valid

scientific research and evidence, and their claims to have proven evolution wrong, insulting to me as a Christian (Moore, 1998, p. 646).

#### Facts, Theories, Laws and The Nature of Science

Moore (1998e) wrote, “John Scopes’ conviction in 1925 for teaching human evolution gave fundamentalists a victory, just as William Jennings Bryan’s death gave them a martyr. Whereas some northern states quietly disposed of anti-evolution legislation after Scopes’ conviction, Mississippi and Arkansas passed their own anti-evolution laws.” (p. 650). Moore also remarked on William Jennings Bryan’s statements. Bryan used themes that were held tightly by the conservative supporters (e.g. that Christians have a right to control the public schools, that the Bible is true, that science breeds atheism). “Bryan repeated his claim that evolution is a ‘bloody, brutal doctrine,’ adding that (de Camp 1969): ‘Evolution is not the truth; it is merely a hypothesis...it is millions of guesses strung together’” (Moore 1998c, p. 571).

#### What’s the difference?

The National Academy of Sciences (1998a) says, “In science, explanations are restricted to those that can be inferred from confirmable data – the results obtained through observations and experiments that can be substantiated by other scientists. Anything that can be observed or measured is amenable to scientific investigation and explanations that cannot be based on empirical evidence are not a part of science” (p. 27). Science cannot depend on common sense. Common sense indicates that the sun does rise and set. Also to be considered is, the statements of science should never be accepted as ‘final truth.’ Instead, over time they generally become increasingly more accurate. In the case of heliocentrism as in evolution, the data are so convincing that the accuracy of the

theory is no longer a question in science (NAS 1998). “Understanding and using ideas without believing them to be (absolutely) true can be fruitful in many contexts. For instance, Kekule, a chemist given credit for suggesting a structure for benzene, in 1867, reportedly wrote, I have no hesitation in saying that from a philosophical point of view I do not believe in the actual existence of atoms...As a chemist, however, I regard the assumption of atoms as absolutely necessary” (Clough 2000, p. 16).

“Science is a particular way of knowing about the world. In science, explanations are restricted to those that can be inferred from confirmable data” (National Academy of Science, 1998, p. 27). In order to understand how science works there must be a consistency in the interpretation of essential terms. A primary source of confusion and misconception, in the world and even in science education, centers in part around four commonly misused concepts. The NAS (1998, p.5) identifies these concepts and defines them as follows:

Fact: In science, an observation that has been repeatedly confirmed (e.g. Older fossils are found buried beneath newer fossils).

Law: A descriptive generalization about how some aspect of the natural world behaves under stated circumstances (e.g. Law of Superposition).

Hypothesis: A testable statement about the natural world that can be used to build more complex inferences and explanations (e.g. If you dig deeper you will likely find older fossils).

Theory: In science, a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypotheses (e.g. Theory of Evolution).

According to Clough (2000) “The words theory, law, and hypothesis are frequently used in science classes, yet their appropriate meanings and relationships are rarely conveyed to students.... Interestingly, not only are laws not a higher form of scientific knowledge, but an understanding of laws is incomplete without a theory to explain them (p. 14).

### What is the Truth?

Mayr (1997b) said that the scientist searches for truth, but many people who are not scientists make the same claim. Not only are the concepts misrepresented, but their relationships are also misunderstood. A common misconception that is persistent in society is that substantiated hypotheses become theories, and that well substantiated theories that have stood the test of time become laws. In a study of eleventh and twelfth grade students, Ryan and Aikenhead (1992) found that 64% of the participants “expressed a simplistic hierarchical relationship in which hypotheses become theories and theories become laws, depending on the amount of ‘proof behind the idea’” (p. 571). “Ideas are not referred to as ‘theories’ in science unless they are supported by bodies of evidence that make their subsequent abandonment very unlikely” (NAS, p 5).

How do we know the earth spins and goes around the sun? It appears we are sitting still and that the sun goes around the earth. After all, the sun rises in the East and sets in the West; everyday! We know the earth is not the center of the universe because we have collected data and this data has allowed us to not only predict future events, but to also explain those of the past. This data has allowed us to predict future events with enough accuracy that we know exactly when the next solar eclipse, lunar eclipse, or visible comet will occur.

Futuyma (1995) states, “Evolution has, by now, the status of fact. It is one of the most important discoveries of science, and one of the most profound concepts in Western thought; so it is a sad irony that, a century after Darwin’s death, the creationists’ movement is stronger than ever, carried forward by the New Right’s rise to power. Part of the reason for this is that many people simply do not know any of the evidence for evolution, and still think of evolution as ‘just a theory,’ because scientists have not been very active in disseminating their ideas and findings outside the scientific community” (p. xi).

### Why Not Creationism?

“Science does not and cannot deny the existence of the supernatural. Explanations employing supernatural events and deities are beyond nature and, hence, beyond the realm of science. Science deals with the natural world, and, consequently, its explanations must be couched in natural expressions with no recourse to the supernatural” (Clough 2000, p. 15). Likewise, “creationists’ theory” is an oxymoron. Creationism arises from faith and should only be argued in those terms. Science has no position to argue terms of faith for any religion. Theories are supported by evidence and in scientific terms, there are no “facts” to support the creation position; therefore, it is not a theory, and it is not science.

### Why Science?

It is often with contempt that some creationists refer to science and evolutionists. In some cases there appears to be a need to avenge the findings of the evolutionists as if they are the enemy. “The greatest scientists want, above all, to discover truths about nature (in addition to acquiring glory, grants, and tenure and improving the lot of

humankind); they want to know. They hope, and trust, that the truth is attainable, not merely an ideal or asymptote, which they eternally approach. They also believe that the quest for knowledge is by far the noblest and most meaningful of all human activities” (Horgan, 1997, p.5).

The apparent lack of understanding of how science works on the part of many creationists is perhaps most frustrating to many who maintain evolutionary integrity. “Scientists have the ability to pose questions and resolve them in a way that critics, philosophers and historians cannot. Theories are tested, experimentally compared to reality and those that are found wanting are rejected. The power of science cannot be denied. It has given us computers and jets and vaccines and nuclear bombs, technologies that for better or worse have altered the course of history. Science more than any other mode of knowledge, literary criticism, philosophy, art, or religion gives durable insights into the nature of things. It gets us somewhere” (Horgan, 1997, p. 4). Scientific processes and understanding our living and non-living world have provided us with unimaginable gains in quality of life. The societies that have promoted this way of thinking have provided great gains in not only the life we live day to day, but also its duration. Gould (2001, p. xiii) says, “First truthful science is liberating in the practical sense that knowledge of nature’s actual mechanisms gives us the potential power to cure and to heal when factual matters cause us harm. When, for example, we know how bacteria and other disease-causing organisms evolve, we can understand, and find means to combat, the development of antibiotic resistance, or the unusual mutability of the AIDS virus.”

## The Roles of Teachers and Textbooks in the Context of Learning Evolution

People that have studied evolution and know the facts that support it, no longer question the validity of the theory of evolution (Mayr, 2000). “Likewise, most of Darwin’s particular theses have been fully confirmed, such as that of common descent, the gradualism of evolution, and his explanatory theory of natural selection... Darwin’s greatest contribution – he developed a set of new principles that influence the thinking of every person: the living world, through evolution, can be explained without recourse to supernaturalism; essentialism or typology is invalid, and we must adopt population thinking, in which all individuals are unique (vital for education and the refutation of racism)” (Mayr 2000, p. 83).

The noted importance of evolution in science education is published in abundance; however, resistance to its fundamental concepts is stifling. “Although evolution is the unifying theme for understanding life, it is being challenged-not by new discoveries, but by the evangelical zealotry of religious fundamentalists” (Moore 1998c, p. 486). These challenges from conservative groups are not only felt in the curriculum development, but are also seen in the way textbooks are written. From about 1925 until the early 1960s, biology textbooks, and thus most school science programs, typically did not include evolution. Although biology textbooks published in the early 20<sup>th</sup> century included presentations of Darwin’s ideas, the impact of John Scope’s conviction in 1925 was the virtual elimination of evolution from the school curriculum as the unifying idea for biology. (Bybee, 2002, p. 617).

In the decades that followed (the Scopes trial), evolution slowly reappeared in biology textbooks (religious quotations also appeared in many biology textbooks;

see Gabiner & Miller, 1974). However, the best-selling textbooks downplayed or ignored evolution. Pro-evolution books did not sell well, and the best-selling biology textbook (Baker and Mills' *Dynamic Biology*) did not include the word evolution. Indeed, that book even included an attack on evolution, likening Darwin's ideas with Lamarck's and noting that Darwin's theory was 'no longer generally accepted' (Gabiner & Miller, 1974). That attack on Darwin was followed by a tribute to God (Moore, 1998a, p. 574).

### Sputnik and Evolution

Before Sputnik (1957) science was taught mainly with knowledge as a product of science. After Sputnik the atmosphere changed, and there was greater concern for "methods of scientific research" (Trowbridge & Bybee, 1990, p. 273). However, science was presented from a "what", but not a "why" or a "how" disposition. Before Sputnik, high school teachers wrote textbooks, but afterwards the scientists were more involved in the writings and the textbooks became larger and more filled with facts. Teachers were forced to cover more information and students were then required to memorize huge amounts of data. There was little attention given to the logic of thought development and for interconnections of the disciplines, or how science works. As a result of this and into the more recent past the curriculum was the textbook and the goals were, by default, also those of the science texts. The textbook was seen as the authority on knowledge (Trowbridge & Bybee, 1990), and teachers are given liberties of requiring that only part be learned, or at least memorized for a short time. Students generally feel more comfortable with a textbook (or their tools) than without one (Trowbridge and Bybee, 1990). The textbook is an established part of learning. It is also a valuable part of

learning with its greatest value determined by the teacher. The teacher must be able to interpret the texts, determine its value, and then include or exclude the information worthy of being passed on to the students. The philosophy that is often drawn out of this type circumstance is one of desperation. This desperation takes away from the ability of teachers to teach and students to learn. We should observe, apply concepts, interpret, interrelate to larger concepts, and solve problems. Instead, Novak (1976) states the sequence is “observe, memorize, test, and forget” (p. 493). Raths, Pancella, & van Ness (1967) suggested that teachers organize their teaching to insure that their students possess in their cognitive structure, general concepts under which they can incorporate new material. He went on to say that concepts should be established before learning tasks.

#### Evolution Today

In 1997, it was determined that 44 percent of Americans believed that through special creation, God brought humans, and maybe even the earth itself, into being only thousands of years ago. (Witham, 2002). In April 2002 Randy Moore published a report card of the states with regard to how they deal with evolution. According to Moore (2002) ten states do an excellent job treating evolution in their educational standards, fourteen states do a good job (grade of B), seven states do a satisfactory job, six states do an unsatisfactory job, and thirteen states received an F for being “useless for the purposes of teaching evolution.” Even the states with high marks (grade of B or above) “large percentages of their biology teachers spend little time teaching it, believe that creationism should be included in science classes, and question the scientific validity of evolution” (Moore, 2002).

The U.S. Supreme Court rulings in 1968 and 1987 were confirmed again by the Court in 2000 and it protects evolution in the public schools. In this ruling eight of the nine high court justices, with Antonin Scalia dissenting, “had no interest in reversing a federal court ruling against Louisiana’s 1994 disclaimer law” (Witham, 2002, p.7). This law directed biology or earth science teachers to say that the theory of evolution was not to dissuade students from believing the Bible and to encourage students to apply critical thinking when dealing with the subject.

There is a trend in the U.S. to promote critical thinking by allowing instruction of alternative ideas. “The Ohio Board of Education voted unanimously on Oct. 15 (2002) to adopt a curriculum that allows schools to teach alternatives to evolution (“Ohio:,” 2002). “In 2001 the U.S. Senate almost unanimously urged teachers of biological evolution to ‘prepare students to distinguish the data and testable theories of science from philosophical or religious claims that are made in the name of science.’” And in Cobb County Georgia the ACLU filed suit in 2002 against the school board after it voted to put evolution disclaimer stickers on middle and high school textbooks. “All of these second thoughts about science may add up to a cultural boost for creationism” (Witham, 2002, p. 9).

#### Alleviation of the Problem

Teacher understanding of the nature of science is critical for appropriate instruction, yet teachers are not given relevant direction to allow them to understand the importance of the nature of science. This understanding of the nature of science and how to apply it to educational circumstances also allows teachers to defend the role of science in controversial issues such as evolution.

Pre-service or in-service courses emphasizing the nature of science can result in significant gains in teacher scores on instruments designed to measure understanding of this concept (Akindehin 1988; Barufaldi, Bethel, & Lamb 1977). Where attempts have been made to include teaching about the history and philosophy of science, they have been found effective in improving the students' understanding of this concept (Clough 1995a and 1995b; Cossman 1969; Crumb 1965; Klopfer & Cooley 1963). Likewise, teachers who understand the nature of science and are able to communicate that understanding can provide a more meaningful learning experience.

