

EVOLUTION AND PRE-SERVICE SCIENCE TEACHERS:
INVESTIGATING ACCEPTANCE AND REJECTION

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ABSTRACT

This study utilized three methodological approaches to examine the controversy and concerns associated with evolution education, taking the examination of acceptance and rejection full circle from concept to conflict. Employment of a critical analysis approach determined existing gaps in the literature surrounding evolution education and provided directionality for further study. A quantitative analysis generated findings that explain variance in the acceptance of evolution among pre-service science teachers in a teaching college in the Southeastern United States. A third qualitative method study explored the lived experiences of pre-service science teachers focusing on the variables of interest and generated a theoretical process model of acceptance and rejection for this group of participants. This study's variables explored aspects of Southern cultural and religious identity, socio-cultural influences on teaching and learning, and dilemmas faced by teachers when teaching controversial topics. This exploration illuminated the current state of evolution education in the Southeastern United States, as well as obstacles to the acceptance of evolution and possible avenues for improvement of science teacher education and classroom instruction.

DEDICATION

This dissertation is dedicated to my wonderful family, without whose love, support, and uplifting I would never have undertaken, and certainly not completed, this level of study. I have had, in my life, the benefit of being influenced in both the old and new ways of thought, and have been both lifted to the stars and grounded firmly in my roots.

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LIST OF ABBREVIATIONS AND SYMBOLS

| | |
|-------------|---|
| <i>a</i> | Chronbach's index of internal consistency |
| AAAS | American Association for the Advancement of Science |
| ANOVA | Analysis of variance |
| ASTE | Association for Science Teacher Education |
| B | Y-intercept of prediction equation |
| BG | Background |
| CCSS | Common Core State Standards |
| <i>df</i> | Degrees of freedom: number of values free to vary after certain restrictions have been placed on the data |
| DED | Father's education level |
| ECK | Evolution Content Knowledge |
| ERIC | Education Resource Information Center |
| F | F-test |
| GEN | Gender |
| JSTOR | Journal storage |
| <i>K-4</i> | Kindergarten through fourth grade |
| <i>K-8</i> | Kindergarten through eighth grade |
| <i>K-12</i> | Kindergarten through twelfth grade |
| <i>M</i> | Mean: the sum of a set of measurements divided by the number of measurements in the set |

| | |
|----------------|---|
| <i>m</i> | Number of variables initially tested |
| MATE | Measure of Acceptance of Theory of Evolution |
| MED | Mother's education level |
| <i>N</i> | Number of cases |
| NARST | National Association for Research in Science Teaching |
| NABT | National Association of Biology Teachers |
| NAS | National Academy of Sciences |
| NCATE | National Council for Accreditation of Teacher Education |
| NGSS | Next Generation Science Standards |
| NOS | Nature of science |
| NRC | National Research Council |
| NSES | National Science Education Standards |
| NSTA | National Science Teachers' Association |
| <i>p</i> | Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value |
| PASW | Predictive Analytic Software |
| PCK | Pedagogical Content Knowledge |
| <i>r</i> | Pearson product-moment correlation |
| R | Correlation coefficient |
| R ² | R-Squared, Coefficient of determination |
| REL | Religiosity |
| RINF | Religious influence |
| SACS | Southern Association of College and Schools |
| SCI | Completed science courses |

| | |
|-------------|---|
| SD | Standard deviation |
| <i>sdr</i> | Studentized deleted residuals |
| Sig | Significance |
| SPSS | Statistical Package for Social Sciences |
| <i>sre</i> | Studentized residuals |
| Std. Error | Standard error |
| STEM | Science, Technology, Engineering and Math |
| <i>t</i> | Computed value of <i>t</i> test |
| <i>t*</i> | <i>t</i> -critical |
| V-NOS | Views of Nature of Science |
| <i>x</i> | independent variable |
| <i>y</i> | dependent variable |
| YR | Year of study (Grade) |
| <i>zres</i> | Standardized residuals |
| < | Less than |
| > | Greater than |
| = | Equal to |
| | Absolute value |

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INTRODUCTION:
INVESTIGATING ACCEPTANCE AND REJECTION
OF EVOLUTION AMONG PRE-SERVICE SCIENCE TEACHERS

Introduction

Evolution remains one of the most controversial topics in biology although it is accepted in the scientific community and recognized as the unifying concept that ties all principles of biology together. Evolution refers to the theory that living things are continually changing over long periods of time. It involves both plant and animal evolution, including the evolution of humans, Earth history such as the age of the planet itself, and concepts of the nature of science, including its ambiguity and the nature of laws and theories as proven. Despite controversy among the general public, leading national organizations in the science and education fields have expounded their positions supporting the theory of evolution and recognize it unanimously as scientific theory that is imperative to teaching and learning in science (National Science Teachers Association, 2004; National Academy of Sciences, 2008; National Association of Biology Teachers, 2008). As Dobzhansky (1973) noted, “nothing in science makes sense except in light of evolution.” With this historical statement on record for more than a quarter-century, it would be logical to expect that the teaching of evolution has come full circle and plays a major recurring role in the high school and college biology classrooms; however, the opposite is true.

The research findings show that not only is evolution not taught as a unifying concept, it is often merely addressed in passing, or left out entirely (Bowman 2008; Goldston & Kyzer, 2009; Moore & Kraemer, 2005). This is true not only of instruction at the secondary level but at

the higher education level where we are training both future scientists and future science educators (Alters, 2004; Alters & Nelson 2002; Catley & Novick 2009). It is also true that there are complex relationships between acceptance and knowledge of content in controversial topics that are not the same as the relationships seen in non-controversial content (Sinatra, Southerland, McConaughy, & Demastes, 2003). For example, students were able to accept the events of photosynthesis as fact after learning more about the process, but the same was not true of students who learned more about evolution, so although knowledge and acceptance are slightly related, advanced knowledge of evolution still does not mean it will be accepted (Sinatra, Southerland, McConaughy, & Demastes, 2003). Thus, acceptance of evolution is more than simply having knowledge of evolution but also involves a multitude of intervening factors, which is the centerpiece of this research.

Background of the Study

Research in evolution has historically shown crests and troughs in popularity. The most repetitive feature over time in the literature was that of religion. It surfaced as a major factor whether the research focused on the acceptance of evolution or understanding evolution with reference to teaching and learning. Despite the centrality of religion in evolution research, the research on evolution also connected to a great many other topics.

In Table 1.1, there have been a number of topics in the literature leading up to the twenty-first century. Historically, studies indicated that students were not learning evolution, as they were other topics in science, leading to many directions of future research. Four major trends have been recurrent in the literature. The most repetitive trend is that of religion as posing a barrier to the teaching and learning of evolution due to conflicting accounts of earth time and organismal origins. Another trend in the research focused on how evolution was taught to

determine whether the method of teaching was inhibiting learning of evolution. A third trend was the understanding, or lack of understanding, of the ambiguous nature of science as an inhibitor to the learning of evolution. Finally, these ideas shifted from a focus on knowledge and understanding as the barrier to evolutionary learning to the idea that acceptance and rejection of evolution, not knowledge, was causing the discrepancy between the scientific community views and those in the lay community.

Table 1.1

Evolution and Pre-service Science Teachers: Key Topics in Evolution Literature Prior to 2000

| Historical Literature: Evolution Education | |
|--|---|
| Historical Studies | Bishop & Anderson, 1990; Lawson, 1999; Smith, 1994 |
| Religious Influence | Bergman, 1999; Dagher & BouJaoude, 1997; Eglin, 1983; Ellis, 1986; Lerner, 2000; Meadows, Doster, & Jackson, 2000; Moore, 1998a; Moore, 1998b; Moore & Kraemer, 2005; Osif, 1997; Tatina, 1989; Van Koevering & Stiehl, 1989; Zimmerman, 1987 |
| Teaching Methods | Alters & McComas, 1994; Demastes, Good, & Peebles, 1996; Lawson & Weser, 1990; Scharmann, 1993 |
| Nature of Science | Griffiths & Barry, 1993; Griffiths & Thompson, 1993; Lederman & Zeidler, 1987; McComas, 1997; Rudolph & Stewart, 1998; Scharmann & Harris, 1992; Smith & Scharmann, 1999 |
| Acceptance | Alters, 1996; Fahrenwald, 1999; Johnson, 1986; Shankar, 1989 |

In the last decade, there was an influx of research conducted regarding aspects of evolution related to education, as shown in Table 1.2. During the late twentieth century, the focus of evolution research expanded from general teaching methods to include teaching of the nature of science as key to understanding and accepting evolution. At the turn of the twenty-first century, the focus shifted again toward the notion of acceptance as the goal for teaching and learning evolution among academics. Some focused on perceptions of teachers, others took the

same approach with students, and many looked at past studies in evolution education to frame methods for teaching and learning of evolution. In addition to these teaching and learning expositions, there was an increase in interest in the relationships among beliefs and understanding of evolution, nature of science, and acceptance of evolution in various combinations. Most of these focused on high school students, college biology majors and non-majors, and in-service teachers, but little was done to test these ideas in the pre-service science teacher population. This gap in the research literature represents an important time in the development of those individuals (pre-service teachers) who intend to become a science teacher.

Table 1.2

Evolution and Pre-service Science Teachers: Key Topics in Evolution Literature After 2000

| | |
|---------------------------------------|---|
| Religious Influence | Alters & Alters, 2001, Colburn & Henriques, 2006; Martin-Hanson, 2006; National Academy of Sciences, 2008; Taber, Billingsley, Riga, & Newdick, 2011; Winslow, Staver & Scharmann, 2011 |
| Acceptance/Rejection | Akyol, Tekkaya, & Sungar, 2010; Brem, Ranney, & Schindel, 2003; Davson-Galle, 2002; Deniz, Donnelly, & Yilmaz, 2008; Ingram & Nelson, 2006; Rutledge & Mitchell, 2002; Sinatra, Southerland, McConaughy & Demastes, 2003; Thagard & Findlay, 2010 |
| Nature of Science | Akyol, Tekkaya, & Sungur, 2010; Cobern, 2000; Dagher & BouJaoude, 2005; Farber, 2003; Goldston & Kyzer, 2009; McComas, 2003; McComas, 2007; Morrison, Raab, & Ingram, 2009; Nadelson, 2007; Nehm & Schonfeld, 2007; Rutledge & Warden, 2000; Scharmann, Smith, James, & Jensen, 2005; Southerland, Johnston, & Sowell, 2006 |
| Teacher Perceptions | Friedrichson & Dana, 2005; Kikas, 2004 |
| Student Perceptions | Moore 2007; Woods & Scharmann, 2001 |
| Teaching/Learning Methods | Adb-el-Khalick & Akerson, 2004; Alles, 2001; Anderson, 2007; Besterman & Baggot la Velle 2007; Matthews, 2001; Passmore & Stewart, 2002; Scharmann, 2005 |
| Knowledge, Beliefs, and Understanding | Chinn & Samarapungavan, 2001; Davson-Galle, 2004; Hokayem & BouJaoude, 2008; Jones & Carter, 2007; Nadelson & Sinatra, 2010; Nehm & Reilly, 2007; Smith & Siegel, 2004 |
| Secondary Students | Bowman, 2008 |
| Post-Secondary Students | Abd-el-Khalik & Lederman, 2000; Nehm, Kim & Sheppard, 2009; Nehm & Reilly, 2007; Trani, 2004 |
| In-service Teachers | Abell, 2007; Chuang, 2003; Donnelly & Boone, 2007; Goldston & Kyzer, 2009; Griffith & Brem, 2004; National Association of Biology Teachers, 2008 |
| Pre-service Teachers | Deniz, Cetin, & Yilmaz, 2011; Deniz, Donnelly, & Yilmaz, 2008 |

Significance of the Study

Pre-service teachers occupy a unique position between that of a student and that of teacher, lending a unique perspective to understanding what happens to their views on evolution between the two positions. Understanding acceptance and rejection of evolution among these individuals gives better insight into the process by which those decisions are made and allows for adjustments to both scientific and teacher education preparation for future science education students.