As might be expected, successful classrooms were more often characterized by attentive students who were actively engaged with materials and subject matter. Explicit comments by teachers concerning the tentative, testable, and amoral aspects of scientific knowledge were common. Successful teachers/classrooms appeared to stress depth, breadth, and accuracy of content more often than unsuccessful teachers/classrooms.... It is clear that teachers who want to increase students' understanding of the nature of science and thus increase their scientific literacy must pay careful attention to what they say and do in the classroom and to the kind of classroom climate they establish. It is not enough for a teacher to have an adequate concept of the nature of science; he or she must communicate it to students (Lederman 1990, p. 1).

## CHAPTER 3: METHODOLOGY

This research was conducted using mixed methods, within the context of a descriptive qualitative case study. According to Creswell (2003) “Mixed methods research has come of age.... The situation today is less quantitative versus qualitative and more how research practices lie somewhere on a continuum in between”(p. 4). Mixed methods research incorporates beneficial resources from both qualitative and quantitative studies into one. Creswell (2003, p. 219) suggests that this type study use a “concurrent transformative strategy” due to the relative importance, and timing of the use of both qualitative and quantitative methods. It is a bounded system (Merriam, 1998) of southern biology teachers’ difficulties with teaching evolution concepts. This topic was chosen because it is an issue of concern. (Merriam, 1998). Through constant comparative analysis (Corbin & Strauss, 1990) I investigated levels of teachers’ understanding of the nature of science and how those levels of understanding, along with changes in those levels of understanding, affected their willingness to teach evolution. This study is heuristic (Merriam, 1998) because it helps explain the reasons for a problem, and the background. This method was selected because of the reliance on the views of certain participants and the discussion of “their view within the context in which they occur to inductively develop, from particulars to abstractions” (Creswell, 1998, p.254) the variables in the study. The abstractions were developed through the use of both quantitative and qualitative methods.

### Quantitative Methods

Quantitative methods included a survey and a questionnaire administered to the

participants involved in the project. This survey was given to participants at the first class meeting. It was a Likert-type scale with 5 rating levels: A - Strongly Agree; B - Agree; C - Undecided; D - Disagree; and E - Strongly Disagree. By convention, 5 to 7 scale points should be used on the Likert scale. There is a loss of information with less scale points, and little if any incremental value in more scale points. The letters associated with each answer were given number values in order to determine levels of acceptance of evolution. The values were also used to calculate willingness to teach evolution. These numbers were used to compare scores within the group of participants and to compare the scores of the final six participants to the total participants' scores.

Similarly the answers to the questions on the NOS questionnaire were rated and totaled. These scores were also used to compare scores within the group of participants and to compare the scores of the final six participants to the total participants' scores.

#### Theoretical Perspective

Michael Crotty (1998) suggests that when developing a research proposal there should be two main questions asked. First we should consider what methodologies and methods are to be used. Second, how are they justified? This justification is based on what "assumptions about reality we bring to our work" (Crotty, 1998, p. 2). These assumptions are the basis for my theoretical perspective and my theoretical perspective is informed by the "constructionism epistemology". Constructionism is an epistemological stance that contends that "truth, or meaning comes into existence in and out of our engagement with the realities in our world" (Crotty, 1998, p. 8). This research deals with exactly that. The information found has meaning beyond the objectivist epistemology because of the interpretive nature of the reality of the information.

This research looks at how people view how science works and how people with education can look at similar information and come up with contrasting interpretations and how they deal with that contrast.

This scientific world is not, of course, the everyday world that people experience. Not even scientists experience it that way in their everyday mode of being. Various authors have considered the example of Tycho Brahe and Johannes Kepler standing together on a hill at sunrise. These two seventeenth-century astronomers held very different views. Brahe thought that the sun circles the earth; Kepler believed that the earth circles the sun. As they watch the sun appear at daybreak, what do they see? Does Brahe see the sun move above the earth's horizon, while Kepler sees the horizon dip below the sun?... We may believe that the earth is round, and 'Flat Earthers' may be our favorite epithet for people we judge to be behind the times- yet, unless we are doing something like buying a round-the-world ticket, we do think and act as if the earth were flat. And we are expected to do so. (Crotty, 1998, p. 28).

In this study, constructionism informs a phenomenological theoretical perspective. The phenomenological perspective is useful because, according to van Manen (1990), it is an exploration of "the essence of lived experience". Phenomenology is a way of exploring research questions that lead to a different way of knowledge being constructed.

### Participants

The participants were taken from 47 teachers who were enrolled in advanced science methods classes at a local university. Of the 47 teachers, 10 had primarily high

school experience, 20 had primarily middle school experience and the remaining 17 had primarily elementary school experience. The original group of 47 also reported having from three semester hours of college level biology taken to as many as 28 semester hours. The teachers were chosen by asking for volunteers who had experience teaching biology. The teachers were also chosen based on criterion-based selection. (LeCompte and Preissle, 1993, p.69) I needed biology teachers with whom it would be easy to exchange information. The volunteers were in-part evaluated based on; years of teaching experience, what their major field of study was in college, and biology classes taken. Convenient teachers were within a radius of 40 miles of Gainesville, Georgia. Once I contacted the teachers, I got oral permission and later written consent to do the interviews. Along with IRB approval from both UGA and the participating University, I acquired the written consent of the “gatekeeper” (Creswell, 1998 p. 60) who was the Dean of the School of Education.

#### Procedures and Instruments for Evaluation

Once the research questions were developed and the instruments for evaluation were chosen the forty-seven teachers each completed a survey on acceptance of evolution (Appendix A). This was followed by an NOS questionnaire (Appendix B), and then by a demographic questionnaire (Appendix C). The survey helped determine their level of acceptance of evolution and their willingness to teach evolution. The NOS questionnaire helped determine their understanding of the nature of science (NOS). The demographic questionnaire helped determine the appropriate candidates for participation. To promote more honest answers to each of the instruments the students were asked to pick a code and write it on their instruments. They were told if they finished the unit and they chose

to be part of the research they could give their name with their code at the end of the course after their grade was determined. Following the initial surveys and questionnaires, the group was presented an inquiry-based unit on the nature of science that extended over the majority of a semester course on methodology of science education. After the midpoint of the course some very informal interviews started during breaks or lunch. These interviews provided an opportunity for the participants to reflect on the issues of evolution and to reflect on the nature of science as it was discussed in class. After the unit on the nature of science the teachers were given a follow-up survey and questionnaire identical to the ones they had before. The data from the surveys and questionnaires were analyzed to determine what differences there were in their acceptance and understanding regarding both evolution and the nature of science. The data were further analyzed for themes that were common to all cases studied as well as themes that may have occurred idiosyncratically. The initial patterns and themes that emerged resulted from commonalities in scores on the instruments used to determine understanding of the nature of science, acceptance of evolution, and willingness to teach evolution. For example, there were many instances where the participants with low scores on the NOS instrument also had low scores in their acceptance of evolution and their willingness to teach evolution.

From the original 47 students that were surveyed there were 11 chosen to be further interviewed according to specified criteria. They were chosen based on their willingness to be interviewed, their relative position to the other participants in their understanding of the nature of science, their relative position to the other participants in their acceptance of evolution, their relative position to the other participants in their

willingness to teach evolution, and changes in each of these categories from pre-instruction on the nature of science to post-instruction. Following the first participant selection process there were a series of other interviews used to further evaluate teacher experience and perception. The teachers were then narrowed down further based on their experience as biology teachers, and their background of biology classes in college. Of the remaining 11 teachers six were chosen for further analysis and more follow-up interviews. All six of the remaining participants had high school biology experience and all with at least the equivalent of 15 semester hours of college level biology.

#### Steps for the Methodology

The following are the steps followed in carrying out the research for this study.

- 1<sup>st</sup> Research questions developed
- 2<sup>nd</sup> Survey and Questionnaire responses before NOS
- 3<sup>rd</sup> Treatment – Unit on NOS
- 4<sup>th</sup> Initial interviews
- 5<sup>th</sup> Survey and Questionnaire responses after NOS
- 6<sup>th</sup> Identification of patterns and themes from pre- and post-instruments.
- 7<sup>th</sup> Identification of participants
- 8<sup>th</sup> Further interviews
- 9<sup>th</sup> Identification of participants for further study
- 10<sup>th</sup> Follow-up interviews
- 11<sup>th</sup> Patterns identified
- 12<sup>th</sup> Themes developed
- 13<sup>th</sup> Conclusions

## Scenarios of Interest

In order to address the research questions three scenarios were designated as areas of interest. First, the teachers who had the greatest change in favor of willingness to teach evolution were asked to discuss what they perceived as difficulties for them and for other teachers. Secondly, I discussed willingness to teach evolution with the teachers who had the highest understanding of the nature of science and the highest acceptance of evolution before and after the class. And finally, I identified the teachers who had a moderate understanding of the nature of science before the treatment and who had little change in their scores for understanding NOS afterwards.

## Treatment

The treatment in this research project was an advanced science methods class designed to provide instruction on, and to illustrate the nature of science. The primary source, for teacher reference, on the nature of science was Teaching Evolution and the Nature of Science published by the National Academy Press (NAS, 1998b). There were a number of activities taken from the book that were used to illustrate the need to understand the nature of science. Appendix D provides a list of class by class lessons that were used to inform the students of the nature of science and how evolution illustrates the way science should be taught.

## Measuring the Understanding of the Nature of Science

According to Lederman (1999), the emphasis on the nature of science should be expected because the “understanding of the nature of science has been identified as an educational outcome in the United States since 1907” (p. 916). The questionnaire used in this study that relates to teachers’ conceptions of the nature of science (NOS) has been

used and at least face validated in other studies (Abd-El-Khalick et al. 1998; Lederman & O'Malley 1990).

Even though there is not a general agreement in all the reform efforts, with regard to all the aspects of the nature of science, Lederman indicated that the following aspects are significant for K-12 science students and, therefore, teachers of science: “Scientific knowledge is (a) tentative, (b) empirically based (based on and/or derived from observations of the natural world), (c) subjective, (d) necessarily involves human inference, imagination, and creativity, (e) necessarily involves a combination of observations and inferences, and (f) is socially and culturally embedded. One more that has not been addressed by reform documents, but is closely related to an understanding of observation and inference is the function of, and relationships between, scientific theories and laws” (Lederman, 1999, p. 917).

The instrument used to measure the nature of science is concisely written in seven questions, however, it measures a very broad understanding of how science works and what science is. “The instrument globally focuses on the complexities of tentativeness in scientific knowledge, and specifically on (a) the use of human creativity and imagination in the development of scientific knowledge, (b) the subjectivity resulting from scientists’ background experiences, knowledge, and scientific paradigms, (c) the difference between scientific theory and law, (d) the importance of both observation and inference to the development of scientific knowledge, and (e) the empirical basis of scientific knowledge” (Lederman, 1999, p. 920).

## MATE – Measuring the Acceptance of the Theory of Evolution

The Measure of Acceptance of the Theory of Evolution (MATE) was designed to, “measure teachers’ overall acceptance of evolutionary theory by assessing their perceptions of evolutionary theory’s scientific validity, ability to explain phenomena, and acceptance within the scientific community (Rutledge & Warden, 1999, p. 13).

In developing the MATE, Rutledge and Warden first addressed concepts. They started with concepts because according to Schwabb (1968) the knowledgeable decisions of either accepting or rejecting a scientific theory are based on evaluations of substantive and syntactical elements of a domain. The axiomatic principles of evolutionary theory and the nature of science were to be addressed by the MATE. Among these principles Rutledge and Warden chose the following: “the processes of evolution, the available evidence of evolutionary change, the ability of evolutionary theory to explain phenomena, the evolution of humans, the age of the earth, the independent validity of science as a way of knowing, and the current status of evolutionary theory with the scientific community” (Rutledge & Warden, 1999, p. 14).

Rutledge and Warden used the five points of the Likert scale to “force a response indicating the strength of an individual’s agreement or disagreement with a statement concerning evolutionary theory” (Rutledge & Warden, 1999, p. 14).

In order to maintain validity with the instrument the items included were critically analyzed by a jury of five university professors who have expertise in the fields of evolutionary biology, science education, and the philosophy of science. The members of the jury rated each item on a scale for accuracy, clarity, and a measure of assessment of

intended concepts. These items met a minimum acceptance level before they were included on the instrument.

Reliability of the instrument was determined using the Cronbach alpha technique and was found to be .98. Item analysis showed each of the 20 items having a corrected item total correlation of greater than  $r = .65$  implying that each item contributed to the overall reliability of the instrument:

The results of their study indicate that the MATE is a valid and reliable instrument for assessing the acceptance of evolutionary theory. The instrument is composed of multiple items addressing fundamental evolutionary concepts. This diversity in items serves to enhance its ability to reliably and validly assess teacher acceptance of the complex and over-reaching biological theory of evolutionary change of living forms. The instrument is homogenous, assessing a single paradigm, which allows for clear interpretation of the results generated from its administration. Further, this instrument serves as an aid in developing additional media for acquiring data.

Use of the MATE with additional instrumentation will allow researchers to explore the potential relationship between teachers' acceptance of evolutionary theory and their teaching of the topic of evolution. Pertinent research that could be conducted utilizing the MATE in conjunction with additional, existing instrumentation includes exploring relationships between teacher acceptance of evolutionary theory and the role of evolution in the curriculum; teacher understanding of evolutionary theory; teacher understanding of the nature of science; and teacher academic background. Studies of this nature may serve to inform efforts to enhance the state of evolutionary biology instruction" (Rutledge & Warden, 1999, p. 16).

In an attempt to determine willingness to teach designated evolutionary concepts there were twelve statements added to the MATE. Ten of the statements were added after original statements and stated, “Based on my understanding of the previous statement and my understanding of the nature of science I would be willing to teach that concept in my science class.” The other two statements were added to the MATE as a link for the previous statement in order to address the participants’ positions regarding evolution of bacteria and man’s lineage with other organisms on earth today. For the purposes of this study the 12 statements regarding willingness to teach were added to the original MATE and along with the original MATE statements will be referred to as the MATE-Plus [MATE+].

### Qualitative Methods

Qualitative methods included semi-structured interviews, using naturalistic inquiry. The interviews were transcribed. Using the research questions as a reference, the transcriptions were analyzed for the presence of patterns or repeated views. The repeated views were then analyzed and themes were established.

### Interviews

After evaluating the answers, I produced an interview guide (Appendix E) with open-ended questions that deal with possible changes in philosophy regarding evolution after learning more about the nature of science. The statements included in the interview guide were created by critically considering noted concerns of prior teachers. In order to minimize researcher bias and promote distinct participant feedback the interview questions were created to maximize the participant’s opportunity to provide his or her perception. After a couple of days to reflect and respond the participants were

interviewed using a tape recorder and asked to elaborate on certain parts of their response. The interviews were an active, face-to-face process using the interview guide, but the respondent's responses determined whether the interview questions were informative or in any way intrusive to the participant. If the participant indicated that the questions were intrusive, the interview was redirected or terminated so the participant was not intruded upon. The participants were asked about the questions and/or statements on the questionnaire and then asked to state why they made the choice they made. The participants were asked how they changed since becoming more familiar with the nature of science.

The interviews lasted from 10 minutes to 60 minutes in length. The average interview was approximately 30 minutes. Participants were given a choice of how they wanted to be interviewed. They could be interviewed either by themselves, in a larger group, or with one or two other people. The participants were given a list of options for times to be interviewed and were asked to see me if they wanted to participate. They were given the option of deciding the number of people in the interview. In these classes there were apparent relationships and many participants seemed to be more vocal when supported by someone else with a similar opinion. This type interview seemed to allow for a more open setting or opportunity for several of the participants. There were also opportunities for some one-on-one interviews after certain participants were interviewed with a peer. The interviews with two or three participants appeared to involve more emotion and honest feelings than the one-on-one interviews did. After the interviews I transcribed each interview.

## Data Analysis

My methods for data analysis were multi-faceted. The surveys and questionnaires allowed me to determine levels of understanding of the nature of science along with acceptance of evolution and willingness to teach evolution. These instruments used as pre- and post-treatment also allowed me to compare changes made by the participants and look for patterns and themes within those changes.

The interviews allowed me to accumulate data with rich, thick description (Geertz, 1983), which yielded emerging themes. I coded all the transcripts using emic and etic coding (Merriam, 1998). I made constant comparisons (Corbin & Strauss, 1990) and content analysis (Merriam, 1998) by developing tables and charts and extracting key words. I used the data from these charts and tables to tabulate occurrences of certain words or phrases. I then re-grouped the data according to the teachers' responses. I also looked for frequency of question type. I coded the data from the interviews using open coding. (Merriam, 1998) This type data makes "thick description possible... to generalize within" (Geertz, p. 56) the case.

The methods of data management (Huberman & Miles, 1994) began with a survey on acceptance of evolution and willingness to teach evolution called the MATE-Plus that would be scored with a prescribed rubric (Appendix F) that distinguishes teachers' acceptance of evolution and their willingness to teach evolution. The MATE-Plus was followed by a questionnaire on the nature of science, then by a series of tape-recorded interviews. The next step was transcribing the interviews. Typing, printing, and saving the data on the computer followed this step. After transcription, the data was printed to allow it to be more easily coded. The tape and transcriptions were secured and

monitored on a daily basis to insure confidentiality. Only the researcher has access to the data.

### Credibility, Dependability, and Transferability

Merriam (1998) says that reliability in qualitative research “is not only fanciful but impossible (pg. 206).” As a result Lincoln and Guba (1985, p. 288) suggest that reliability be discussed qualitatively in terms of “dependability” or “consistency”, and internal validity more appropriately should be likened to credibility, while external validity parallels transferability. These characteristics are measured in qualitative case study by way of how the interviews are constructed, and how the content of the documents is properly analyzed. The qualitative study should “provide the reader with depiction in enough detail to show that the author’s conclusion ‘makes sense’” (Firestone, 1987, p. 19).

In order to insure credibility, transferability, and ethics, I used several methods. For increased credibility I used triangulation of different kinds of data. I used a questionnaire and followed that up with a series of interviews. In addition, I used member checks (Merriam, 1998) on the transcriptions as well as peer review (Merriam, 1998) with my committee and fellow doctoral students. I attempted to recognize and clarify researcher bias early in the study. In order to establish transferability I used rich, thick description (Geertz, 1983) in the findings and correlated the ratings with the predetermined codes assigned to the statements. I incorporated a typicality or modal category. (Merriam, 1998). I noted how the “experts” typically rate the statements and I compared that to the teacher’s interpretation. I also used triangulation and provided an audit trail (Merriam, 1998). In order to comply with IRB requirements and ethical

concerns I received a consent form (Appendix G) from the participants to use their data. There were concerns about the interviews on the part of the interviewer because of the role the discussion of evolution plays in this study. I assured the participants of confidentiality and was able to maintain that by using pseudonyms and keeping all recorded information coded and concealed. I did not intend to deceive or harm anyone.

## CHAPTER 4: FINDINGS

### Introduction

Biology education is under fire today in the same context it was 75 years ago when John Scopes was on trial. There is massive support for alternatives to the theory of evolution in the science classroom. Despite pleas from the vast majority in the science community the policies of school boards around our country are being challenged, and in some cases changed, regarding the way science is taught. The changes in policies will undoubtedly affect the way science classes are conducted.

Teachers deal with many pressures regarding not only what they teach but also how and why they teach it. There is pressure not only from churches, communities and students, but also from state administrators, county administrators, local school administrators, and even peers. There are standards that prescribe what should be taught in order to allow students success at the next level. When these standards are compromised at any level the teacher has to find a way to deal with it. They could try creative ways to appease everyone, or they could teach exactly what is in the book, or they could just skip it all together. Teachers deal with these issues in different ways and in this study we will look at both how and why they deal with it the way they do.

The findings of this research are organized according to how the participants responded to the surveys, questionnaires, and interviews they participated in. Use of the MATE-Plus provides an opportunity to determine what level of acceptance the participants have of evolution. Their responses to the NOS survey from pre- to post-instruction on NOS provided a measuring stick with which to compare not only their

understanding of the nature of science but also how it might affect their position with regard to evolution. The interviews were potentially the most enlightening source for information regarding the difficulties teachers encounter not only personally but also professionally. Using an open-interview format provided a great deal of flexibility for the interviewer and the interview and that in turn provided for more productive data.

### Purpose

“In the science classroom, teachers will encounter students who have a wide range of beliefs about religion and evolution” (Meadows et al., 2000, p.106). The purpose of this study is to document why science teachers approach teaching evolution the way they do. In this study the participating teachers were evaluated on their acceptance of evolution, of their understanding of the nature of science, and of their willingness to teach evolution both before and then after they were taught a unit on the nature of science.

Different combinations of high school, middle school, and elementary school teachers enrolled in three separate science education methods classes at a local university. On the first day of each of the classes each of the teachers/students was asked to fill out a survey on the measurement of the acceptance of the theory of evolution (MATE) that had been edited (MATE-Plus) to include questions about the teacher’s willingness to teach particular evolutionary concepts. On the first day they were also asked to fill out a questionnaire measuring their understanding of the nature of science. Upon completion of the unit on the nature of science, which covered approximately 20 hours of instruction, the students were asked to once again complete both the survey and the questionnaire. The answers to both instruments were evaluated and the participants were categorized according to the way they completed each. Teachers were then given the opportunity to

discuss the issues in a group setting or one on one with the researcher. The interviews focused on individual perceptions of the nature of science as well as their perceptions of evolution for them personally and for them professionally. The data gathered allowed comparisons and contrasts of perspectives, including but not limited to, past experiences dealing with evolution, past understanding of the nature of science, and current understanding of the nature of science.

## Results

### *Demographics for Participants*

The participants were all graduate students who, at the time of the interviews, were teachers in North Georgia high schools. Some of the teachers were working on their Masters' Degrees while others were working on their Specialist Degrees. The demographics include the level at which the participants are teaching, the teaching experience they have, the number of hours of college level biology classes they have taken, the size of the school where they are currently teaching, and the number of days spent teaching evolution (Table 1).

### Evaluative Instruments

The instruments used to measure the changes in understanding of NOS, and the changes in acceptance of evolution were instruments developed and tested by leaders in the field of science education. Rutledge and Warden developed the "MATE" to "measure teachers' overall acceptance of evolutionary theory by assessing their perceptions of evolutionary theory's scientific validity, ability to explain phenomena, and acceptance within the scientific community" (Rutledge & Warden, 1999, p. 13). It has prior

Table 1

Demographics for Participants

Name	Years teaching experience	Biology credit hours	School size	Days spent on evolution
Amy	25	21-30	Large	3
Charles	23	21-30	Large	7
Mitch	11	21-30	Medium	7
Sandra	15	21-30	Large	6
Tracie	21	21-30	Large	7
Trisha	12	15-20	Large	5

Note. All teachers were high school level teachers.

validation and served this research very well to establish a measuring device for change in teachers' acceptance of evolution. (For complete data for interviewees responses to the MATE-Plus see Appendix H.)

Also critical to this study was the ability to measure the participants' initial understandings of the nature of science and then measure a change in those understandings. The questionnaire used was developed and validated by Abd-El-Khalick et al. (1998). It provided a qualitative evaluation of the participants understanding of the nature of science and gave me a source for developing my interview questions and remarks.

Table 2 illustrates the changes in the participants' level of understanding of NOS. These changes were measured and calculated based on the difference in their scores on instruments given prior to their unit on NOS and then again after the unit on NOS. For complete data for interviewees NOS scores see Appendix I.

Table 2

Change in NOS scores pre-test to post-test

Name	NOS before	NOS after	Percent change in NOS
Amy	5/16	12/16	44%
Charles	15/16	16/16	6%
Mitch	5/16	15/16	63%
Sandra	11/16	16/16	31%
Tracie	14/16	16/16	12%
Trisha	7/16	12/16	31%

### Research Questions

*How does understanding the nature of science affect the teacher's acceptance of evolution?*

How will teachers that understand the nature of science deal with evolution differently than those that don't understand it? To provide some insight into this question there was a comparison made between teachers who understood the nature of science prior to and after a unit on the nature of science and a teacher who displayed a poor understanding of the nature of science prior to and also after a unit on NOS (Table 3).

Tracie and Charles both taught biology for a number of years and when tested on their understanding of the nature of science both did very well. Tracie got a score of 84% of the NOS questionnaire and Charles got a score of 94% before the unit on understanding the nature of science. Following the unit on NOS they both got scores of 100%. They also scored the highest possible score, also 100%, on their acceptance of evolution prior to and then again after the NOS class.

Tracie is a veteran teacher of 21 years. Previously she taught in Ohio and in North Carolina and for the last 5 years in a large metro Atlanta school. Tracie taught at the middle grades level as well as high school and taught biology, chemistry, and earth science. Tracie and Charles taught at the same school for the last 5 years and were taking classes together to get their Master's degree. Charles is a veteran of 23 years and taught in Pennsylvania for five years before coming to the metro Atlanta area. He taught chemistry and biology at the high school level his entire career.