Purpose of the Study

This study sought to understand pre-service science teachers' acceptance and rejection of evolution and the continuum between the two directions. This exploration involved three connected studies that built upon one another, first by identifying a direction for further study; then empirically determining factors that influence acceptance and rejection among pre-service science teachers in the Southeastern United States; and finally, exploring the lived experiences of pre-service teachers in the Southeast to develop a theoretical process model for acceptance and rejection of evolution.

The first study began by examining the research and conducting a critical review of the literature on evolution education since 2000, a year chosen because it closely coincides with the release of National Science Education Standards that advocate the teaching of evolution (NSTA, 2004). It also reflects a time when pre-service teachers were being prepared for teaching science during the standards movement, prior to their becoming teachers. A critical review provided insights into the quantity and quality of the research already conducted regarding evolution education and led to the selection of acceptance of evolution as a focal point for the study.

In the second study, scores were collected for pre-service science teachers on their level of understanding of nature of science; level of evolutionary acceptance; level of evolutionary content knowledge understanding; science background information such as courses completed, year of study, and number of family or peers in science, math, and technological fields; family educational background; and religiosity. These values were analyzed using multiple regressions to determine whether there were statistically significant relationships between the variables.

Finally, an investigation into the lived experiences of contemporary pre-service educators was conducted in order to understand, from their own world-views, what exposures they had regarding evolution and how they navigated their understandings and experiences to accept, (in various degrees), or reject evolution. These data was then used to generate a theoretical model to describe the process by which the average pre-service teacher--those with moderate acceptance--chooses to accept or reject evolution. Many of these lived experiences aligned with the statistically influential factors identified in the quantitative study. A more detailed description for each study is outlined in the following section.

Organization of the Study

The following chapter describes three independent, yet connected, articles that center on gaining insights into multiple factors that influence pre-service science teachers' acceptance of evolution. Each article provides a piece to the complex puzzle of understanding how and why pre-service educators choose to accept or reject evolution, a decision that, ultimately, influences not only their teaching practices and epistemologies, but the generations of students those practices will inform.

Article One: Evolution and Pre-service Science Teachers: A Critical Analysis of Literature

Purpose. Article One of the dissertation is the critical review of existing literature on evolution in education from 2000 to 2013. The critical review provided a method for examining research findings on evolution to guide the development of the two subsequent studies. The purpose of the review was not to discuss the existing body of knowledge, but to critically examine the extensive body of research on evolution education in an effort to determine what the research trends have been, identify findings, and evoke questions, issues, or gaps in knowledge that lie therein. This type of review is appropriate in cases where the existing body of literature is expansive, as it is with evolution, and where there has been such a volume of research as to warrant the evaluation of the depth and breadth of the literature. The review was advantageous in that it provided a more comprehensive view of what had been done in evolution education research, prevented the repeat of studies that were already sound and generalizable, and showed where the literature lacked saturation.

Research questions. The critical review provided the justification for the quantitative and qualitative studies found in chapters three and four by answering the following questions:

- (1) Where has evolution education research been focused since the endorsement of the National Science Education Standards and the early cycles of implementation in 2000; and
- (2) How have the research findings contributed to our knowledge of evolution relative to teaching and learning, and what may further illuminate our understanding of evolutionary acceptance and rejection?

Methodology. A critical review of literature began with a general survey of the topic of evolution, in order to evaluate the volume of literature and select a time range for article

identification and selection. Once the time frame from 2000 to 2013 was selected, key terms, such as *evolution education*, *teaching evolution*, *acceptance*, and *evolution learning*, were identified by a general search of evolution literature in general databases. Using keywords to search academic databases and locate a wide range of studies, the existing literature was systematically searched to identify articles for initial review.

The critical review included both qualitative and quantitative research presented in peer-reviewed journals. These preliminary searches enabled conceptualization of the research foci taken and were the basis for formulation of criteria used to select literature to include and reject. The next step involved examination of the abstracts of all selected articles for the topics of evolution and education. Any article identified in the initial scan upon abstract review, that did not involve evolution directly was eliminated. The initial review of abstracts resulted in 213 articles for further evaluation of which 59 were selected for the critical analysis. Following the selection, the rejected literature was evaluated then organized in an informational matrix to document exclusion and prevent removal of related articles due to possible bias

The selected articles were analyzed and evaluated for methodological soundness, validity and reliability, and what results or implications they supported. Next, they were grouped into units that represented the various foci of the overall body of knowledge. The foci included acceptance/rejection of evolution; knowledge, belief, and understanding; religion and evolution; nature of science and evolution; teaching methods for high school students, college non-majors, and college majors in biology; and how the learning process relative to evolution.

Article Two: Evolution and Pre-service Science Teachers: Factors Influencing Acceptance and Rejection of Evolution

Purpose. Article Two is a quantitative study that expanded upon prior research findings that identify influential factors associated with the acceptance or rejection of evolution conducted across the United States or abroad. The purpose of this study was to determine what, if any, relationships existed between acceptance and rejection of evolution and identified variables including the nature of science, content knowledge, education experience, science background, and religion in pre-service secondary science teachers in the Southeastern United States.

Research questions. The quantitative article centered on the following questions:

- (1) What relationships exist between the worldview variables and acceptance of evolution among pre-service secondary science teachers; and
- (2) Which combination of these variables explains the most statistically significant amount of variance in the acceptance of evolution among pre-service secondary science teachers?

Methodology. Regression analysis was employed to determine the amount of variance explained by the identified factors and which were significantly correlated to acceptance or rejection. Such information gives insight into whether increasing the acceptance of evolution among the secondary pre-service teachers can be influenced through external interventions such as education coursework, professional development, and further scientific study; or whether the greatest explanation is determined by internal factors, such as religiosity, that require a restructuring of closely held beliefs before acceptance is achieved.

Article Three: Evolution and Pre-service Science Teachers: A Theoretical Process Model of Acceptance and Rejection of Evolution

Purpose. The purpose of this study was to examine the lived experiences of pre-service science teachers relative to the variables identified as significant influences on acceptance and rejection of evolution in the quantitative study of chapter three. It is important to understand not only what influences pre-service teachers' decisions regarding evolution, but how those influences are processed, how they constructively or destructively interact with one another, and how the individual prioritizes and enables each influence in their own mind. This study led to the creation of a theoretical process model to explain how pre-service science teachers in this study filter and construct multiple forms of influences to make their choice to accept or reject evolution at various levels. Currently, no models have been found to explain this process, Previous research has focused primarily on simple linear relationships and not on the overlapping influences and how personal choices impact the process.

Research questions. The qualitative study sought to answer the following questions:

- (1) What factors influence the acceptance or rejection of evolution among pre-service secondary science teachers; and
- (2) What process model of acceptance and rejection of evolution among pre-service science teachers emerges through a lens of worldview in the rural Southeastern United States?

Methodology. A qualitative interview approach was undertaken using grounded theory methodology to analyze the data. Prior to the interviews, students were asked to complete the Measure of Acceptance of Theories of Evolution (MATE) survey which, when scored, was used to sort students into groups based on their level of acceptance of evolution. Groups were sorted

as very high, high, moderate, low, or very low acceptance based on student scores. Sorting enabled the selection of students from each level of the acceptance continuum for a more representative snapshot of experiences.

From each group, two students were randomly selected to participate in one-on-one interviews where they were asked about their ideas and experiences about a range of topics including what factors they feel influence their actions and ideas, their school and home experiences, their exposure and beliefs regarding evolution, and conflict they feel about evolution. These interviews were coded in multiple stages according to grounded theory methodology in an effort to identify categories and the underlying theoretical process that was common or unique to their experiences.

Continued evaluation of the data revealed that the experiences across the spectrum did not lend themselves to a single model interpretation and that a better representation of the process of acceptance and rejection of evolution in pre-service science teachers would be best expressed through a deeper examination of experiences at the moderate level. Three additional participants were randomly selected from the moderate acceptance level to allow the formulation of the process model for acceptance of evolution.

The theoretical process model developed is a conceptualization of the process by which pre-service science teachers accepted or rejected aspects evolution in terms of emergent relationships (Charmaz, 2006). The creation of the model was the result of multiple levels of both axial and theoretical coding (Birks & Mills, 2011; Charmaz, 2006; Corbin & Strauss, 2008) prescribed by grounded theory methodology. This involved the identification of themes followed by reorganization based on the identified factors and the interactions of these factors within each participant. This approach led to a visual model for representing the relationships and

interactions among the influences in decision making by the participants and the pathways by which the choices relative to acceptance or rejection were made.

Summary

This work sought to understand issues surrounding the acceptance or rejection of evolution by pre-service secondary science teachers and how teaching evolution continues to be an issue of great controversy with implications for its widespread rejection. To accomplish this, three methodological approaches were taken in articles one, two, and three to provide a cohesive discourse on the complex interplay of influences related to the acceptance or rejection of evolution. By critically analyzing the existing literature to identify gaps in understanding, it became apparent that we have a range of information on evolution but little understanding of the acceptance and rejection of evolution among pre-service science teachers. The subsequent articles contribute to the knowledge base in two ways. One way is by determining, statistically, which factors were significant in determining whether a pre-service science teacher accepts or rejects evolution and second by describing the processes that took place within pre-service teachers from their point of reference. Synergistically, these three studies provided support for one another by looking at both the internal and external factors interacting as a holistic, dynamic process surrounding an individual's acceptance or rejection of evolution.

ARTICLE ONE:
EVOLUTION AND PRE-SERVICE SCIENCE TEACHERS:
A CRITICAL ANALYSIS OF LITERATURE

Introduction

Evolution has been a topic that has both fascinated and frustrated humankind since the beginnings of our understanding of its place in science. For over 150 years, the theory and its postulates have drawn the attention of scientists and the public alike. Countless research studies have been conducted in the attempt to understand the chasm between what is accepted by scientists and what is often adamantly refuted, or willfully ignored, by the general public (Baker, 2013; Bowman, 2008; Goldston & Kyzer, 2009; Moore, 2004, 2008; Rutledge & Mitchell, 2002; Rutledge & Warden, 2000; Thagard & Findley, 2010; Wiles & Alters, 2011). With the changing perspectives regarding best practices for teaching evolution, the focus of research often shifts, leaving more questions than answers in the wake of new findings.

The development and implementation of the National Science Education Standards in 1996 was a major step toward bringing more uniform practice to science teaching across the country (National Academy of Sciences, 1996). A notable standard was a focus on evolution and equilibrium as a unifying concept of science and the inclusion of basic concepts of evolution beginning in the K-4 school content standards. The NSES standards and guidelines were meant to improve the teaching of science and training of science teachers in order for them to better represent the nature of science, scientific processes, and principles of science to students. They further aimed to provide students with experiences in science that were more closely aligned to

the practices of science. Seventeen years later, a new set of national standards, the Next Generation Science Standards (NGSS) have been adopted and are building upon the NSES groundwork by including vertical scaffolding to connect the concepts from grade to grade in addition to scaffolding key unifying concepts such as evolution, adaptation, natural selection, origins, and biodiversity beginning in early grades and continuing throughout elementary and secondary school (National Research Council, 2013). These, along with the adoption of the forthcoming science Common Core State Standards (CCSS) by 48 states, have the potential to take science reform to a new level in the coming years (Common Core State Standards Initiative, 2012).

Since the mid-twentieth century, research on evolution in education has increased in volume due to the continued pattern of rejection among non-scientists despite technological advances that lend, so far, scientifically irrefutable evidence to the theory of evolution (Akyol, Tekkaya, & Sungar, 2010; Brem, Ranney, & Schindel, 2003; Davson-Galle, 2002; Deniz, Donnelly, & Yilmaz, 2008; Gallop, 2011; Ingram & Nelson, 2006; Rutledge & Mitchell, 2002; Sinatra, Southerland, McConaughy & Demastes, 2003; Thagard & Findlay, 2010). A range of experts from scientists to teachers have tried to understand the *how* and *why* needed to provide understanding of acceptance and rejection of evolution. The concern with this expansive volume of research is threefold. First, it becomes difficult to identify what is and is not methodologically sound or relevant in expanding our understanding of evolution in education without taking time to analyze what has been done. Second, in such large quantities it is more complicated to ascertain which avenues of research have been exhausted and which have not. Finally, without a deep evaluation of the existing research, it is nearly impossible to determine directionality for further study to address unanswered questions in the existing literature and meaningfully expand

on what is already well understood about evolution with respect to teaching and learning of evolution.

Purpose

The purpose of this study was to examine existing research findings in an effort to determine the contributions to our knowledge of evolution as it relates to teaching and learning. This evaluation was intended to illuminate our understanding, especially regarding the acceptance and rejection of evolution among pre-service science teachers and to provide a guide for future areas of research.

Research Questions

- (1) Where has evolution education research been focused since the endorsement of the National Science Education Standards and their early cycles of implementation in 2000; and
- (2) How has the research literature contributed to our knowledge of evolution relative to teaching and learning, and what additions are required to further illuminate our understanding of evolutionary acceptance and rejection?

Methodology

Background

Critical literature review, as a methodology, requires a researcher to move beyond traditional review of literature to meticulous analysis, comparison, and evaluation of a large body of existing research in a topic (Pajares, 1992, 1996). Evolution, as a research area of study, has been extensively examined over the past two centuries, a collection that naturally lends itself to critical review in an effort to determine exactly what has been researched, what value the research holds based on measures of reliability and validity (quantitative) or trustworthiness

(qualitative), and what directions should be taken with future research on the topic. According to Pajares (1992; 1996), a critical literature review involves a series of steps prior to, during, and following the actual review. This study followed these guidelines. First, there must be a large existing body of information from which articles are pulled. The body of information is first searched generally to identify the range of parameters for a critical review. If the topic is too narrow, there is little room for critical analysis. Second, during this time, a research journal is kept, containing searches and details pertinent to the information viewed in the searches and tracking the directions and decisions made.

Prior to the selection of articles for review, a general overview detailed the primary searches, namely whether the searches returned a large enough collection of articles for the methodology and what other searches might increase the collection prior to article selection. This information guided the criteria for selecting articles for further viewing and possible analysis. I first reviewed the papers excluded and provided an overview of the articles to demonstrate that the selection of articles, though purposeful, is done in such a way as to include a wide range of article positions and not reflect bias. The articles chosen for review were analyzed to determine what, if any, themes exist in the literature. As patterns emerged, they were defined, and the articles sorted. Each article was evaluated for selection based on criteria explained by Kane, Sandretto, and Heath (2002), which include a) critique of the theoretical framework, b) research focus, c) research methods, d) sample and population applicability, e) methodology, and f) what the study would inform (p. 185).

Article Selection

A preliminary search was conducted on the online search engine Google Scholar to glean the breadth of information available on evolution and evolution education. The inclusion of

evolution education within the search was selected to eliminate all articles in biological and other sciences with applied research with respect to evolution rather than evolution as a topic of science teaching and learning. A preliminary search indicated that a large variety of studies were conducted and published regarding evolution in leading science and education journals. To narrow the field, a date range of approximately thirteen years between 2000 and 2013 was chosen to represent research in evolution conducted since the implementation of the National Science Education Standards in education (National Academy of Sciences, 1996). Although the movement began in 1996, the year 2000 allowed time for teacher awareness and implementation of the national standards in classrooms. The closing year, 2013, represented the emergence of the Next Generation Science Standards and was selected to include current research as well.

Following the selection of a date range, broad searches were conducted in key full-text databases including Education Full Text, Educational Resources Information Center (ERIC), Wiley Interscience, and Journal Storage (JSTOR) with the keywords, in varying combinations: *evolution and education, conceptual ecology, conceptual change, rejection, acceptance, knowledge, understanding, religion, schools, teaching, learning, nature of science, and influences*. These keywords were identified through evaluation of abstracts and suggested further searches generated by the initial scan of the literature. A beginning collection of 213 articles was gathered.

Abstracts were evaluated to determine whether the articles met the criteria for full review. The primary criterion was that the study should focus on evolution education, not evolution history or specific content. Second, the study was applicable to one of the following groups: teachers of evolution, pre-service teachers of science at the secondary and elementary levels, secondary students, or higher education science students. The third criterion was that the studies

were in scholarly journals, with preference given to national and international publications including those journals that frequently publish evolution research (e.g., *Journal of Research in Science Teaching*, *Science Education*). The final collection included 59 articles.

Review Criteria

To conduct consistent evaluations on selected articles, question protocols were created to guide the review process and provide points for comparison across collected articles. Table 2.1 shows the questions that were addressed for each aspect of contention in the collected qualitative articles. These questions were adapted from the Guidelines for Critical Review Form for Qualitative Studies by Law, Stewart, Letts, Pollock, Bosch, and Westmorland (1998).

Table 2.1

Evolution and Pre-service Science Teachers: Question Protocol for Critical Review of Qualitative Articles

| | |
|--------------------|---|
| Study Purpose | Was the purpose clearly stated? Is qualitative study appropriate for the purpose? |
| Literature | Was the review relevant to the study? |
| Design | Is the design appropriate based on the questions and purpose? Was a theoretical/conceptual framework identified? |
| Methods | Are the methods described? Are the selected methods appropriate for the purpose and questions? Was the sample appropriate to the design? Was the data rich enough for relevance (saturation)? Was consent obtained? Was the process and reasoning clear? |
| Collection of Data | Are descriptions provided for location, role of researcher, site, and participants? Are assumptions and research position defined? |
| Rigor | Was enough data collected to support the study? Were methods appropriate for the setting of the study? |
| Analysis | How was the data analyzed? Did the research provide adequate support for conclusions? Were the reported findings consistent with the data? Was the thought process between findings and conclusions illustrated and clearly defined? Was the resulting report meaningful to the theoretical construct? Were multiple sources used to reduce the chance of bias? |
| Conclusions | Did the findings and the conclusions appropriately align? Were the conclusions meaningful in such a way as to contribute to future study, theory, or practice? |

Since there was no necessity to eliminate articles based on whether they were qualitative or quantitative studies, a second protocol was developed for the outline review of quantitative articles. Table 2.2 shows the questions used to critically analyze quantitative studies that were part of the original collection. These questions were adapted from the Guidelines for Critical Review Form for Quantitative Studies by Law, Stewart, Letts, Pollock, Bosch, and Westmorland (1998b).

Table 2.2

Evolution and Pre-service Science Teachers: Question Protocol for the Critical Review of Quantitative Articles

| | |
|------------------------------|--|
| Purpose and Problem | Was there a clearly stated problem/purpose of the research? Does it support the question? What are the research questions? What theoretical frame was given, if any? |
| Measurement | What are the independent and dependent variables? How are they defined? Was definition appropriate? Are they valid and reliable? |
| Design | What design was used? What biases were present? |
| Sample | What was the sample? Was it detailed? Was the size appropriate and explained? What technique was used? Are there issues with generalizability? How will the sample affect the findings? |
| Outcomes | Was reliability and validity established? How often did measurement occur? What measurement was used? |
| Intervention | Was an intervention applied? Can it be repeated? What was the intervention? |
| Data Collection and Analysis | What method was used? What are advantages and disadvantages of the chosen method? How was data analyzed? |
| Results | What were the results? Was significance established? Was analysis appropriate? Were there multiple outcomes? Were they accounted for in analysis? What is the importance of the results? Were there any drop-outs or outliers removed from the study? Why? |
| Conclusions and Implications | What were the conclusions? Were they appropriate? What were the implications? What limitations existed? |

Once the reviews were completed, the articles were sorted and grouped based on common trends that are discussed in the following review.

Review of Literature

Upon initial analysis of the research articles, fourteen categories were identified. However, further analysis demonstrated that, in some cases, the originally defined categories were interconnected or overlapped to the point that they would better serve as sub-categories of a larger category. The final categories presented include the following: *(1) approach to evolution in the classroom, (2) knowledge, understanding, and acceptance of evolution, (3) attitudes and perceptions of evolution, (4) factors impacting the teaching and learning of evolution, (5) evolution conflict and coping strategies, (6) evolution and religiosity, and (7) proposed evolution teaching methods, courses, and assessment.* For the purpose of clarity and to demonstrate the connections within the literature, the results and analysis are framed in terms of those categories and their subsequent sub-categories seen in the following sections. A chart listing the studies found in each category and sub-category is presented in Appendix A.

Approach to Evolution in the Classroom

According to the studies reviewed, the approach of the teaching of evolution in United States classrooms is non-existent at worst and, at best, weak and inconsistent (Bowman, 2008; Moore, 2004, 2008; Rutledge & Warden, 2000; Rutledge & Mitchell 2002). Many interesting points come to light that are in conflict with, or direct violation of, legal precedents regarding evolution. Goldston and Kyzer (2009) found state-provided disclaimers about evolution in the front of biology textbooks, while courses are taught every day in schools that include, or solely focus on, creationism as a scientific theory (Moore, 2008) and evolution is being repressed by parents, teachers, and administrators alike (Moore & Kraemer, 2005). According to Bowman

(2008), three of ten students in modern classrooms are being taught creationism and another two, out of ten, are being taught intelligent design (p. 303). The Supreme Court has ruled on what can and cannot be done in these cases, but, based upon Bowman's work, somewhere between the legal system and the education system, the ruling loses impact.