In the interview with Tracie and Charles we started by discussing the recent decision by Cobb County Georgia to put stickers in the front of their biology textbooks. As part of this discussion I asked them what they thought was the greatest influence on how evolution is taught. Charles began by saying, "I think it is purely political". I responded by asking how he could explain how someone who knows the importance of promoting the proper ideas in science could insult the teachers, the students, and the parents who understand what science really is, all in the name of politics. Tracie stepped in and said, "I think Charles is right. I think it is political. If the politicians don't do what the people want, then they don't stay long. If they don't vote to put the disclaimer in, as they did in Cobb County, they are not doing their job. At the very least they cannot take

the side of the opposition that would teach evolution as fact.” I replied, “But evolution is fact and that is why it should be taught without a disclaimer and if the nature of science is understood, then we would have fewer problems like this” (referring to Cobb County situation). Charles: “Understandable, however, unless the majority, in this case the voters, understand the nature of science and why it is factual, there will be these kinds of proclamations to deal with.” Tracie: “And without our legal system, who knows what kind of silly rules we might be dealing with now.”

There is an understanding that transcends the science issues into the social issues involved in this situation. As two experienced teachers Tracie and Charles are able to pick out the subtleties of a situation involved in dealing with evolution. Experience alone however is not adequate to promote an understanding of the nature of science or an acceptance of evolution.

Amy is also a veteran teacher. She has 25 years experience teaching at the high school and the middle school level. She taught 8 years in the Washington D.C. area before moving into the Atlanta area 17 years ago. Amy taught life sciences at each level. Prior to the unit on understanding the nature of science Amy, who performed poorly on the NOS understanding before (31%) and, despite a large change in her NOS score, only demonstrated a moderate understanding after (75%), was asked what affected the way evolution was taught. She told me,

I don't think you can teach evolution without teaching creationism. You've got to teach students both sides. They have to see both sides of the coin. You know, especially for me being someone who teaches 14 and 15 year olds, they are so impressionable. You have to be so careful and give them both sides of the story.

They have nothing to compare evolution to. I remember when I was in Junior High and I remember when they told us about evolution and for years I thought we evolved from, I mean I believed we evolved from or, or came from apes. Now I actually believe that. When I think about evolution I think that man evolved from apes. That age group of children is very curious and when you start talking about evolution they're going to have many questions, so you have to teach creationism. They have a right to know. They should have both sides of the story.

Amy obviously felt like it was a teacher's responsibility to teach both views of the beginning of life while Tracie and Charles appear to feel victim to politics at the local level. When Amy was probed further regarding the difference between science and creationism she made reference to "evidence" collected to support the existence of Noah's Ark. I asked what would be an example of evidence that would support the biblical view. Amy responded by saying, "I'll give you an example. Scientists have found evidence that Noah's Ark did exist. You know they really went back and they actually found evidence that it did exist." I asked if we didn't find evidence for Noah's Ark does that mean that God doesn't exist or that religion is wrong? Amy responded by saying, "Exactly. But when I think of evolution, and I know this is a different mindset that people in our society think of, I think of it as a change over time. You know, I see it as evolving from apes. I know we have some of the same features, you know we walk upright and other characteristics but I do not see evolution as evolving from an ape." Amy had discussed what makes science different and we emphasized evidence as a key for that. As a result she appeared to be trying to tie evidence to creation efforts. She also appeared to be adamant about pointing out that she did not believe she came from apes.

Trisha was in-between the two levels of understanding and acceptance examined so far. She taught twelve years of science and has approximately 15 semester hours of life sciences at the college level. She was reared in the northern United States and has been in the south for approximately 10 years. She had a change in her NOS scores from pre to post of approximately 31% however she began with a score of 70% on her willingness to teach evolution and ended with a score of 68%. Despite her small change and relatively low score on the willingness scale Trisha made several remarks about the necessity of teaching “what they (the students) need to go on (on to the next level of education).” She said, “If they are going to college they need to know what science says is the truth.” And when someone mentioned a local problem getting the information out Trisha said, “It is a problem here though, especially in this area. As science teachers we have to take some sort of stance so our students can get what they need.” When it was mentioned that only one system in the state of Georgia has the word evolution in their standards or objectives for science Trisha said, “I think it is a North-South thing and the parents and their desire to hold on to their beliefs. It seems that most of the counties have very traditional populations and would rather not bother with such a goal or standard.” When asked where she thought the greatest pressure came from to either teach evolution or not she replied, “The church is very influential. My husband grew up in the Catholic Church and didn’t agree with much of what his church believed so he has become a Methodist.”

We are able to see two different perspectives or interpretations of evolution and its role in education. The role of evolution seems to be tied very closely to the understanding of how science works. Despite her low score on willingness to teach evolution, Trisha expressed a somewhat urgent need for students to know the major

evolutionary concepts. She had a moderate score on her acceptance of evolution, 79%, however she scored 68% on her willingness to teach evolution. Tracie and Charles have an excellent understanding of evolution and expressed a concern over the attitudes of others in their class. Tracie said, “Do you know one of the most shocking things that we heard in the class we had with you was when you mentioned that the Bible says the earth was created by God in seven twenty-four hour days and one of the ladies very quietly whispered, ‘It was six days.’” Charles replied, “It is like we were back in the Middle Ages and we asked ourselves, ‘do civilized people really believe this?’”

Table 3

Percent Change in NOS and MATE scores from before to after						
Name	NOS before	NOS after	Percent change	MATE+ before	MATE+ after	Percent change
Trisha	44%	75%	31%	76%	79%	3%
Amy	31%	75%	44%	56%	67%	11%
Sandra	69%	100%	31%	58%	88%	30%
Mitch	31%	94%	63%	59%	89%	30%
Tracie	88%	100%	12%	100%	100%	0%
Charles	94%	100%	6%	100%	100%	0%

*How does understanding the nature of evolution affect the teacher's acceptance of evolution?*

Teachers who understand the nature of evolution are the ones that demonstrated knowledge of evolution and evolutionary processes in the interviews. These same people also provided some basic answers to fundamental assumptions of evolution on the MATE-Plus survey (Table 4). As an example, it could be inferred that someone who accepts the scientifically determined age of the earth would be more understanding of evolution than someone who doesn't. Perhaps a more conclusive way to gage an understanding of the nature of evolution is an understanding of three areas that Gould (2001) suggests best express the factuality of evolution. First he mentions the factuality of evolution through improved crops, better medicine, changes in domesticated animals, documented insect adaptations, etc.... He next mentions the presence of links or direct evidence from one species to the next, which have inappropriately been reported as missing, but there are those who ignore the presence of several species with quite complete fossil records. The third and final area Gould emphasizes as indicative of evolution's factuality deals with organs, habits, imperfections, and so on that are not apparently needed today. The most logical explanation for these is concluded through evolution and natural selection.

In the final interview with Amy it appeared through discussion of basic evolution concepts she began to understand the Nature of Science a little better and commented on the need to teach evolution. Early on Amy reluctantly and almost shamefully stated "I remember when they told us about evolution and for years I thought we evolved from, I mean I believed we evolved from, or, or came from apes." and in reference to thinking

evolution meant she came from an ape she went on to say “I believe it today”. She was obviously bothered by the fact that she “came from apes”. In fact, over a series of interviews that lasted a combined 35 minutes, she mentioned being descendant from apes a total of eight times. After the unit on NOS Amy took a very neutral stance to most issues on the MATE-Plus. Of 32 items scored on the instrument she scored none in either the 5 or 1 categories. All her answers were either Agree, Undecided, or Disagree with no answers in either the Strongly Agree or Strongly Disagree area. She was undecided on whether evolution actually occurred. She was undecided on the scientific validity of evolution. She was undecided whether evolutionary theory generates testable predictions with respect to the characteristics of life. I conclude that each of these items would promote a positive response of agree or strongly agree for someone who understands the nature of evolution.

On the other hand, Charles and Tracie were each educated in environments where the nature of science was clearly explained and the role of evolution was unquestioned. They displayed a strong understanding of evolution in their responses on the MATE-Plus and in their interviews. They were therefore aghast at the attitude of the teachers who initially refused to consider evolution. They commented about a situation in one of their other classes when a teacher/student suggested that there would be no harm in allowing alternative ideas and Tracie commented out loud, “You can’t be serious.” Tracie said the reaction to her comment was “as if I had thrown rocks at the Pope. It felt as if everyone in the room wanted to tar and feather me.” There is an obvious intolerance on the part of those who know for those who think they know but are wrong. This attitude of intolerance appears to go both ways and when combined with an inability to

communicate terminology creates a static and even inverted path for education and learning.

Table 4

Percent Change in MATE+ and Willingness to Teach Evolution From Before Treatment to After

Name	MATE+ before	MATE+ after	Percent change	Willingness to teach evolution before	Willingness to teach evolution after	Percent change
Trisha	76%	79%	3%	70%	68%	-2%
Amy	56%	67%	11%	62%	62%	0%
Sandra	58%	88%	30%	56%	96%	40%
Mitch	59%	89%	30%	60%	86%	26%
Tracie	100%	100%	0%	100%	100%	0%
Charles	100%	100%	0%	100%	100%	0%

*Does a change in understanding of the nature of science affect a teacher's acceptance of evolution?*

This part of the research focuses on the teacher that showed the greatest progress in their understanding of the nature of science and how those teachers changed their acceptance of evolution (Table 5). Mitch has been teaching for 11 years at the same school in an area where he grew up. He was finishing his Master's and has 25-quarter

hours of college biology classes. Mitch went from a score of 31% on his understanding the nature of science to a score of 94% illustrating the biggest change of any of the people evaluated. He also had a large change in his acceptance of evolution as indicated by his 30% change in score on the MATE-Plus. On the other hand Tracie and Charles had minimal change in their understanding of NOS and in fact had a very good understanding before the NOS unit and they both had the highest acceptance of evolution possible before and after the unit on NOS.

Of interest for Mitch are the items that had the biggest change on the MATE-Plus. Items numbered 4, 6, 17, and 20 were all changed by 3 points on a 5 point Likert Scale. On number 4 and number 17 he went from a choice of Disagree to a choice of Strongly Agree, and on number 6 and number 20 he changed from Strongly Disagree to Agree. Items numbered 4 and 20 relate to human evolution and the time for humans to change. Items 6 and 17 are statements related to the way science works or the nature of science. There was a 2-point increase in items numbered 5, 8, 12, 15, 16, 18, 19, 21, 23, 24, and 28. In each of these items the score went from either Disagree to Agree or from Undecided to Strongly Agree. In either case he changed to some level of agreement with the item. The change in acceptance of the items listed is best explained by a change in attitude about what science represents. Prior to the course on NOS Mitch disagreed with the statement that evolutionary theory generates testable predictions with respect to the characteristics of life. After the unit on NOS he strongly agreed. Mitch made several statements that indicated he gained an understanding of the nature of science and in the process gained an acceptance for evolution. When asked how he would deal with a student that (a) believes the earth is less than 10,000 years old and, (b) will need to have

the scientifically right answer to pass his college entrance exam, Mitch explained, “I would tell him the evidence shows, the science is the earth is much older than that.” This statement helps illustrate the importance Mitch places on evidence with regard to science. When asked where he thought the greatest pressure came from regarding the teaching of evolution Mitch very quickly answered, “the local community standards”. He went on to say, “It seems to me that it is what is allowed by community standards and what that would dictate.” Shay, another participant in the interview, suggested that teaching evolution is part of the QCC so we teach it, but Mitch shook his head no and said, “If the parents say no, then you are going to have a tough time.” From this it might be suggested that even though the understanding of the nature of science may change and allow someone to accept evolution they may still be reluctant to teach evolution or avoid teaching it all together.

Table 5

Percent Change in NOS and MATE+ from Before Treatment to After

Name	NOS before	NOS after	Percent change	MATE+ before	MATE+ after	Percent change
Trisha	44%	75%	31%	76%	79%	3%
Amy	31%	75%	44%	56%	67%	11%
Sandra	69%	100%	31%	58%	88%	30%
Mitch	31%	94%	63%	59%	89%	30%
Tracie	88%	100%	12%	100%	100%	0%
Charles	94%	100%	6%	100%	100%	0%

*To what extent do teachers understand evolution and the nature of science?*

Elementary through high school teachers, under the guidelines of the National Science Standards, should prescribe some level of inference to the role of evolutionary processes in promoting evolution, which is the foundation for biology and biological processes (Table 6). Trisha, Amy, and Mitch initially showed a poor understanding of the nature of science and through the interview process Amy and Mitch demonstrated a lack of understanding of the basic processes involved in evolution. Amy gave creationism the same value as evolution with regard to validity. She said, “All I want to know is, why can’t we teach both ideas? I mean if they have proof of occurrences from the Bible, why can’t we teach it when we teach evolution?” Amy explained that there was evidence found that lead researchers to believe they found parts of what might have been Noah’s Ark. She went on to say that if they have that evidence then it should be allowed in the classroom.