Moore (2004) examined whether teachers in the classroom are aware of the legal rulings that guide the teaching of evolution in public schools. Arguably, this awareness is important as it not only provides support for the teaching of evolution but also allows avoidance of legal repercussions. He found that teachers were not aware of key legislation regarding the teaching of evolution, teaching of creationism, refusal to teach evolution, and other issues. He also found that teachers were unable to accurately respond when asked questions about potential lawsuits for compliance with, or defiance of the legal precedents prohibiting both the teaching of Creationism and state exclusion of evolution. This means that teachers lack the background in legal issues that protect them if they teach evolution, prevent them from teaching creationism, and prevent states from enacting legislation which conflicts with these rulings.

In a comprehensive study of the teaching of evolution, Bowman (2008) looked at trends and influences on the teaching of evolution in state universities in eight states. Using *evolution, creationism, intelligent design, standards, red/blue state status, and geographical region* as variables, she sought to determine the factors influencing what was being taught in classrooms across the United States. This study looked at an equal number of red or blue political states, states with both weak and strong standards, and states from major geographical regions. Relying on the students' recollections of their high school biology experiences, she found that 92% of those involved were taught evolution in some form in high school, but only 47% felt their background was somewhat adequate (Bowman, 2008). Those states with weak standards tended

to report lower percentages of the teaching of evolution, less explicit instruction at only 60%, and were three times more likely to be taught that evolution is not scientifically credible (Bowman, 2008). Furthermore, southern and eastern regions of the United States were significantly less likely to receive credible instruction with those regions only showing 56% compared to 76% in the northern states, and 82% in the western states.

Looking into the classroom, Veal and Kubasko (2003) examined the differences in how evolution is approached by earth science instructors and biology instructors. They did this by looking at geology and biology as separate domains with separate communities of practice. They found that biology teachers know less about geology than what the geology teachers knew of biology, meaning that they were able to make more connections and activate a wider span of prior knowledge than the biology teachers. They also found that, due to the focus of biology on the animate aspects of evolution, there was more focus on the misconceptions and religious conflicts in the biology courses than in the more inanimate geology courses where the focus was further removed from human evolution.

Oliveira, Cook, and Buck (2010) found that new teachers rely on direct instruction and avoidance due to their lack of experience in dealing with the complexities of teaching controversial topics. In addition to their findings suggesting that new teachers are not prepared to deal with the conflict of evolution in the classroom, Oliveira, Cook, and Buck (2010) also found that teachers often took on the role of novice, rather than expert, when dealing with the topic of evolution. In their observations they noted that teachers tended to take on a joking tone, step back from the role of expert, and took on the approach of legal obligation to discuss evolution rather than addressing the conceptual content and history of the theory. The teachers further dismissed the importance of evolution by making discussion participation optional and by trying

to maintain politeness rather than focusing on concepts and the nature of science. These observations underscore the teaching of evolution wherein teachers remove themselves as authorities and address evolution superficially leaving students to find their own knowledge and understanding.

Examining how biology teachers approach controversial issues, Goldston and Kyzer (2009) followed three teachers throughout a school year to compare their teaching of traditional biological topics with their treatment of the more controversial topic of evolution. A thematic analysis showed that teaching identities of experienced teachers are changed when they are teaching evolution, ultimately affecting their decision to teach evolution as well as the manner in which it was taught (Goldston & Kyzer, 2009). They further found that when teachers perceived a strong student or community set of beliefs opposed to evolution, such as creationism, their teaching identity shifts to take care in addressing evolution or omit it completely from the curriculum, despite the standard requiring it be addressed. Surprising results of textbook and standards analysis showed that the texts often did not provide the strength of support for evolution that the teachers sought to legitimize their instruction, furthermore, the state in this case included a disclaimer in the textbooks that sent confusing and conflicting messages about the relevance of evolution, leaving the teachers to choose whether to include it in their teaching. This autonomy resulted in a liability in which teachers could opt out of teaching evolution to avoid controversy. These studies, conducted around the United States paints a landscape rife with inconsistencies in teaching evolution. Evolution is being taught in some places, omitted in others, and, in other cases, taught alongside non-scientific alternative concepts such as intelligent design and creationism.

Knowledge, Understanding, Belief and Acceptance of Evolution

Within the literature exploring evolution education, there is an ongoing disagreement about the purpose of science education relative to evolution and whether that purpose is for students to believe or accept evolution. For most, the concept of belief is one disassociated with the realm of science, leaving acceptance and the influences on acceptance as focal points for the reform of evolution instruction in schools. In their study, Sinatra, Southern, McConaughy, and Demastes (2003) distinguished between these two concepts, noting that *acceptance* differs from *belief* in that it is founded on factual information rather than feelings or opinions of the individual. This means that those who support knowledge and understanding as the goal of science teaching want a focus on an evolution course creation and testing. In contrast, those who support acceptance as the educational goal call for creation of more philosophical and methodological evolution courses, focusing on elements such as religious conflict, nature of science, and scientific history. Those supporting the latter stance tend to view acceptance as a more lasting form of understanding in which the bearer has not only knowledge of a concept, but a willingness to apply those concepts in the decision-making process.

Knowledge, belief, and acceptance of evolution among students. To begin understanding the relationships and concepts associated with acceptance of evolution, it is necessary to identify the knowledge that is valued for the acceptance of an idea as fact. Moore, Cotner, and Bates (2009) addressed this by surveying undergraduate biology students about what been taught in high school and what impact that teaching had on their knowledge of evolution. They found a variety of high school experiences, including a focus on evolution-only, evolution and creationism, creationism-only, and a lack of evolution instruction. First, the researchers found students, in general, know relatively little about evolution despite their high school courses

(Moore, Cotner, & Bates, 2009); however, a unique aspect of their study was a focus on the impact of teaching approaches on evolution content knowledge. The authors found students who had been taught only evolution in high school had the highest level of content knowledge of evolution in college; while students exposed to both evolution and creationism in high school had less content knowledge than the evolution only students. They also found that religiosity negatively affected content knowledge of evolution. Overall, knowledge of evolution was strongly associated with the amount of evolution content that was taught in high school, but only when it was the only thing taught.

Along a different line, Nadelson and Sinatra (2008) sought to determine whether there existed a cadre of professionals with evolution content knowledge, and who accept evolution, to evaluate the emerging discipline of evolutionary education psychology. This research focus emerged as there were, at the time, fewer professionals willing to discuss evolution from the stance of acceptance, knowledge and understanding. The need for this study implied that these individuals might be found in a narrow enough range to warrant great concern. They found such a group, whose commonalities included academic/research experience, evolutionary knowledge, and evolution acceptance that were willing to engage in discourse (Nadelson & Sinatra, 2008). Since acceptance requires a deep knowledge of the concepts and underpinnings of a topic, it can be viewed as a greater investment for science instruction in that acceptance enables the transfer of concepts and their meaning to other situations, a key goal for science literacy. For this reason, a number of studies have focused on aspects related to the acceptance and rejection of evolution and the relationships that influence one's choice.

This category of research naturally lends itself toward subdivision in that it spans a wide range of diverse groups such as university science majors and non-majors, pre-service

elementary and secondary science teachers, in-service secondary and elementary teachers and professors. The two least explored avenues, at least among samples within the United States, are those of high school students and pre-service science teachers across levels, arguably important populations in terms of reaching long-term, wide-spread success of scientific literacy. Although studies conducted in college-level samples can provide a snapshot of some of the concerns of students regarding evolution, those samples are representative of only a portion of the public entity, which is the target population for scientific literacy and poses the greatest resistance to evolutionary theory. Likewise, pre-service K-12 science teachers represent the future of United States science education; thus, their positions, ideas, and conflicts will be carried into classrooms ultimately influencing thousands of future students.

Several studies have been conducted to examine elements of evolutionary acceptance among college students. These include studies of undergraduate non-majors, biology majors, and mixed major studies. Sinatra et al. (2003) found that, although there are statistically significant relationships between knowledge and acceptance of general theories in biology, these same relationships do not exist between knowledge and evolutionary acceptance. Further support by Rutledge and Sadler (2011) revealed that acceptance of evolution was, as a whole, slightly less than the acceptance of other non-evolution theories key to biology (e.g., cell theory and germ theory). Furthermore, there were no significant relationships between acceptance and understanding of the nature of science regarding evolution (Rutledge & Sadler, 2011). The lack of relationship between knowledge and acceptance of evolution is further supported by data from Nehm and Schonfeld (2007) whose pre/post-course data confirmed no correlation despite increases in content understanding. Nehm and Reilly (2007) suggested that students learn the

evolution concepts for testing purposes, but revert back to their original ideas when assessment is complete.

Although Ingram and Nelson (2006) specifically mentioned attitudes about evolution as a variable of study, the instrument they employed is widely used to measure acceptance of evolution. Their results were grouped giving either a positive (moderate to very high scores) or negative (low to very low scores) attitude toward evolution. Like Nehm and Reilly (2007), they found that acceptance of evolution increased following an evolution course and that achievement in the course was not related to acceptance of evolution. This suggests that acceptance of evolution is not necessary for students to understand, and be assessed, on the content of evolution for coursework; however, it was not tested whether the knowledge would be used or retained beyond the assessment period. Although there is some agreement among samples in college biology and non-biology majors regarding the lack of relationships between acceptance of evolution, and other variables, there were several prominent concerns. First, the use of dichotomous labels does not appear to provide an accurate depiction of the spectrum of acceptance and rejection, rather it assumes that one either wholly accepts or wholly rejects evolution or is either pro-evolution or pro-creationism, positions that eliminate the possibility of other positions.

Matthews (2001), in a similar course, looked at the use of creation stories in tandem with evolution instruction in the classroom and how that approach influenced students' attitudes about evolution upon completion. In a small study group (n=37) of junior college science students in New York, a pilot course was taught including a variety of creation stories from Genesis, Bering Strait Eskimo Creation myth, Hopi creation myth with a female deity, Lamarckism, and catastrophism, among others (p. 35). Another standout feature of the study was the inclusion of a

self-evaluation of personal beliefs, scientific evidence and processes in addition to the traditional method of study, discussion, and timelines. He found that time was the only significant factor impacting attitudes in the group, and that more scientific responses were given by the group upon completion of the course. He also noted that including creation stories led to more fostering of scientific views.

Knowledge, belief, and acceptance of evolution among current and future teachers.

The concepts of knowledge, belief, and acceptance of evolution have been the focus of a number of studies, especially regarding the meaning of each, and which should be the goal of science education. In these studies, knowledge refers specifically to evolution content knowledge or pedagogical knowledge relative to the teaching of evolution (Rutledge & Warden, 2000) and belief and acceptance are differentiated based on the delineation made by Sinatra et al. (2003) with acceptance- a measured evaluation of fact whereas beliefs are based on extra-rational interpretations and expectations held by an individual. There was wide agreement across these studies in regards to the definitions of acceptance and belief posited by Sinatra et al. (2003).

Although there are a number of studies focused on pre-service teachers and acceptance, most took place in Greece, Korea, or Turkey. One pre-service teacher elementary teacher study by Athanasiou and Papadopoulou (2011) found with Greek pre-service teachers, taking a course in evolution did cause an overall increase in acceptance. They further examined relationships among variables and acceptance, finding positive relationships between thinking dispositions, namely open-mindedness and acceptance; as well as negative relationships between religion and acceptance of evolution. Due to limited science exposure of elementary education majors, findings were expected to align closely with similar findings in non-biology majors at the undergraduate level, which it did.

In two studies of Korean pre-service secondary science teachers, findings of their acceptance scores as determined by the Measure of Acceptance of Theories of Evolution (MATE) instrument were similar to those of secondary pre-service science teachers in an Indiana study; however, Korean pre-service science teachers had fewer conflict issues with Biblical accounts and evolution. Furthermore, there were significant positive relationships between acceptance and the nature of science; acceptance with evolution content knowledge; and the nature of science with evolution content knowledge (Kim & Nehm, 2011). Ha, Haury, and Nehm (2012) looked at a course of secondary pre-service science teachers in Korea, finding major differences in both knowledge and misconceptions across the number of years they had been in a study program (first, second, third, fourth) but not across religions. They also found a slight increase in MATE and feelings of certainty (FOC) following a course that centered on genetics and evolution (Ha, Haury, & Nehm, 2012).

In Turkish secondary pre-service science teacher samples it was found, that 7.2% of variance in acceptance of evolution is explained by understanding the nature of science and understanding of evolution content, however, only the nature of science was statistically significant as a predictor of acceptance (Akyol, Tekkaya, & Sungur, 2010). A separate exploration found significant positive relationships in the following: a) between acceptance and content knowledge understanding, b) acceptance and flexibility/open-mindedness, and c) acceptance and parent education levels; however the expanded model only explained 10% of variance in acceptance of evolution (Deniz et al., 2008). Deniz and Donnelly (2011) conducted a study of secondary pre-service science teachers in the United States finding no relationships between understanding of evolution content knowledge and acceptance of evolution. They did

find significant positive relationships between acceptance and the variables for thinking/open-mindedness and epistemology; however, the sample size (n=32) limits the findings.

In-service secondary science teacher acceptance and teaching preferences. It is assumed that science teachers are experts in both content and pedagogy; therefore, they should have similar levels of content knowledge, nature of science understandings, acceptance of evolution, and willingness to teach evolution as others in various realms of the scientific community. Although this may be an assumption, it was found that teachers in Indiana were not adequately prepared to teach controversial topics, such as evolution, and did not have a clear understanding of the nature of science (Rutledge & Warden, 2000). Teachers, in this study, demonstrated only moderate scores for acceptance, understanding the nature of science, and evolution content knowledge, trends which align more closely with undergraduate and high school student scores than with the scientific community at large (Deniz, Cetin, & Yilmaz, 2011; Rutledge & Warden, 2000). This finding is troublesome as science teachers are expected to prepare students to be scientifically literate members of society.

One notable relationship found by Deniz, Cetin, and Yilmaz (2011) in Turkish secondary science teachers was that religion was a statistically significant negative influence on acceptance of evolution. Turkish teacher studies showed that teacher preference for teaching evolution, creation, or other combinations of origin ideas, was influenced significantly by acceptance of evolution and religiosity (Deniz, Cetin, & Yilmaz, 2011). Similarly, Nehm and Schonfeld (2007) found negative correlations between religiosity and both the nature of science, and content knowledge, in teachers before, and after, a fourteen-week course on evolution. Nehm, Kim, and Sheppard (2009) found that teachers who were more religious were more likely to have conflicting views with evolution and want other topics, such as creationism, taught alongside

evolution. These findings are noteworthy when contrasted to findings with significant positive relationships between acceptance and both content knowledge and nature of science understanding (Rutledge & Warden, 2000).

Another study of secondary science teachers, in Oregon public schools, looked at the relationships between religious beliefs, the understanding of evolution, and the nature of science (Trani, 2004). Specifically, whether those teachers who claimed to reject evolution due to religious conflict had weak or strong nature of science and evolution content understanding. Conversely, he explored whether those teachers who had strong understanding of evolution and the nature of science accept evolution despite having strong religious beliefs. His study was more representative across groups in the public school system in its design, which employed surveys among science teachers in all the classifications of public schools in the state and selected an even number of participants from each level. Participants in this study showed a high level of acceptance based on the Measure of Acceptance of Theories of Evolution (MATE) test, but demonstrated only low understandings of the nature of science and evolution content knowledge. They found a number of relationships among variables, including the following negative correlations: a) acceptance of evolution and religious convictions, b) presentation of evolution and religious conviction, and c) religious conviction to both evolution content knowledge and nature of science understanding (Trani, 2004, p. 422). In essence, those with greater religious convictions had scores that were considered outliers compared to the body of data having greater deviations than other participants in the study (Trani, 2004, p. 424). He further noted that those teachers, who had higher understandings of the nature of science and evolution content knowledge demonstrated the ability to accept evolution regardless of the strength of their

religious convictions. This finding provides support for strengthening the development of teachers as a tool to improve acceptance.

Attitudes and Perceptions of Evolution

An important aspect of science teaching and learning is understanding the underlying beliefs, prior knowledge, and misconceptions that are held by the learners. This endeavor is of greater importance in topics such as evolution, given its controversial nature and its history of discordance and concern. For the teaching and learning of evolution, there are a number of stakeholders, including students and teachers, but also administrators, parents, communities, and, as we have seen with the number of legal cases and edicts, even state and federal government officials. The bulk of research into the perceptions and attitudes held about evolution focus only on teachers and students, so those focal points will be addressed in the next sections.

Student perceptions of evolution. Brem, Ranney, and Schindel (2003), in their study of conceptual change, looked at the undergraduate and graduate levels in a public university to try and determine what relationships exist between student beliefs, the closely held ideas and expectations they have based on their experiences; perceptions, how they interpret these experiences; and preferences for the teaching of evolution in terms of what they prefer to be taught, rather than what they would teach. After categorizing students as either evolutionist, creationist, or uncertain, they looked at five areas of impact of evolution: *sense of purpose in life, perceptions of race and ethnicity, sense of spirituality, perceptions of selfishness, and sense of self determination* (p. 184). Analysis showed distinct relationships, with selfishness and racial discrimination increasing, and life purpose, spirituality, and self-determination decreasing with increased belief in evolution. They also found that the more participants knew about evolution, the more likely they were to perceive negative impacts of evolution. They found no relationship

between beliefs and knowledge of evolution, but did find that those who were evolutionists had greater exposure to pro-evolution messages than those who were creationists, although the creationists reported having been exposed to both pro-evolution and anti-evolution messages. All of the students in the study reported a belief that students should be allowed to choose what they do and do not believe regarding evolution. Last, students rejected any plan for teaching that marginalized their own beliefs (p. 194).

In a study of senior level biology majors in Lebanon, Dagher, and BouJaoude (2005) also looked at the perceptions of students relative to evolution but included their perceptions and understanding of the nature of science. Comparing student objections to evolution fell under four arguments including: a) the nature of evidence for evolution, b) levels of certainty of the theory, c) experimentation in science, generalization of theories, and d) reproducibility of events. In short, “students used generic understanding of the nature of science as ammunition to dismiss evolutionary theory” while “very few students in this study referred to the sociological or historical dimensions of evolutionary theory” (Dagher & BouJaoude, 2005, p. 387). Such use of the nature of science appears to be taken as an event rather than as an ongoing process of exploration and is meaningless when disconnected from epistemological foundations, practice, and theory (Dagher & BouJaoude, 2005).

In a study in Lebanon with college biology majors in an evolution course, Hokayem and BouJaoude (2008) looked at perceptions of relationships between religious beliefs, (both Muslim and Christian); science epistemology; and student perceptions of causality and nature relative to evolution. The authors’ position was that some teachers and professors teach evolution with no regard for student background saying, “student personal beliefs should not be dismissed or underestimated when teaching the theory of evolution,” (p. 395). Students who accepted

evolution shared similar views about the nature of science with the exception of whether science was subjective or universal. They were also more likely to believe that science provided the more likely answers when considering the conflict between science and religion and preferred science causality (p. 405). Those who were not certain had similar views to the acceptance group but felt that the evidence for evolution was not strong enough. They further perceived religion and science mostly as independent of one another but sometimes as conflicting. Their overall responses were science based, but the strength of their belief in science was not as strong as the acceptance group. Only one of eleven participants rejected the theory, a percentage not representative of the general population. This student took the position of skeptic, questioning the evidence for the theory rather than rejecting it based on religious beliefs. He believed that science was the result of accumulation and that nature is a balanced system. One item that stood out was that students will accept scientific explanations for other events, but not for evolution.

In a more recent study, Winslow, Staver, and Scharmann (2011) examined students' extant views on creationism and evolution, looked for the aspects of the two that cause conflict, and the factors influencing student perceptions of evolution and creationism. In their sample of biology majors at a Christian university, they found, as expected, dominant Christian views, but that these views had changed over the course of the students' lives. Most reported their parents as the greatest influences in their lives and described being raised to believe in Christianity while rejecting evolution. Upon further evaluation of early beliefs, most were identified as Young Earth Creationists in their upbringing, but only one remained so at the time of the study with the rest more closely aligning with Theist Evolutionary beliefs. For these students, science was seen as a way of knowing while recognizing the fallibility of the people who generated that knowledge. Through their journeys of conflict and resolution, they were able to maintain their

trust and commitment to religion while embracing science as well. They accepted evolution, including that of humans, as accurate through their evaluations of evidence, a non-literal interpretation of Genesis, and disconnecting the idea of evolution from salvation. The benefit of studying science in a Christian setting also appeared to aid the students' acceptance in that most reported the modeling of acceptance by their Christian professors as influencing their perceptions of evolution as well as the conflict between evolution and religion (Winslow et al., 2011).

Student perceptions regarding evolution demonstrate a wide breadth of possible positions and beliefs. The researchers point out that student positionality is important (Hokayem & BouJaoude, 2008) and the teaching of evolution should focus on more than just facts and evidence (Winslow et al., 2011).