Tracie and Charles on the other hand had problems understanding why there is a problem. They were educated in an environment where evolution is accepted as fact and the church has no public issue with it. They had an outstanding background in evolution and in the nature of science. Their contributions to the class were effortless and they appeared to appreciate and look forward, with great curiosity and excitement, to representations demonstrating the nature of science. I assume this was true because they had such a great understanding of science and of what evolution is.

In the writings of Lederman, Wade, and Bell (1998) it is evident that the understanding of the nature of science is lacking among teachers and students alike. In this study it became evident that many teachers were initially lacking in their

understanding of the nature of science. Only three of the original 47 teachers/students had a score above 80% on their NOS survey prior to the class on NOS. Equally alarming was the level of understanding or at the very least acceptance of evolution by these students. There were only two that had above 80% on that as well. However, there were a number of students that scored above 70% on the MATE-Plus.

Scientific literacy is a goal of many organizations from the American Association for the Advancement of Science (AAAS, 1989) to the National Science Teachers' Association (NSTA, 1982) and beyond. The methods for producing scientifically literate people are arguable, however the need for people to be scientifically literate meets with little obstruction.

*How does a change in understanding of the nature of science affect a teacher's willingness to teach evolution?*

Of interest here is the change in the level of understanding of the nature of science by some teachers and how that change affects the teacher's way of dealing with the evolution (Table 7). Sandra had a large change in her willingness to teach evolution. Her change in understanding NOS wasn't very large however she had one of the highest initial NOS scores of all so she didn't have much room for change. Mitch had the largest change in NOS understanding and the second largest change in willingness to teach evolution.

When Sandra was asked why she might not teach that the age of the earth is 5 billion years, or that evolutionary processes have occurred over billions of years, she said, "One reason I do not teach it in great detail is because I don't have a good background in carbon dating and so forth. I need a little more information and understanding myself in

order to explain it better.” She went on to later say, “They want to know how do you know. I know they use carbon dating but I wouldn’t know how to explain that as well as I would like.”

Table 6

The Extent that Teachers Understand Evolution and NOS from Before a Treatment to After

Name	MATE+ before	MATE+ after	Percent change	NOS before	NOS after	Percent change
Trisha	76%	79%	3%	44%	75%	31%
Amy	56%	67%	11%	31%	75%	44%
Sandra	58%	88%	30%	69%	100%	31%
Mitch	59%	89%	30%	31%	94%	63%
Tracie	100%	100%	0%	88%	100%	12%
Charles	100%	100%	0%	94%	100%	6%

Rose, a less experienced teacher, was sitting in on the interview and in response said, “I would want to know so I could defend myself because some people are so closed minded that I would want to be able to prove myself to them or to parents, so they know I am not just making it up.” I said in a curious tone, “Making it up?” And she replied, “Yes, I think that is a perception that it is just made up.”

I then asked if they would be willing to teach that there is a connection between man and other primates. Sandra responded, as a few others had in other interviews, by

saying that it depends on where the students are developmentally. She said, "It is like you wouldn't expect them to hit a baseball at 5 years old. You start them at t-ball and move them up. If you try to get them started on it too early there is a problem. Sometimes you can do more damage than good if it is not explained right.... Once they are more independent, as in college, you would be able to introduce that concept more easily." I then asked what concepts she thought her students could deal with appropriately and she referred to a demonstration we had seen the day before with a watermelon and a cucumber in which they were sliced open lengthwise and crosswise to examine similarities and differences. She said, "That is one they can handle. They are familiar with that. They have enough of a background and it is concrete. They can handle that and they don't have to think so much about it." She made this statement as if it was a good thing that the students not have to think about things that were controversial. She went on to say, "And with it they can see how there is a common ancestor and then we do a DNA activity and they can see the relationships. That sort of puts a cap on personal beliefs."

When asked where they thought the greatest pressure comes from to teach, or avoid teaching, certain concepts Sandra responded very quickly. She said, "If parents say no then there is a problem. I'm talking about professional, well-educated parents. Now we're talking about two huge Baptist churches over there (in reference to her school). I mean one of them is really, really huge and they will tell you what they expect. If the parent says they don't want their kid learning about that (referring to evolution) then there is a problem." Rather defiantly she went on to say, "It is however your job to teach that kid. It is your job! I would tell them that their job is to teach them morals and religion and it is my job to teach them science." This attitude is contrary to the opinion

she expressed on the willingness to teach survey she completed prior to the NOS unit. Sandra, in fact prior to the unit on NOS, had a one of the lowest scores in the class on her willingness to teach evolution concepts. Much like Sandra, Mitch also had a very low score prior to the NOS unit. Despite his initial non-acceptance of evolutionary theory according to his scores on the pre-NOS (31%) and MATE-Plus (59%) after the NOS unit Mitch was not especially tolerant of those who would not accept evolution. In talking with Mitch after the NOS unit he had an air of disdain for those whom would choose to teach anything but evolution. He went so far as to say, “Well I have heard a few Baptist preachers, more than one, stand in the pulpit and rant and rave around about how they have the Bible on their side and there is no way they came from no monkeys, using those exact words. They do not have the, I guess you could say they are illiterate in the basic information as far as what scientists say and what the difference is between creationism and evolution. They really, they just don’t know what they are talking about. I have tried to teach my kids both sides and that God is part of our belief and religion and is separate from the evidence we have for evolution.” This ties in very well with what Gould (2001) says is the reason the United States is so slow to accept Darwin’s theories of evolution and natural selection. He said, “in the most technologically advanced nation on earth - I can only conclude that our misunderstanding of the broader implications of Darwinism, in particular our misreading of his doctrine as doleful, or as subversive to our spiritual hopes and needs, rather than as ethically neutral and intellectually exhilarating, has impeded public acceptance of our best documented biological generality (Gould, p.xii).”

Mitch and Sandra, in separate interviews, both referenced differences in attitudes they attributed to cultural pressures defined in part by geographic position. Sandra, who

grew up in the Northern U.S. said, “Another thing may be a Northern-Southern thing. Some of the mindset of the south is there is slowness to change. It’s their particular attitude about things and they don’t want to discuss it.” Mitch, who was born and raised in the South, when asked if being from the south has any affect on attitude said, “Oh absolutely. Our culture doesn’t tolerate outside ideas. We are not very welcoming to change. If you can get anyone to discuss it then it becomes potentially a very volatile situation.” Shay, who was also interviewed with Mitch and was reared in the South, spoke up and said, “I know, my husband won’t discuss this with me.” Mitch followed that up by saying, “And these people will start quoting things out of the Bible and won’t listen to anything else.”

#### Summary

There were a number of observations to be made from the detailed descriptions of influences expressed in the interviews. Of particular note are the references to the southern attitude, the emotional ability of the students to deal with the concepts, the role of politics in how the curriculum is developed, legalities, misconceptions, social pressure, peer pressure, the role of the church, intolerance, the lack of understanding of evolution, the lack of understanding of NOS, community standards, the role of standards and their effect on what is taught, expertise regarding evolution, dealing with ignorance about NOS, and many other subtle encumbrances. As educators of science, teachers must deal with many issues in determining what they should teach. These interviews have provided a look at some of the many concerns we have as teachers of science. Of perhaps equal or greater importance might be the implications this information has for educators of future science teachers. It might also be of interest to look at a broader range of teachers.

Despite the inclusion of the middle school teachers in the interview process the comments were primarily taken from the high school teachers. There were many more teachers from different grade levels who contributed data and were not interviewed or whose interviews were not used.

Table 7

Percent Change in NOS and Willingness to Teach Evolution From Before Treatment to After

Name	NOS before	NOS after	Percent change	Willingness to teach evolution before	Willingness to teach evolution after	Percent change
Trisha	44%	75%	31%	70%	68%	-2%
Amy	31%	75%	44%	62%	62%	0%
Sandra	69%	100%	31%	56%	96%	40%
Mitch	31%	94%	63%	60%	86%	26%
Tracie	88%	100%	12%	100%	100%	0%
Charles	94%	100%	6%	100%	100%	0%

## Quantitative Analysis

Further quantitative analysis of the data gathered on all the participants allowed for a more detailed statistical evaluation. The paired t-test, a Pearson Correlation, and a Spearman Rank Correlation were all used.

The paired t-test uses 2 or more repeat measures of a variable, measured on the same or matched subjects. The measurements were taken at different times with a treatment for one of them. The paired t-test is a more powerful test than independent samples test because it can eliminate between-subject variation.

The Pearson Correlation properly tests for an association between two related variables. It is known as the linear or product-moment correlation used to measure normally distributed, or parametric, data to determine how linearly related the variables are.

The Spearman Rank Correlation formally tests for an association between 2 related variables that are non-parametric or that do not have a normal distribution. It is equivalent to ranking the observations and then applying the Pearson Correlation.

## Quantitative Results

A paired t-test was performed on the original 47 participants to determine the relationship between the understanding of the nature of science before the treatment and the understanding of the nature of science after the treatment. This analysis indicated that the difference between the means is very highly significant ( $n = 47$ ,  $p \ll .0001$ ,  $df = 46$ ,  $t = 22.6453$ ). When a paired t-test was performed on all 47 participants to determine the relationship between the acceptance of evolution before the treatment and the acceptance of evolution after the treatment the analysis indicated that once again the difference

between the means is very highly significant ( $n = 47$ ,  $p \ll .0001$ ,  $df = 46$ ,  $t = 13.359$ ).

The final t-test was performed on the 47 participants to determine the relationship between the willingness to teach evolution before the treatment and the willingness to teach evolution after the treatment. This analysis indicated that once again the difference between the means is very highly significant ( $n = 47$ ,  $p \ll .0001$ ,  $df = 46$ ,  $t = 6.878$ ).

In order to determine the effect of the treatment, an evaluation of the correlation between the understanding of the nature of science and acceptance of evolution was needed. Gain scores (pretest minus posttest) were used to determine the relationship between these two variables. In order to determine the correlation between gains in understanding of the nature of science and gains in the acceptance of evolution the Pearson Correlation was used. The analysis ( $n = 47$ ,  $p = .0013$ ,  $df = 46$ ,  $r = .454$ ) gave a significant correlation. Since gain scores for willingness to teach evolution covered a broad range but were very highly skewed, the Spearman Rank Correlation was used instead to determine the significance of the relationship between the change in the scores for understanding the nature of science and the change in scores for willingness to teach evolution. This analysis ( $n = 47$ ,  $p = .14$ ,  $Rho = .217$ ) does not indicate a significant correlation of the scores for the entire group. Gain scores were also used with the Spearman Rank Correlation to determine the significance of the relationship between the change in the degree of acceptance of evolution and the change in scores for willingness to teach evolution. This analysis ( $n = 47$ ,  $p = .028$ ,  $Rho = .323$ ) does indicate a significant correlation of the scores for the entire group. An explanation for this discrepancy may lie in the fact that most of the elementary teachers and some of the middle grades teachers were not biology teachers and therefore felt no need to advocate willingness to teach

evolution since it is not part of their curriculum. This is despite the earlier finding that there was a significant increase in willingness to teach evolution from before the treatment to after the treatment for all levels.

Another interesting statistic that arose from the quantitative analysis was the pre-treatment to post-treatment changes in the understanding of the nature of science from one grade level to the next. The participants were categorized according to the level at which they taught. There were 17 elementary teachers, 20 middle school teachers, and 10 high school teachers who participated. Prior to the treatment the Mean scores for each group were; elementary school .372, middle school .421, and high school .589. These numbers indicated there was a significant difference from one grade level to another ( $n = 46$ ,  $df = 2$ ,  $F = 9.386$ ,  $p = .0004$ ). After the treatment the Mean scores for each group were; elementary school .813, middle school .878, and high school .889. These numbers indicated no significant difference ( $n = 46$ ,  $df = 2$ ,  $F = 3.131$ ,  $p = .0535$ ). It is possible to consider the positive effect of the treatment on the overall understanding of the nature of science by all levels of teachers.

## CHAPTER 5: CONCLUSIONS, DISCUSSIONS, AND RECOMMENDATIONS

### Conclusion

The purpose of this study was to investigate the reasons teachers have difficulty teaching arguably the most fundamental part of biology – evolution. The interacting factors: teacher acceptance of evolution, teacher understanding of evolution, teacher understanding of the nature of science, and teacher willingness to teach evolution. These factors were used to evaluate and determine what dictates the level of emphasis and accuracy of instruction related to evolution being presented in the biology class.