Teacher perceptions of evolution. As the often-autonomous decision makers relative to evolution curriculum and instruction in the classroom, teacher attitude and perceptions of evolution play an important role in how and whether evolution is taught (Goldston & Kyzer, 2009). Rutledge and Mitchell (2002) first looked at teacher attitudes about evolution among secondary in-service teachers in Indiana. In a sample of more than 500 teachers, they found that 33% of teachers spent less than three days teaching evolution and that there was an association between teacher acceptance and the time spent teaching (p. 22). Furthermore, there were significant associations between acceptance of evolution and the number of biology courses taken; acceptance and the completion of an evolution-specific course; and acceptance and the completion of a course on the nature of science. They explained that if teachers did not accept evolution and don't have a strong understanding of the nature of science or evolution content knowledge, they were not qualified to make informed professional decisions, yet this was occurring in classrooms every day.

Similarly, BouJaoude, Wiles, Asghar, and Alters (2011) explored the perceptions and backgrounds of both secondary science teachers and professors in Lebanon to determine their positions on evolution, how religious affiliation influences those positions, and what their beliefs were regarding the teaching of evolution. Beliefs in this case referred to the fundamental religious beliefs held by Muslims, including the five pillars of Islam. This study is novel in that, in Lebanon, more than 60% of all students attend private schools that are aligned with Christian or Muslim beliefs, unlike the United States where public schools separate church and state and teach all students who wish to attend. Through semi-structured interviews, they found that religion played an important role in the decision making process of many teachers, with clear divisions between the beliefs of Christian and Muslim participants. This was especially true in the group that rejected or only partially accepted evolution, which consisted of mostly Muslim teachers compared to the acceptance group that consisted of self-reported Christian or Druze followers. Furthermore, the rejection or partial acceptance group members were less likely to be influenced by scientific evidence and were weaker in the nature of science understanding. It is noted that the nature of science misconceptions held by this group were closely aligned with misconceptions commonly seen in college students, including the belief that evolution is “just a theory,” that laws come from proven theories, and that there is little or no evidence for evolution. Last, the findings revealed that teacher beliefs and attitudes did influence their curricular and pedagogical choices and at least in the case of half of the participants, evolution was not accurately represented in their classrooms if at all.

In a study of elementary and middle-grades (K-8) combination math and science teachers, Nadelson and Nadelson (2010) explored the role of evolutionary perceptions in the prediction of teacher perceptions. What they found was a wide gap between the lower level and

upper level science and math teachers regarding their understanding, interest, and perceptions. Although all the teachers were graduate level students and had at least five years of experience, the upper grades teachers demonstrated significantly higher perceptions of evolution than those in the lower grades as well as more interest in evolution. Most of the teachers reported having beliefs that were compatible with evolution, a factor shown to be a significant predictor of perceptions of evolution as important to learning life science; however, the levels of those who were either uncertain or who had conflicting beliefs, still outnumbered those who were compatible. Teachers at the elementary levels are not prepared to teach evolution in the same manner that those at the secondary level and some did not respond to questions posed due to their belief that their grade level precluded them from teaching evolution. These findings suggest that teacher beliefs have a significant influence on the implementation of curriculum topics, especially regarding evolution.

In their study, Schrein, Lynch, Brem, Marchant, Schedler, Spencer, Kazilek, and Coulombe (2009) looked middle school level teachers in addition to secondary teachers in an effort to gain awareness into the teaching and learning of evolution before students enter college. This awareness, they claim, benefits college professors by encouraging them to engage in professional development to improve the teaching of evolution at the lower levels of study and by providing them with the insights needed to more effectively plan and implement instruction. To do this, they hosted a standards-based evolution workshop to help prepare teachers for new teaching requirements in the state of Arizona. Their goals were to provide knowledge and resources, make teachers aware of legal and cognitive issues, address misconceptions, assess acceptance, and draw conclusions about teacher preparedness to teach evolution. Due to its' elective nature and application-based acceptance into the workshop, they found that all of the

teachers had a high or very high level of acceptance of evolution, which stands in sharp contrast to levels of acceptance by the United States general public. Through the course teachers developed concept maps and addressed both common misconceptions and general topics in evolution such as Darwin's role, mechanisms of change, and common terminology. Evaluation of the workshop revealed the teachers, at least those who already accept evolution, wanted and needed more time to discuss biases counterintuitive to evolution, more interactive discussion about misconceptions, and more resources and content support before they were ready to teach evolution.

Chuang (2003) looked at the impact of teacher held perceptions and whether they transfer to students in those classrooms. He found that professors in Utah universities had a significant difference in rating the importance of evolution based on their own backgrounds, with those who advocated for evolution having stronger perceptions of importance. Furthermore, they found that while experience was not an influencing factor in their rating of the importance of evolution, it was in their rating of the importance of student understanding of evolution. Interestingly, it was not the advocates of evolution who faced greater or more frequent challenges, most often religious in nature, by students, but those who were against evolution, showing a negative correlation between teacher attitude and student challenges. These results led the authors to conclude that by focusing on the division of religion and evolution, we may cause more questions than by focusing on the science behind evolution.

Factors Impacting the Teaching and Learning of Evolution

One approach taken to examine the learning experiences with evolution in high school was to ask college students to reflect on their experiences in high school to determine what was being taught about evolution and what factors influenced the knowledge they retained in college.

Moore, Brooks, and Cotner (2011) revealed two key findings. First, students have relatively low understanding of evolution, with an average score of 53% on their evolution knowledge examination, and only 57% in the highest achievement sub-set in an undergraduate college biology course in Minnesota. Second, course content from high school, namely the teaching of creationism, in combination with religious views, were significant predictors of evolutionary knowledge when students are in college.

Research with mixed biology and non-biology majors, (Nehm and Schonfeld; 2007), revealed that knowledge of evolution had no impact on students' preferences for being taught evolution, creationism, or a combination of the two. Furthermore, there were no significant relationships between knowledge and evolutionary acceptance or beliefs about what should be taught and whether what is taught should be believed by students. The pre-course and post-course aspects of this study suggest that misconceptions can be decreased and key concept knowledge and term usage increased by specific study of evolution concepts and common misconceptions. However, the increase of key concept usage and decrease of misconception frequency did not guarantee any significant impact on acceptance or beliefs (Nehm & Schonfeld, 2007).

A study conducted in New York explored the effects of science coursework on teachers' beliefs about evolution and their expectations for teaching and learning (Nehm, Kim, & Sheppard, 2009). By comparing scores of biology and non-biology science teachers, they found that, although there was a higher percentage of content knowledge and nature of science understanding in the biology cohort, the frequency and range of misconceptions about evolution were similar to that of non-biology teachers with limited coursework in biology. This is contradictory to findings that misconceptions were negatively correlated to both content

knowledge and nature of science understanding, implying that greater misconceptions should be present among those teachers with less background (Nehm, Kim, & Sheppard, 2009).

Donnelly and Boone (2006) examined the role that standards play in the teaching of evolution in Indiana. They note that, among the teacher sample, standards were regarded in a positive manner and were used by teachers to justify the teaching of evolution. The teachers also reported a high number of days spent teaching evolution, with an average of 14 days of coverage. In terms of relationships, the findings identified teacher attitudes and practices as factors influencing the amount of time spent teaching of evolution. One contradictory finding is that, although they report that time spent teaching evolution did not demonstrate variance across demographics, they did find that demographics influence attitudes and practices of teacher. Therefore, it leads to the question of how demographics can be non-influential in terms of time spent teaching evolution when they do impact the variables of *teacher attitude* and *practice* that do influence time spent teaching evolution.

Nehm and Schonfeld (2007) also explored factors that influence whether teachers prefer to teach evolution, avoid evolution, and what concepts of evolution to include. Their study focused on relationships between the secondary science teachers' preferences and their content knowledge, as well as their understanding of the nature of science following a short course on evolution. The researchers found no change in the teaching preferences of non-certified secondary in-service science teachers following their fourteen week evolution course, meaning that those who preferred evolution continued to do so and those who were against the teaching of evolution remained against. Negative correlations between religion and evolution content knowledge and understanding of the nature of science before and after the course were found. The findings suggest that the course did not have the intended impact on evolution knowledge or

teaching. It was specifically noted that those teachers who supported teaching creationism also wanted their students to believe in creationism, and those who were more religious were more likely to support the teaching of creationism and to feel conflict with evolutionary concepts (Nehm, Kim, & Sheppard, 2009).

Evolution Conflict and Coping Strategies

The ability to cope with conflict that arises from differences in beliefs and expectations is, perhaps, the strongest tool held by teachers in dealing with evolution. Several studies of evolution addressed the conflicts or looked at the strategies that some teachers employ to handle conflict that they encounter. In a study of pre-service secondary science teachers, Dotger, Dotger, and Tillotson (2009) had participants engage in simulated conversations with briefed actors portraying parents to discuss issues that arise with the teaching of evolution. They found three recurrent themes in the anti-evolution movement that included: a) what counts as science, b) justifications for teaching evolution, and c) the impact of conferences on both parents and teachers. Implications point out a need to prepare pre-service teachers to articulate the nature of science and other complex information to parents such as providing reasoning for the inclusion of evolution in the standards when challenged about why they teach evolution. Furthermore, they must be ready to recognize that there are many alternative perspectives about evolution coming into their classroom. This is especially true in light of the public sanctioned hostility toward the teaching of evolution in public school classrooms (Griffith & Brem, 2004).

Aside from being able to communicate effectively with parents, there are other concerns about the teaching of evolution, as seen in the study by Sanders and Ngxola (2009) of South African science teachers preparing to teach new evolution standards after years of a conservative, state-mandated, non-evolution stance. Using a stages-of-concern framework, they determined

that more than half of the teachers held self-concerns about teaching evolution, including inadequate content knowledge (p. 123). They also discovered procedural concerns among teachers, including knowing what to teach, where to begin, what to expect, lack of resources, support, and time (p. 124). Clearly, the teachers reported feelings of inadequacy regarding the teaching of evolution. Of four the groups of teachers who participated in the workshops, the last group, completing the workshop just before the start of the school year where the new curriculum would be implemented, held more concerns overall. This left them little time to navigate the upper levels of the stages of concern to reach a state of coping before they started to teach the evolution content. At the end of the program, “teachers left the workshop seeking professional help to the last minute, and were panicking about coping” (Sanders & Ngxola, 2009; p. 126). These findings are consistent with the findings of Griffith and Brem (2004) who noted that teachers face intimidation and uncertainty of their ability to handle evolution and therefore focus on protecting themselves from both internal and external conflict (p. 793).

Meadows, Doster, and Jackson (2000) expounded on the concept of coping and conflict with their study by interviewing conservative Christian pre-and in-service teachers, teacher educators, and professors. They explored their beliefs about evolution, how those beliefs related to their held religious beliefs, whether they felt conflicted and how they resolved that conflict. Finding fell into four categories or themes of conflict in this population: (1) awareness, (2) avoidance, (3) disturbance, and (4) management. Overall, convergence of beliefs was key to managing the conflict. In order to cope, there were several approaches the participants embraced. Some forcibly kept religion and science separate in their lives or refused to confront the discordance. Others contextually based their beliefs, practiced cognitive dissonance or managed the two with mental models. Some examples include the acceptance of microevolution while

rejecting macroevolution, accepting all but human evolution in favor of religious creationism, and integration of science into religious beliefs (i.e., the conceptualization of single days in creation as possibly billions of years). A common issue among those who were unable to manage the conflict with the concept of inerrancy versus literalism, (to believe anything but the literal interpretation of the Biblical account of creation) would challenge their belief that the Bible was factual rather than metaphorical and thus render their beliefs false. When faced with such a conflict, resolution regarding evolution is clearly a complex condition and cannot be forced (Meadows, Doster, & Jackson, 2000, p. 107).

Also exploring belief conflicts with evolution, Griffith and Brem (2004) sorted teachers into three categories based on their conflict and coping methods that showed distinct demographic patterns. Those dubbed as *scientist teachers* were classified as having very little or no stress about evolution, a love of science and a strong sense of what was and was not appropriate for the classroom. Scientist teachers did have fear of retribution for their teaching of evolution, but did not let that external concern impact their scientific approach. This group consisted of all males who were tenured in their teaching appointments. The *selective teacher* group was more female, with only one male participant and a wider range of experiences and tenure statuses represented. Despite having the love of science and belief in evolution, it was characterized by the high value placed on classroom and community harmony. In contrast, selective teachers were so effective in coping by picking and choosing what to teach and how to present it, that they often lost sight of the tradeoffs they were making.

In addition to selecting what to teach, they actively choreographed the classroom experience by strictly controlling time spent, reducing interpretation opportunities, avoiding questions, and providing disclaimers. The final group, the *conflicted teachers*, was the smallest

group and a mixed gender makeup. The key feature of this group was that all were new teachers who had not yet earned tenure. These teachers dealt with internal, external, and situational stresses and fully explored the issues with their students to find their own answers and teaching identities. Despite the differences in the groups, they all were in agreement regarding the positive consequences of teaching evolution, but some had greater fear or concern for negative consequences that inhibited their approaches. These widespread accounts of stress, conflict, and difficulty to reconcile and cope with the conflict provides a glimpse into the reasons why evolution is, and is not, being taught in U.S. classrooms

Evolution and Religiosity

For researchers, understanding the dimensions and connections of evolution and religion held by teachers are complex and many. While some researchers seek to understand the conflict between religion and evolution, others look at the relationships that exist between the two and how they are enacted in the science classroom. Moore (2008) explored the teaching of creationism in classrooms in Minnesota, attending to whether creationism was taught and what types of creationism were included. In a study of nearly fifteen hundred mixed major college students over a four year time period, he found that although 51% of participants felt they had an average understanding of evolution, they not only had major misconceptions, but between 26-40% viewed Creationism as scientific fact. This was true despite evidence that most teachers (52%) did not teach Creationism in their classrooms (Moore, 2008). Four factors were attributed to the teaching of Creationism either in tandem with evolution, or in absence of evolution: (1) external pressures, (2) evolutionary rejection, (3) legal ignorance, and (4) personal beliefs (p. 83). When identify the types of Creation taught, it was primarily Christian Biblical Creation presented as a scientific alternative to evolution (p. 81).

Unlike the teaching of evolution in the United States, the teaching of evolution in other nations, such as Pakistan, has taken a different path governed by religious law rather than the separation of church and state. Asghar, Wiles, and Alters (2010) examined evolution in state textbooks from Pakistan where they found that Islamic scripture, creation myth, religious beliefs, and evolution were presented as unified and supportive of one another (p. 67). At the secondary level, they found it was customary to begin with an Islamic Creationism-only approach for grade nine where the focus of the course was on religious explanations of origins and change. This approach transitioned into more scientific study from tenth to twelfth grades, developing evolutionary theory by adding cell complexity, neo-Darwinism and modern synthesis, population genetics, and artificial selection to the religious curriculum. Differing from Moore's (2008) finding that Creationism was taught as science, the religious and non-scientific inclusions in the Pakistani texts were clearly marked as being either scientific or religious in nature. They did not attempt to measure the impact of this teaching style on the learning of evolution, so implications are narrow beyond the possibility of both (creationism and evolution) being formally offered together in textbooks.

It is known that creationism is being taught in classrooms in the United States, but few studies have looked at the complexities of creationism, a point made by Murphy, Hickey, and Beggs (2010), who noted that Christianity, and therefore Christian beliefs, are not unified across denominations and that there are many interpretations, expectations, and requirements individually held by the different religious sectors that influence their experiences. Colburn and Henriquez (2006) took the discussion outside of the classroom and interviewed clergy from various Christian denominations to get their views of the science and religion as well as evolution and creationism. Their findings provide a useful insight into clergy members' personal

beliefs and views of evolution. Clergy tended to view religion and science as compatible with God playing a role in nature and evolution in varying ways and times. They further added that the Bible was not meant to be literally interpreted, a position that is in stark disagreement with Christian Fundamentalist beliefs predominant in the Southeastern United States. They did acknowledge great difficulty in conceptual change, specifically moving between concrete and abstract concepts such as religion and evolution, adding that religion should not be taught in public schools, but that a focus should be put on helping students reconcile what they learn in science and their own worldview.

Schilders, Sloep, Peled, and Boersma (2009) explored evolution and worldview among students in the Netherlands to determine what strategies would be appropriate to help students cope with conflicts. They found that students return to their old ways of thinking when they are not engaged at their original levels of understanding, consistent with similar findings by Verhey (2005). The participants represented a wide range of beliefs from atheism to strict creationist but consistent across all groups were many misconceptions and little understanding of the nature of science. One issue noted was that teachers commonly minimized issues that would arise regarding evolution and avoided discussing the controversies instead of trying to help the students cope. They concluded that traditional approaches to teaching evolution lack the depth necessary for conceptual change and students' worldviews play a prominent role in the conflict that prevents acceptance. Conceptual change for students is exacerbated when teachers embrace teaching methods and topics that further confuse students about evolution.

Moore and Kraemer (2005) looked at the assumptions we make about teachers. These include: a) they are experts, b) they understand evolution, c) and they share a commitment to teach evolution and not teach Creationism. They found that between 1994 and 2003 there was an

increase in time spent on evolution, with more evolution content in textbooks and more pressure for teachers to teach evolution due to standards. However, the percentage of teachers teaching Creationism in the classroom has also gone up, as has the time spent on Creationism in the classroom. In addition, an increased percentage of teachers who had been pressured to avoid teaching evolution by parents and administrators rose from 19% in 1994 to 48% in 2003, as well as pressure to teach creationism, 69%. These results support the continued “educational malpractice” regarding the teaching of evolution in public schools in the standards era (p. 463).

Baker (2013) was in agreement with the position and power of worldviews in the science classroom, especially relative to evolution. Although some factors, such as degree attainment, positively impact the acceptance of evolution, worldviews, more specifically literalist worldviews, can have an attenuating factor on that influence. In light of the lack of lasting increases in the acceptance of evolution, despite standards and scientific reform efforts, he points at sub-cultural beliefs as the major obstacle to evolution. By studying results of over fifteen hundred Gallop poll questionnaires he determined that one-third of the population of the United States are literalists and that the issues of religious conflict and interpretation are the reasons why our reform efforts relative to evolution are failing. This was especially true in women, rural communities, those who frequently attended church or church functions, and those who identified as Evangelical Christians. This suggests that “despite legal rendering, Creationism has maintained strong cultural currency” and is not easily replaced by scientific theory.

Proposed Evolution Teaching Methods, Courses, and Assessments

A wide range of studies have addressed teaching methods, tested existing or proposed courses, and methods of assessment for evolution. Robbins and Ray (2007) looked at the use of a variety of new approaches for teaching evolution in addition to traditional methods in non-major

science courses. The authors proposed that lectures be preceded by identification of prior knowledge and misconceptions, and followed by lab interpretation sessions with peers to synthesize the guiding principles of evolution (p. 463). They found, based on single question identification, acceptance increased from 59% to 92% following the four-lesson program. They also found that following labs and synthesis activities on fossils, comparative anatomy, DNA, and other contemporary examples, 92% of students were able to explain the scientific aspects of evolution compared to only 6% before the sessions. They further argue that a lack of self-assessment is a hindrance to evolution instruction due to the inherent conflict between religion and evolution.

In line with the use of evaluation in scientific situations and evidence, Farber (2003) suggests taking a case study approach to teaching evolution where biology would be presented as a series of questions that scientists were currently investigating. Students examined how the questions emerged and explored currently proposed answers, “stressing a lineage of questions that guide scientific research” (p. 350). He explained that this approach allowed individuals to address religion through historical views such as those by Darwin and his contemporaries who were steeped in both science and religion. This further served the purpose of demonstrating the nature of science and moved away from traditional textbook learning and rote memorization and toward the questions and ideas that get scientists excited. This indirect approach is also supported by Pramling (2008), who adds that “evolutionary processes cannot be pointed to in a direct sense, rather they have to be inferred” by the learner (p. 536). To do so, he argued that metaphors should be employed, much like Darwin used to relate meaning to evolutionary accounts. As frequently taught, “Knowledge in science is detached from its origin and history”

this, coupled with “conflicting scientific meanings for everyday terms” makes for a confounded path of evolution study (p. 536).

Rankey (2003) also expressed problems with the traditional memory-based method of teaching in science, proposing that a critical thinking approach improves the teaching of evolution in geology courses. The method applied was one of argument and counter argument, with students identifying whether they accept or reject evolution, then constructing a written argument in support of the position opposing their own, followed by a second written argument in rebuttal of the first. Of sixteen participating college students, twelve showed a shift in beliefs on a scale of one to ten for evolution. Four of those students moved drastically from creationism to accepting evolution; while students identified as extremists in terms of their beliefs, were unyielding in their position (p. 306).

Focused on geological concepts of evolution, Catley and Novick (2008) applied macroevolution as a method to improve evolution instruction, noting that, in many classrooms, the focus is on microevolution with the big picture, macroevolution, being avoided due to implications regarding origins. They argued that science literacy requires knowledge of the chronology of major events in Earth time from the beginning of the solar system to hominid evolution. Students from the South and Midwest were asked to estimate time periods of major events, including the age of Earth, oldest dated fossils, appearance of eukaryotes, and appearance of *Homo sapiens*. In many cases the estimates were grossly underestimated, including Earth age estimates from four thousand to six hundred billion years old. This array of estimates was common regardless of student background, with only slight differences in the range across groups.

Banet and Ayuso (2003) proposed a combined approach to the teaching of evolution, using constructivist scaffolding to teach genetics and evolution in tandem in high school settings. In their test group, the researcher taught a concurrent genetics and evolution unit over a six week time period. Through pre-post comparisons, 70% of students reconstructed or amplified their knowledge regarding transmission of genetic information, chromosomal models, between cell transmissions, and mutations. However, the students still viewed evolution as Lamarckian in nature and, in some cases, digressing in understanding. In addition to concerns about the lack of conceptualization of Earth time by students, in a separate study Catley (2006) calls for the increased use of phylogenetics and cladistics, methods of mapping origins and relationships among organisms, to teach evolution. He claims that to achieve true biological literacy, the use of scientific tools such as these should be the norm, not the exception. This would better align classroom learning with the practices employed in the field, in turn bringing the nature of science into the classroom as a daily tool rather than an abstract concept. Passmore and Stewart (2002) also worked on the creation of a high school course, providing details of its construction. This approach, like Catley's (2006) put students into the role of scientists, treating them as a research community and allowing them to go further than mapping origins by examining, in case format, models and evidence generated by Lamarck, Paley, and Darwin.