### The Problem

That mankind evolved from apelike creatures—much less an “ooze” from the ocean is currently and will most likely continue to be impossible for many to believe. Creationists hold tight to a literal interpretation of the Biblical account of how the earth and man were brought into being. According to Genesis approximately 6000 years ago God created the heavens, the earth, man and all animals in 6 – 24 hour days. Also, man and all animals exist in the same form today as they did in the initial creation. To many creationists to suggest otherwise, in any fashion, would have you condemned to hell for eternity. To add to these moral and ethical pressures there are also legal issues that teachers must deal with. There are lawsuits across the country today that are either promoting a religious view or denouncing the validity and reliability of evolution and therefore providing ‘fuel for the fire’. There is a need to find out what factors teacher perceive as problems or reasons for the inadequate coverage of evolution in the science class.

## The Questions

The following research questions guided this study:

- 1 How does understanding the nature of science affect a teacher's acceptance of evolution?
- 2 How does understanding the nature of evolution affect the teacher's acceptance of evolution?
- 3 Does a change in understanding of the "nature of science" affect a teacher's acceptance of evolution?
- 4 To what extent do teachers understand evolution and the nature of science?
- 5 How does a change in understanding of the nature of science affect a teacher's willingness to teach evolution?

## The Nature of Science

Accepting change is difficult in many cultures. Accepting change because someone tells you to change without understanding why is difficult. Accepting change in the understanding of who you are and why you are is virtually impossible without an answer or mechanism for that change. Understanding the nature of science provides the path or tool to make that transition. In The Structure of Scientific Revolutions Thomas Kuhn (1996) suggested that in order for great changes to take place the old ideas would have to die with the old people and the new generations would gather new information, assess the information, and create new paradigms. Many of the old ideas are dying but without an understanding of how and why science works the battle between evolution and creation is likely to be a long and costly one. Understanding the nature of science is an important part of making the transition to not only tolerate explanations of evolution,

but also process the explanations to develop thoughts that will allow each person to fill in their own gaps for understanding.

Perhaps a more important question than the ones listed earlier is why should we teach evolution. Or better yet, aside from the constitutionality of the issue, why should we choose evolution over creationism? Horgan (1997) sums it up by simply saying that unlike other disciplines science is responsible for getting us somewhere. By understanding the nature of science and by using it we are able to make progress in our quality of life. Stephen Gould (2001) said that science sets us free by putting our destiny in our own hands. Gould (2001, p. viii) further states, “Also, when we recognize how recently our so-called human races diverged from a common African ancestry, and when we measure the minuscule genetic differences that separate our groups as a result, then we can know why racism, the scourge of human relations for so many centuries, can claim no factual foundation in any real differences among human groups.” If for no other reasons, the ones Gould lists here make learning evolution essential for all that contribute to local, national, and even worldly decisions. He goes on to a more personal appeal and suggests “by taking the Darwinian ‘cold bath,’ and staring a factual reality in the face, we can finally abandon the cardinal false hope of the ages-that factual nature can specify the meaning of our life by validating our inherent superiority, or by proving that evolution exists to generate us as the summit of life’s purpose. In principle, the factual state of the universe, whatever it may be, cannot teach us how we should live or what our lives should mean-for these ethical questions of value and meaning belong to such different realms of human life as religion, philosophy, and humanistic study. Nature’s facts can help us to realize a goal once we have made our ethical decisions on other grounds-as the

trivial genetic differences among human groups, for example, can help us to understand human unity once we have agreed on the unalienable rights of all people to life, liberty, and the pursuit of happiness.” (Gould, p.xiii)

#### Conclusions for Question 1

*How does understanding the nature of science affect the teacher’s acceptance of evolution?*

In order to answer this question there was a measure of understanding of the nature of science along with a measure of acceptance of evolution. Tracie and Charles recorded very high scores in their understanding of the nature of science and in their acceptance of evolution prior to and after the unit on the nature of science. In talking with Tracie and Charles it was apparent that they had no problem teaching evolution except with their peers. They were both surprised when they heard there was an issue regarding instruction about evolution. On the other hand Amy, who has taught biology for several years, had a low score representing her understanding of the nature of science and also showed a low acceptance of evolution. She initially insisted that students should hear both sides of the issue because that was what would be fair. She tried to justify equal time for creationism by suggesting that there was evidence to corroborate some of the stories in the Bible. As the discussions and interviews went on she admitted that whether there was evidence or not had little effect on her acceptance of the Bible. She also expressed great concern in being descendent from apes and said she just couldn’t accept evolution if that is what it meant. Initially Amy had great problems sorting out why science was different from religion and the true nature of either one. She tried to connect evidence to religion and a belief system to science.

## Conclusions for Question 2

*How does understanding the nature of evolution affect the teacher's acceptance of evolution?*

In order to accept evolution it would make sense that you understand it although it is not required. As Amy talked more and more about evolution and about the nature of science she became more at ease with the acceptance of its principles. In the beginning she shamefully said she was taught that evolution meant she came from apes. That was not an option in her mind. However when she was told that it is just as true that apes came from us she was consoled and when she found out that evolution suggests that there is a common ancestor for apes and man and that there were thousands and thousands of fossil records to make the connection, she appeared to be amazed. In learning the facts of evolution Amy was able to liberate herself from the idea that apes were somehow her superiors in terms of her lineage. In our last segment of our last interview Amy said, "...and what about those kids that don't get it (evolution) and then go off to college? That is putting them at a great disadvantage if they don't hear this in high school." And when questioned about the role of understanding science in dealing with the difficulties of teaching evolution she said, "I agree. I feel much better about the position I have as an educator and as a Christian by understanding the way science works and what evolution really means. I just didn't know and thought evolution meant we came from apes."

On the other hand, Tracie and Charles had a great understanding of evolution all along and had trouble relating to why this was a problem in the first place. They gave several examples of being caught off guard by the lack of understanding and even

hostility surrounding evolution. It seems there is a great difficulty in understanding those who don't accept evolution after one knows all the evidence.

### Conclusions for Question 3

*Does a change in understanding of the nature of science affect a teacher's acceptance of evolution?*

An understanding of the nature of science facilitates acceptance of evolution as a valid explanation of events, regardless of your acceptance of it as the actual mode of operation. Mitch showed a dramatic increase in his understanding of the nature of science from prior to the unit on NOS to after the unit on NOS. He also showed a large gain in his acceptance of evolutionary concepts. He changed from not understanding how science works and what evolution is to having a strong understanding of each. By understanding the role of evidence, the definition of facts, and how science is different than religion, Mitch was able to identify problems that he hadn't recognized as problems before. He noted the attitudes of community members and noted why those attitudes were restrictive to policies centering on evolution. Eugenie Scott (1994) reported that all the way to principals and superintendents there is pressure to prevent teachers from teaching evolution. Perhaps the most disturbing part of her study was that much of the time these administrators failed to support the teachers or even the established curriculum.

### Conclusions for Question 4

*To what extent do teachers understand evolution and the nature of science?*

Rutledge, Warden, Lederman, Clough, and Moore, to name but a few science educators, have answered this question in different contexts in past studies. This study took a look at 47 teachers of science. Of the original 47 there were only three that scored

above 80% on their pre-assessment of their understanding of the nature of science. Equally alarming were the relatively low scores on the MATE-Plus, however there were a number of students who scored above 70%. Amy's position regarding the evidence supporting the Bible's validity illustrated a lack of understanding of evolution and of what represents science. It also was a misrepresentation of the issue. The situation Amy referred to dealt with evidence of Noah's Ark, which if substantiated has nothing to do with the scientific accounts of evolution. It does however help illustrate the knowledge status of many people who oppose evolution - if the Bible is true then science is not and visa-versa.

#### Conclusions for Question 5

*How does a change in understanding of the nature of science affect a teacher's willingness to teach evolution?*

Amy never demonstrated a strong understanding of the nature of science and all along was very reluctant to consider even discussing evolution as a credible interpretation of information regarding the origin of man or the origin of life. She had a difficult time accepting that she came from apes. She appeared to deny any consideration for evolution at that point. Once she was able to discuss the meaning of evolution and the role of factual information in defining science she was able to open up a little to the principles of evolution. To the end of the class she still expressed a reluctance to consider teaching young children the concepts. Mitch on the other hand had a very big change in his understanding of the nature of science and also showed a dramatic increase in his acceptance of evolution. As a result of his new understanding he even developed a somewhat adversarial position toward those who wouldn't consider the merits of

evolution. He even went so far as to call a group of the extremely conservatives ignorant of the ways of evolution and science. It appeared that the change in understanding how science works and why science and religion are different made a difference in the attitude of Amy and had a profound impact on the Mitch's perspective.

#### Conclusions for Interview Analysis

The semi structured interview format worked well. This format promoted more in-depth responses to the questions by allowing the interviewer the freedom to ask questions based on responses not based on a script. Allowing participants to make a choice with regard to the number of people present at the interview also promoted a more open environment. They were set up to interview from 1 to interview groups of 2 or 3. The interviews with 1 person at a time allowed the participants more privacy and perhaps opportunity to say what they felt without feeling pressure from their peers. I thought the interviews with 2 or 3 were a little more open and extensive. The participants in these groups seemed to provide a sort of support for one another and to provide stimulus for the memories and past occurrences of the others. The interviews brought out many points as reasons teachers might have difficulties teaching evolution.

#### Conclusions for Questionnaire Analysis

The questionnaire was very beneficial. It allowed the participants to express their thoughts and support those thoughts unlike many instruments measuring NOS. Because of its subjective nature this questionnaire provided a deeper, richer, and more meaningful evaluation of the changes in understanding the nature of science. There were many participants that showed marked increases in their understanding of the nature of science from before the unit on NOS to after.

## Conclusions for Survey Analysis

The survey, in conjunction with the questionnaire, allowed me to identify conditions of interest. The survey provided a measuring stick of attitudes and beliefs regarding not only evolution but also willingness to teach the concepts. This survey provided a quick but effective way to access the participants' positions regarding the subject both prior to and after the unit on NOS.

## Discussions

Generally speaking, this study provides an opportunity to take a mixed methods look at some issues of concern. From a qualitative perspective the rich, thick descriptions offered by the participants helped get to the heart of a very deep problem faced by far too many science teachers, administrators, parents, and students. Of primary concern should be the education of our children and their potential contribution to society. This study provides an area for reflection for those interested in addressing concerns for not only our students, but also our teachers who might be better prepared to deal with controversial issues such as evolution. Teachers of teachers must also be aware of the difficulties facing not only in-service but also pre-service teachers. It has been noted that the instructor's conceptual framework is influential in the student's learning of science (Demastes, Settlage, and Good, 1995). It is therefore a primary concern for educators of educators to know what teachers think and how they deal with concepts as controversial as evolution. Woods and Scharmann (2001) point out those students possess a variety of different views of evolutionary theory that may impede their acquisition of information regarding evolution. It is evident from this study that teachers also possess a variety of views that may serve to reduce their ability to interpret the theory of evolution, and

consequently inhibit their ability to instruct on the matter. According to Woods and Scharmann (2001) students would better be able to deal with the concepts of evolution if they are presented the information in an inquiry-based fashion. This would allow the students to begin to reconstruct their own knowledge about evolution. Teachers who struggle with the dilemmas of teaching evolution may also benefit from learning more about the nature of science through inquiry-based activities.

From a quantitative perspective there are several issues addressed in this study. The results of the study have implications for science teaching and science teacher education. Understanding of the nature of science, teachers' acceptance of evolution, and willingness to teach evolution all went up significantly from before treatment to after treatment. This study supports previously indicated shortcomings in each of the previously mentioned areas and provides a treatment to accommodate gains in those areas.

Further emphasis on the importance of understanding the nature of science was indicated by the significant correlation between gains in the understanding of NOS and gains in the acceptance of evolution. It was also indicated that all levels of teachers, from elementary through high school, achieved approximately the same level of understanding of the nature of science with the treatment despite a significant difference in understanding of the nature of science before the treatment.

It appears that knowing the nature of science plays an important role in the acceptance and ultimate understanding of evolution. Interestingly there were several teachers who understood evolution and understood the nature of science, yet they still said they would not teach certain concepts because of the emotional/mental level of their

students and their students' parents. I am sure that without an understanding of the nature of science it will be hard for teachers to teach evolution and it will be hard for students, parents, board members, and others to deal, in an appropriate manner, with controversy surrounding evolution.

#### Implications and Recommendations for Further Study

The information gathered here was a great help in illuminating the often-taboo subject of evolution. As the study went on, and as people became more familiar with the class they began to open up and offer greater and greater insight. Gathering data this way helped establish credibility, dependability, and transferability (Lincoln and Guba, 1985). The participants also let down their guard a little as the class progressed. As one of the southern born and raised students said, "Our culture doesn't tolerate outside ideas. We are not very welcoming to change. If you can get anyone to discuss it then it becomes potentially a very volatile situation." Meadows, Doster, and Jackson (2000) submitted the belief that "students will respond much better to the winsome witness of a sensitive science teacher than they will to the dogmatic sermons of an evolutionary fundamentalist" (p. 107). I submit that so will teachers. It takes great care and sincerity regarding a very personal issue to deal with topics like this. Unless it is a study over time through relationships it may yield little valuable information. As noted by several of the participants, one of the most outstanding things seemed to be the difference in regional opinions about evolution. In one of our open class discussions this point was brought out several times by people born and reared in the south and by others that have moved in. As a lifetime member of the southern culture I have had first hand experience with the power of the emotions of the deeply religious. As a science teacher for 17 years and a

science student all my life I have had first hand experience with the power of science and what thinking scientifically can accomplish.

There are a number of issues of concern facing science educators today. As the often-proclaimed foundation of biology, evolution is certainly included in these concerns. The principles of evolution are not a subject of debate among the vast majority of scientists today yet many teachers avoid those principles due to a number of pressures both outside the school system and in.

There are certainly a number of other studies to be done to improve problems associated with trying to teach evolution at the elementary, middle, and especially high school level. [Foremost among these may be studies dealing with what teachers believe is true about evolution, its role in biology, and how they think evolution should be taught.]`

There is potentially valuable information in finding out what associations may be made between particular religions and local policies and between religion and teacher willingness to teach evolution. This study dealt with in-service teachers all working on advanced degrees. It might be beneficial to do a similar study of pre-service teachers to find out what restrictions teachers enter science education with regarding the teaching of evolution. This study also dealt with teachers at primarily large schools of over 2000 students. It might also be beneficial to research the attitudes and opinions of teachers from smaller schools and in more rural settings.

There are also potential implications for the instrument developed in the form of the lesson plan used in this research. The combination of activities provided throughout the treatment of this research, or some derivation thereof, may serve as a guide to

promote a better understanding of the nature of science and of its role in promoting evolution in education.

If there are to be changes made in the way our society views evolution it will start in the schools. In order for there to be an effective change in the schools, it must start with the teachers.

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## APPENDICES

## Appendix A

### The MATE-Plus Instrument

For the following items, please indicate your agreement/disagreement with the given statements using the following scale.

A	B	C	D	E
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

1. Organisms existing today are the result of evolutionary processes that have occurred over millions of years.
2. Based on my understanding of the previous statement and my understanding of the nature of science I would be willing to teach that concept in my science class.
3. The theory of evolution is incapable of being scientifically tested.
4. Modern humans are the products of evolutionary processes that have occurred over millions of years.
5. Based on my understanding of the previous statement and my understanding of the nature of science I would be willing to teach that concept in my science class.
6. The theory of evolution is based on speculation and not valid scientific observation and testing.
7. Most scientists accept evolutionary theory to be a scientifically valid theory.
8. The available data are ambiguous as to whether evolution actually occurs.
9. The age of the earth is less than 20,000 years.
10. There is a significant body of data which supports evolutionary theory.
11. Organisms exist today in essentially the same form in which they always have.
12. Evolution is not a scientifically valid theory.
13. The age of the earth is at least 4 billion years.
14. Based on my understanding of the previous statement and my understanding of the nature of science I would be willing to teach that concept in my science class.
15. Current evolutionary theory is the result of sound scientific research and methodology.
16. Based on my understanding of the previous statement and my understanding of the nature of science I would be willing to teach that concept in my science class.
17. Evolutionary theory generates testable predictions with respect to the characteristics of life.
18. Based on my understanding of the previous statement and my understanding of the nature of science I would be willing to teach that concept in my science class.
19. The theory of evolution cannot be correct since it disagrees with the Biblical account of creation.

20. Humans exist today in essentially the same form in which they always have.
21. Evolutionary theory is supported by factual, historical, and laboratory data.
22. Based on my understanding of the previous statement and my understanding of the nature of science I would be willing to teach that concept in my science class.
23. Much of the scientific community doubts if evolution occurs.
24. The theory of evolution brings meaning to the adverse characteristics and behaviors observed in living forms.
25. Based on my understanding of the previous statement and my understanding of the nature of science I would be willing to teach that concept in my science class.
26. With few exceptions, organisms on earth came into existence at about the same time.
27. Evolution is a scientifically valid theory.
28. Based on my understanding of the previous statement and my understanding of the nature of science I would be willing to teach that concept in my science class.
29. Many bacteria evolve rapidly and continuously.
30. Based on my understanding of the previous statement and my understanding of the nature of science I would be willing to teach that concept in my science class.
31. Man has lineage with other organisms on earth today.
32. Based on my understanding of the previous statement and my understanding of the nature of science I would be willing to teach that concept in my science class.

## Appendix B

### NOS Questionnaire

1. After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach theories. Defend your answer with examples.
2. What does an atom look like? How certain are scientists about the structure of atoms? What specific kinds of evidence do you think scientists used to determine what an atom looks like?
3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.
4. How are science and art similar? How are they different?
5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/ investigations, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate.
6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.
7. Some astronomers believe that the universe is expanding, while others believe it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

## Appendix C

### Questionnaire for Participant Demographics

Identity Code Number \_\_\_\_\_

Date \_\_\_\_\_

Please fill out the following questionnaire as accurately as possible, by writing in or checking the appropriate answer/s.

At what level/s have you taught science and for how many years have you taught at that level?

<u>Level</u>	<u>Years teaching at that level</u>
_____ College	_____
_____ High School	_____
_____ Middle School	_____
_____ Elementary School	_____

How many hours of biology have you earned credit for at the college level? (Check the best answer) \*A typical semester class is 3 credit hours and a typical quarter science class is 5 credit hours and each may or may not prescribe an additional hour for a lab class.

\_\_\_\_\_ Less than 6  
\_\_\_\_\_ 6 – 10  
\_\_\_\_\_ 11 – 20  
\_\_\_\_\_ 21 – 30  
\_\_\_\_\_ More than 30

Were these semester hours or quarter hours ? (Check the correct answer)

What is the size of the school where you teach according to the list below? (Circle the correct answer)

\_\_\_\_\_ Less than 1000  
\_\_\_\_\_ 1000 to 2000  
\_\_\_\_\_ Over 2000

How many days do you spend, over the course of the school year, on the topic of evolution and evolutionary concepts? (Write in the approximate number)

\_\_\_\_\_ days.

In how much depth do you cover evolutionary concepts? Please choose all that apply.

\_\_\_\_\_ Avoid it  
\_\_\_\_\_ Introduction to micro-evolution  
\_\_\_\_\_ Basics of micro-evolution  
\_\_\_\_\_ Introduction to macro-evolution  
\_\_\_\_\_ Basics of macro-evolution  
\_\_\_\_\_ In depth study of macro-evolution

## Appendix D

### Lesson plans for Advanced Science Methods

#### 1<sup>st</sup> meeting – 4 hours

- Students fill out the NOS questionnaire and the MATE survey.
- The students will be shown a series of optical illusions to illustrate the ability of different people to look at the same information and interpret the information differently.
- Toilet paper tubes and strings will be used to develop an activity from Teaching About Evolution and The Nature of Science. The activity comes from a vignette that illustrates the nature of science and science research. The students will see the model of the tube and string without seeing what is inside. They will then be given the assignment of reproducing the model with what knowledge and resources they have.
- Discussion of the Nature of Science.

#### 2<sup>nd</sup> meeting – 4 hours

- Students will be introduced to a cube activity that is also taken from Teaching About Evolution and the Nature of Science. It is “Activity 1” in the book.
- The students will draw the relative positions of the sun, earth, and moon, the way they think it is, at the first of each month, for 1 year (12 separate drawings).
- There will be a discussion on Heliocentrism and Geocentrism and the difficulties the science community had in disposing of the idea of an earth centered universe. Teaching About Evolution and the Nature of Science will be the primary source for discussion of this topic as well.
- The students will be given an NOS quiz to reaffirm their correct ideas and allow them to correct their misconceptions.

- There will be a discussion on the purpose of evidence in science and why evidence is what makes science different from other ways of knowing and discovering.
- Facts, theories, laws, and hypotheses will be a major focus of the class and will be discussed along with misconceptions using Teaching About Evolution and the Nature of Science to define these terms. The hierarchy of these terms and the misuse of the terms in day to day conversation will also be discussed.

3<sup>rd</sup> meeting – 4 hours

- The students will be given a paper written by Anthony Lorscheid and Kenneth Tobin from Research Matters – to the Science Teacher, titled “Constructivism as a Referent for Teaching Science”. This paper summarizes the constructivist epistemology and allows the students to focus on a way of viewing science teaching and science learning that allows the use of inquiry learning and utilization of the nature of science to be a better science teacher. They will be given the assignment of writing a critique of the paper that summarizes the paper and provides their opinion of the ideology.
- The students will experience the water-creating machine during our third meeting. This activity will provide an opportunity for the students to, once again, consider how science works and why science and religion are different.
- From Teaching About Evolution and the Nature of Science the five E’s of inquiry learning will be discussed. The five E’s provide a structure or a method that allows teachers to develop and also check their approach to either teach a unit or develop their entire philosophy of teaching.

- The students will be shown a transparency about a material that they must identify. It will be presented as being more evil than guns or drugs. They will be shown true statements about the material and asked to guess what it is. It will be an attempt to illustrate the value of knowledge and skepticism when looking at data and making decisions.
- There will be a series of quotes that will be made into transparencies. The students will be led by the instructor to read the transparencies and discuss them. The quotes are centered on the nature of science.
- The class will be introduced to the basics of a pendulum. The students will then be given a scenario of a clock company that needs to know how to adjust the pendulums so they can adjust the speed of the clock. The students will be put in the position of a research team and asked to investigate how they would solve the problem. They are to tell how they did their research and tell why it is an inquiry activity.
- Based on the information the students have been given to date, they will be asked to develop a teaching strategy/philosophy. This will be a reflective exercise that allows them to evaluate their own way of thinking about teaching and incorporate what they have discovered in the class. They will write this exercise up as a 1 to 2 page paper.
- The students will do the alternative fuel activity as a way of emphasizing what inquiry learning is and the role of inquiry learning in problem solving.

4<sup>th</sup> meeting – 4 hours

- The generative model for learning will be discussed.

- There will be a fossil footprint activity taken from Teaching About Evolution and the Nature of Science. It is “Activity 5” in the book and the details of the activity will be followed as it is prescribed therein.
- The students will be asked to create activities and use current activities to illustrate a concept with which they are familiar and that they can use in their class.
- The students will be given a horse puzzle. This follows the same rationale as the optical illusions. The point that will be made is that the way we see and think of things may not be the way others do. We need to be able to adjust our thinking outside the accepted norm, because there may be a better way out there to be discovered.

5<sup>th</sup> meeting – 4 hours

- The students will be given assignments in earlier classes and will be asked to give a presentation of their lessons along with an explanation of how it fits in with inquiry learning and how it can be used promote the learning of the nature of science.
- The students will be given assortment of items from home and will be asked to create their own inquiry science activity that will promote the nature of science. The activity will be assigned to be presented at the next class meeting. The items given the students were things like plastic cups, food coloring, M&M’s, different types and lengths of string, magnets, cake frosting, cue-tips, clothes hangers, etc. They were allowed to work in groups and were given the option of including at least one or more of the given items with whatever else they wanted from home.
- There will be a discussion on the paper that was critiqued earlier.

6<sup>th</sup> meeting – 4 hours

- The students present their created activities and discuss its relevance to our class.
- We look at National Science standards and standards for inquiry learning and discuss the importance of those standards.

7<sup>th</sup> meeting – 4 hours

- Presentation of projects and discussion on how their major projects may or may not meet inquiry standards.
- Discussion and review of major concepts in preparation for the final.

8<sup>th</sup> meeting – 4 hours

- The students will be provided with an activity that will be presented as “Hooey Magic”. They will be asked to differentiate magic from science that will lead into a review of the nature of science, science terminology, inquiry learning, constructivist epistemology, etc.
- NOS questionnaire/Mate survey
- Final exam

## Appendix E

### Interview Guide

The interview will start off with a reminder to the participant that the information gathered during the interview will be kept strictly confidential, and that if they feel uncomfortable at any time they can terminate the interview.

The interview will center around a survey previously completed by the participant and will start off with the interviewer reading one of 20 statements from the survey, then asking what problems might be associated with teaching that statement. The statements to be read will be picked based on an analysis of the statements and how the participant's opinion changed over the course of time and instruction on the nature of science. The participants will all start their interview as described below and will be asked to elaborate based on their response to the initial statements.

Instructions to participants will read as follows:

I have chosen one of the statements you responded to earlier this week (month, year). Would you currently have a problem teaching that concept? If so, why?

Why do you think someone else might have a problem teaching that concept?

Is there a way you might modify the statement to make it more acceptable to you as a teacher or would you leave the statement as it is?

Is there a key term in the statement that affects your attitude about the usefulness of the statement?

With which concepts would you anticipate the most trouble teaching and why?

## Appendix F

### MATE Scoring Instructions

To account for positively and negatively phrased items, the scaling of responses must be appropriately reversed so that responses indicative of a high acceptance of evolutionary theory receive a score of 5 while answers indicative of a low acceptance receive a score of 1. To score the MATE, follow the three steps below:

Step 1. Scoring of items 1, 4, 7, 10, 13, 15, 17, 21, 24, and 27 is as follows:

Strongly Agree = 5

Agree = 4

Undecided = 3

Disagree = 2

Strongly Disagree = 1

Step 2. Scoring of items 3, 6, 8, 9, 11, 12, 19, 20, 23, and 26 is as follows:

Strongly Agree = 1

Agree = 2

Undecided = 3

Disagree = 4

Strongly Disagree = 5

Step 3. An individual's score on the MATE is equal to the sum of the scaled responses of all 20 items.

## Appendix G

### Human Subjects Consent Form

I \_\_\_\_\_ agree to participate in the research titled “Reflections on the Difficulties of Teaching Evolution in Biology”, which is being conducted by Clyde Wylie with the Science Education Department at the University of Georgia; 212 Aderhold Hall; Athens, Georgia 30602-7126. His telephone number is (770) 869-3562. He is under the direction of Dr. Norm Thomson of the UGA Science Education Department; 212 Aderhold Hall; Athens, Georgia 30602-7126. His telephone number is (770) 542-1763. I do not have to take part in this study; I can stop taking part at any time without giving any reason, and without penalty. I can ask to have information related to me returned to me, removed from the research records, or destroyed.

1) The reason for the research is to see how well biology teachers understand the nature of science and the nature of evolution and to determine relationships between the two that affect the attitudes of teachers regarding the teaching of evolution.

2) I will not benefit directly from this research.

3) If I volunteer to take part in this study, I will be asked to do the following things:

- fill out a 20-question survey (10 minutes).
- answer 7 questions about the nature of science (15 minutes).
- I understand that the researcher might contact me for a follow up interview that will be tape-recorded. The contact will be made through either email or telephone. Following grade assignments, the researcher will request that I identify my code so he may contact me for a face to face interview. I understand the information I provide is strictly confidential and will not be made available to anyone else or for any other reason, except if required to by law.

4) No discomforts or stresses are foreseen.

5) No risks are foreseen.

6) The results of this participation will be confidential, and will not be released in any individually identifiable form without my prior consent, unless otherwise required by law. Any taped interviews may be kept for 1 year, but will be erased after that.

7) The researcher will answer any further questions about the research, now or during the course of the project, and can be reached by telephone at home at (770) 869-3562 or work at (770) 945-9558.

8) My signature below indicates that the researchers have answered all of my questions to my satisfaction, and that I consent to volunteer for this study. I have been given a copy of this form.

\_\_\_\_\_  
Signature of Researcher / Date

\_\_\_\_\_  
Signature of Participant / Date

Please sign both copies of this form. Keep one and return the other to the investigator.

For questions or problems about your rights please call or write: Chris A. Joseph, Ph.D., Human Subjects Office, University of Georgia, 606A Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-6514; E-Mail Address [IRB@uga.edu](mailto:IRB@uga.edu).

## Appendix H

### MATE+ Item Score Analysis for Interviewees

Statement	Amy before treatment score	After treatment score	Change	Charles before treatment score	After treatment score	Change
1	4	4	0	5	5	0
2	4	4	0	5	5	0
3	1	4	3	5	5	0
4	4	2	-2	5	5	0
5	4	4	0	5	5	0
6	1	4	3	5	5	0
7	4	4	0	5	5	0
8	1	3	2	5	5	0
9	5	4	-1	5	5	0
10	4	4	0	5	5	0
11	2	2	0	5	5	0
12	2	3	1	5	5	0
13	4	4	0	5	5	0
14	4	4	0	5	5	0
15	4	3	-1	5	5	0
16	3	3	0	5	5	0
17	3	3	0	5	5	0
18	3	3	0	5	5	0
19	5	4	-1	5	5	0
20	2	2	0	5	5	0
21	3	4	1	5	5	0
22	3	3	0	5	5	0
23	3	4	1	5	5	0
24	1	3	2	5	5	0
25	1	1	0	5	5	0
26	2	2	0	5	5	0
27	1	4	3	5	5	0
28	1	1	0	5	5	0
29						
30	5	5	0	5	5	0
31						
32	3	3	0	5	5	0
Acceptance of evolution	56/100	67/100	11	100/100	100/100	0
Willingness to teach evolution	31/50	31/50	0	50/50	50/50	0

Note. Participants choosing from a Likert scale 1-5 determined statement scores. Change in acceptance represents the scores out of 100 on the MATE before and after treatment. The change is represented by changes in statements 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 15, 17, 19, 20, 21, 23, 24, 26, and 27. Willingness to teach evolution is represented by a score out of 50 on the MATE+. The change in willingness is represented by change in statements 2, 5, 14, 16, 18, 22, 25, 28, 30, and 32. Items 29 and 31 were used as a reference for items 30 and 32 and were not include in the calculation.

Appendix H (continued)

MATE+ Item Score Analysis for Interviewees

Statement	Mitch before treatment score	After treatment score	Change	Sandra before treatment score	After treatment score	Change
1	4	5	1	2	5	3
2	4	5	1	3	5	2
3	4	4	0	2	2	0
4	2	5	3	2	5	3
5	2	4	2	2	4	2
6	1	4	3	4	5	1
7	4	4	0	2	1	-1
8	3	5	2	2	5	3
9	4	5	1	4	5	1
10	4	4	0	4	5	1
11	4	4	0	2	4	2
12	3	5	2	3	5	2
13	4	5	1	3	5	2
14	4	5	1	3	4	1
15	2	4	2	3	5	2
16	2	4	2	3	5	2
17	2	5	3	3	5	2
18	2	4	2	3	5	2
19	3	5	2	4	5	1
20	1	4	3	2	2	0
21	3	5	2	3	25	2
22	3	4	1	3	5	2
23	3	5	2	4	5	1
24	3	5	2	3	5	2
25	3	4	1	3	5	2
26	2	2	0	4	4	0
27	3	4	1	2	5	3
28	3	5	2	2	5	3
29						
30	4	4	0	4	5	1
31						
32	3	4	1	2	5	3
Acceptance of evolution	59/100	89/100	30	58/100	88/100	30
Willingness to teach evolution	30/50	43/50	13	28/50	48/50	0

Note. Participants choosing from a Likert scale 1-5 determined statement scores. Change in acceptance represents the scores out of 100 on the MATE before and after treatment. The change is represented by changes in statements 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 15, 17, 19, 20, 21, 23, 24, 26, and 27. Willingness to teach evolution is represented by a score out of 50 on the MATE+. The change in willingness is represented by change in statements 2, 5, 14, 16, 18, 22, 25, 28, 30, and 32. Items 29 and 31 were used as a reference for items 30 and 32 and were not include in the calculation.

## Appendix H (continued)

### MATE+ Item Score Analysis for Interviewees

Statement	Tracie before treatment score	After treatment score	Change	Trisha before treatment score	After treatment score	Change
1	5	5	0	4	5	1
2	5	5	0	4	4	0
3	5	5	0	3	2	-1
4	5	5	0	4	4	0
5	5	5	0	4	3	-1
6	5	5	0	3	4	1
7	5	5	0	4	4	0
8	5	5	0	4	4	0
9	5	5	0	4	4	0
10	5	5	0	4	4	0
11	5	5	0	5	5	0
12	5	5	0	4	4	0
13	5	5	0	3	3	0
14	5	5	0	3	3	0
15	5	5	0	4	4	0
16	5	5	0	3	4	1
17	5	5	0	4	4	0
18	5	5	0	4	4	0
19	5	5	0	3	4	1
20	5	5	0	4	4	0
21	5	5	0	3	4	1
22	5	5	0	3	4	1
23	5	5	0	4	4	0
24	5	5	0	4	4	0
25	5	5	0	4	3	-1
26	5	5	0	4	4	0
27	5	5	0	4	4	0
28	5	5	0	4	3	-1
29						
30	5	5	0	3	3	0
31						
32	5	5	0	3	3	0
Acceptance of evolution	100/100	100/100	0	76/100	79/100	3
Willingness to teach evolution	50/50	50/50	0	35/50	34/50	-1

Note. Participants choosing from a Likert scale 1-5 determined statement scores. Change in acceptance represents the scores out of 100 on the MATE before and after treatment. The change is represented by changes in statements 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 15, 17, 19, 20, 21, 23, 24, 26, and 27. Willingness to teach evolution is represented by a score out of 50 on the MATE+. The change in willingness is represented by change in statements 2, 5, 14, 16, 18, 22, 25, 28, 30, and 32. Items 29 and 31 were used as a reference for items 30 and 32 and were not include in the calculation.

## Appendix I

### Interviewees Changes in NOS Understanding and Willingness to Teach Evolution

Statement	Amy before treatment score	After treatment score	Change	Charles before treatment score	After treatment score	Change
1	2	3	1	3	3	0
2	0	3	3	3	3	0
3	1	2	1	2	2	0
4	1	2	1	2	2	0
5	0	0	0	2	3	1
6	1	2	1	1	2	1
7	0	0	0	1	1	0
Total	5/16	12/16	7/16	14/16	16/16	2/16
Percent change	31%	75%	44%	88%	100%	12%
Acceptance of evolution	56/100	67/100	11/100	100/100	100/100	0/100
Willingness to teach evolution	31/50	31/50	0/50	50/50	50/50	0/50

Note. Total represents the NOS scores out of 16 before and after treatment and the changes. Change in acceptance represents the scores out of 100 on the MATE before and after treatment. The change is represented by changes in statements 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 15, 17, 19, 20, 21, 23, 24, 26, and 27. Willingness to teach evolution is represented by a score out of 50 on the MATE+. The change in willingness is represented by change in statements 2, 5, 14, 16, 18, 22, 25, 28, 30, and 32. Items 29 and 31 were used as a reference for items 30 and 32 and were not include in the calculation.

Appendix I (continued)

Interviewees Changes in NOS Understanding and Willingness to Teach Evolution

Statement	Mitch before treatment score	After treatment score	Change	Sandra before treatment score	After treatment score	Change
1	0	3	3	3	3	0
2	2	3	1	1	3	2
3	0	2	2	1	2	1
4	0	1	1	2	2	0
5	2	2	0	3	3	0
6	1	2	1	1	2	1
7	0	2	2	0	1	1
Total	5/16	15/16	10/16	11/16	16/16	5/16
Percent change	31%	94%	63%	69%	100%	31%
Acceptance of evolution	59/100	89/100	30/100	58/100	88/100	30/100
Willingness to teach evolution	30/50	43/50	13/50	28/50	48/50	20/50

Note. Total represents the NOS scores out of 16 before and after treatment and the changes. Change in acceptance represents the scores out of 100 on the MATE before and after treatment. The change is represented by changes in statements 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 15, 17, 19, 20, 21, 23, 24, 26, and 27. Willingness to teach evolution is represented by a score out of 50 on the MATE+. The change in willingness is represented by change in statements 2, 5, 14, 16, 18, 22, 25, 28, 30, and 32. Items 29 and 31 were used as a reference for items 30 and 32 and were not included in the calculations.

Appendix I (continued)

Interviewees Changes in NOS Understanding and Willingness to Teach Evolution

Statement	Tracie before treatment score	After treatment score	Change	Trisha before treatment score	After treatment score	Change
1	3	3	0	2	2	0
2	3	3	0	2	3	1
3	2	2	0	0	2	2
4	2	2	0	1	1	0
5	2	3	1	1	2	1
6	2	2	0	1	1	0
7	1	1	0	0	1	1
Total	15/16	16/16	1/16	7/16	12/16	5/16
Percent change	94%	100%	6%	44%	75%	31%
Acceptance of evolution	100/100	100/100	0/100	76/100	79/100	3/100
Willingness to teach evolution	50/50	50/50	0/50	35/50	34/50	-1/50

Note. Total represents the NOS scores out of 16 before and after treatment and the changes. Change in acceptance represents the scores out of 100 on the MATE before and after treatment. The change is represented by changes in statements 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 15, 17, 19, 20, 21, 23, 24, 26, and 27. Willingness to teach evolution is represented by a score out of 50 on the MATE+. The change in willingness is represented by change in statements 2, 5, 14, 16, 18, 22, 25, 28, 30, and 32. Items 29 and 31 were used as a reference for items 30 and 32 and were not included in the calculations.