One aspect of evolution research that is growing is the creation and testing of various courses aimed at improving how teachers teach evolution and how students learn about evolution. McKeachie, Lin, and Strayer (2002) examined how taking a college biology course affected student beliefs about evolution, how beliefs affect performance in class, and the difference between belief sets in terms of motivation, anxiety, and learning strategies. They found that if the goal in teaching evolution is understanding, it is being met, but if the goal is

belief we are not only failing, but we face an ethical dilemma in trying to change beliefs that are often tied to religion. An interesting problem they encountered was a decrease from 60 students to only 28, with a majority of those students identifying with Creationism not completing the study. In other words, they found that, when it comes to their learning experiences with evolution, “creationists experience cognitive dissonance” (p. 192). To deal with this they noted that some students dropped the course entirely, some worked around the conflict, and others did what they had to do to pass the class while maintaining their original ideas and beliefs.

In a study of students attending an invitational Governor’s summer program in Arkansas, Wiles and Alters (2011) found significant increases in acceptance of evolution following completion of an elective evolution course with sustained increases following re-evaluation a year later. Conversely, Cavallo and McCall (2008) found that evolution treatments in their high school sample did not have any increase in levels of acceptance, despite significant positive relationships found between evolutionary content knowledge and acceptance of evolution in the same population. This suggests the possibility that there is a way to increase acceptance with a course-based experience provided the course covers the right topics and whose duration is long enough for conceptual change to occur.

In today’s information age, there are a number of online or computer-based programs established to aid in the teaching of evolution. Several studies have addressed the impact of specific interactive programs on evolution teaching and learning. Nadelson and Sinatra (2010) looked at pre-service secondary science teacher understanding and acceptance of evolution, the nature of science, and situations of chance using the web site *Understanding Evolution* as an instructional tool. They found that prior to using the website; evolution understanding was correlated to nature of science understanding and situations of certainty. After using the site, they

found a modest shift in acceptance of evolution but no impact on evolution knowledge or situations of chance, suggesting that it may be possible to “achieve modest changes in acceptance of evolution with modest instructional interventions” (p. 13).

Crawford, Zembal-Saul, Murford, and Friedrichsen (2005) used software to improve evolution understanding in pre-service secondary science teachers. They implemented the program in a 12-hour treatment during a fifteen-week methods course with a five-week embedded practicum. They found that 18 of 21 students had alternative evolution conceptions and that most had no mastery of the nature of science. Even the two most advanced students, in terms of research, essentially failed regarding the nature of science. Furthermore, no relationship was found between the scientific discipline and understanding of evolution. Following completion of the course, 14 of the 18 students with alternative conceptions moved toward enhanced understanding of evolution.

Two studies sought to create meaningful assessments to measure elements of evolution such as preconceptions, learning progress, and patterns of evolutionary reasoning (Nehm & Ha, 2010; Zabel & Gropengeisser, 2011). Zabel and Gropengeisser (2011) studied the experiences of middle grade students and the journey they must take when learning about evolution. Following a five-week, ten lesson units they used content analysis of over two hundred pre-course and post-course student generated documents from 107 students. These documents were analyzed to identify nine explanatory patterns used by students to explain evolution including basic descriptions of change, evolution caused by environment, evolution by need, intentional adaptation, generational adaptation, usage and disuse, evolution by interbreeding, evolution by type variation and natural selection, and evolution by full variation and natural selection. By mapping students’ explanations before and after the course, they found that most of the students

progressed from one position to another at varying speeds to varying final positions. At the beginning of the study, only five participants used more than one of the nine explanations in their texts about evolution, but fifteen students did so at the conclusion. By the end of the study, 42 of the students had progressed to the eighth or ninth level of explanations (evolution by type variation and natural selection or by full variation and natural selection).

Nehm and Ha (2010) also addressed the lack of assessment for patterns of reasoning in evolution by examining whether prompts could be identified that facilitate certain reasoning patterns and assessments could be designed to make use of them if they do exist. To do so they created 12 questions. Six were interspecific, focused on changes between different species, and six were intraspecific, focused on changes within a species. The questions were used with introductory biology courses for majors. Coding 1200 essays revealed that students are better able to explain evolution gains, the changes that make a species more complex, than losses, those that make them less complex, with more key concepts used for gain and naïve concepts appearing for losses. The same pattern was true for changes within and across species, with inter-species better explained by core concepts, while intra-species changes demonstrated naïve ideas such as adaptation as a response to the environment, spontaneous generation of new traits, and loss of traits through disuse. These naïve ideas about evolution tended to be more variable than the key concepts and core ideas that students presented. The study revealed six categories of naïve ideas that should be a part of evolution assessment. These include, “*needs and goals, use and disuse, intentionality, adapting and acquiring traits, deliberate energy allocation, pressure as a direct cause*”; and three core concepts, “*variation and its causes, hereditary variation, differential survival and reproduction*” (Nehm & Ha, 2010, p. 246).

Critical Analysis of the Literature

Limitations

Using a critical review methodology posed its own limitations in terms of research, the greatest of which is subjectivity of the researcher, both in regards to the selection of articles for review and the review itself. In an attempt to lessen this limitation in the selection process, a detailed procedure was recorded and notes included in the analysis, keeping the process as transparent as possible. For the article review process, guiding questions for consideration were also provided to demonstrate the thought process ongoing during the reading of existing literature. Beyond those measures, there is still an issue of subjectivity in terms of the interpretation of meanings and researcher bias that can only be monitored through journaling and continued self-evaluation throughout the study. In addition to subjectivity, there is the limitation present in undertaking a study not utilizing its own sample and data for analysis. It is the researcher's position that, although it is difficult to draw conclusions based on a critical analysis and synthesis of ideas from other studies, sometimes that position is necessary to evaluate the depth and breadth of the existing literature in order to determine where to begin filling in potential gaps and provide support for what is currently known.

Limitations of Existing Research

In addition to the discussed limitations inherent in critical analysis, the component studies all faced at least one common limitation, the inability to determine causality in empirical studies. Sample method, most of which were convenience or purposive samples, sample size, generalizability of results, imperfect recollection of participants, and self-reporting are limitations. In a number of studies, additional or unique limits were present but not mentioned. Representative samples are also a common problem, as a majority of studies utilize purposive

samples to represent a limited group within the greater population, usually students or teachers of science, and are often samples of convenience, both of which limit the generalizability of findings to the greater population. Since public schools represent only a portion of the greater picture of each state's school representation, Moore and others noted sampling of only public schools as problematic to the application of study results to other schools (Moore, 2008; Asghar, Wiles, & Alters, 2010). Other non-representative population issues were experienced in studies by Moore and Kraemer (2005) whose study sample consisted of science teachers at a national conference or Wiles and Alters (2011) whose sample was taken from exceptional education students at an invitation from the only governor's school program. Each of these groups represents highly skewed groups within the main population of science teachers or students limiting generalizations. Such limitations are arguable as well about any study that also relies on self-reporting, elective courses, or selective participation.

In terms of religion, several studies acknowledged limited application due to a focus on single aspects of religion, such as considering Christianity as a single entity rather than the multitude of denominations with their individually held beliefs and expectations (Murphy, Hickey, & Beggs, 2010). Asghar, Wiles, and Alters (2010) mention that relationships are not always clear when discussing religion and evolution. In quantitative studies, we are left to extrapolate meanings since they are often conducted with limited or no opportunity for clarification of meaning. In addition, inherent qualities of religious beliefs in individuals are limited applications of results related to religious-only or non-religious populations. Examples include studies conducted in religious schools (Winslow et al., 2011) and in countries where the predominant religion, in these cases, Islam, is strictly aligned with the government and associated teaching, including Lebanon (BouJaoude et al., 2011; Dagher & BouJaoude, 2007;

Hokayem & BouJaoude, 2008); Pakistan (Asghar, Wiles, & Alters, 2010); and Turkey (Akyol, Tekkaya, & Sungur, 2010; Deniz et al., 2008). These considerations are important to note because, according to Murphy, Hickey, and Beggs (2010), “growing up in different denominations means starkly different backgrounds, beliefs, and expectations (p. 79).

In some cases, the lack of formal definitions or delineation between closely connected variables such as beliefs, attitudes, and acceptance is a problem. For example, Ingram and Nelson (2006) specifically discuss attitudes toward evolution as being either positive or negative, but this dichotomy stems from the use of the Measure of Acceptance of Theories of Evolution (MATE) instrument by Rutledge and Mitchell (2000) that was meant to measure acceptance of evolution on a continuum. The shift from a five-category range to dichotomous categories of positive or negative detracts and limits the degrees of evolutionary acceptance and oversimplifies the interpretation. As Rankey (2003) stressed, “many shades of gray exist between the black and white... and individual components do matter” (p. 307). Furthermore, limitations can derive from issues of distinguishing between belief and acceptance. Rankey (2003) agreed with this position, stating that the “lack of clear delineation between acceptance and belief blurs the distinction between faith and fact” (p. 307).

With respect to measurement of variables and constructs, many studies relied on single question measures of complex variables or failed to provide details of reliability or validity of those or other measures that were used (Nadelson & Nadelson, 2010; Robbins & Roy, 2007). Others reported possible test fatigue from long instruments, lessened reliability due to self-reporting, and flawed instrumentation as additional limitations to the generalizability of findings (Moore, 2008). In some instances, for the clarity of the data and ease of interpretation, the results appear oversimplified, such as the case by Sanders and Ngxola (2009) who reported the need to

sort the results of their measurements of concern only by the highest rated concern of each participant when multiple concerns were held. Similar limitations were noted by Rankey (2003) with his ten-point scale used to measure evolution and creationism beliefs-a scale that was not fully indicative of the full range of beliefs and their complexities.

Often it is noted that empirical studies lack in their ability to explain the meanings and beliefs behind the variables they measure, but this is not a problem unique to quantitative research. Goldston and Kyzer (2009) reported that, even after the year of following the three teachers in their study, they were only able to capture small snapshots in the larger time scale of the classroom. They further noted that the result is a highly subjective capture of thoughts and experiences of the individual being observed or interviewed. This was also a problem reported by Schilders et al. (2009) who encountered limited opportunities to truly capture the opinions and beliefs of student participants, and Oliveira et al. (2009) who were unable to interview the participants from their study.

Examination of research on standards brings to light the question of whether the authors were attributing traits to the standards that were not inherent. For example, review of the Indiana standards shows a marked similarity to concepts of understanding of the nature of science, which could mean that the focus on the nature of science in the standards as the possible influential factor, rather than the standards themselves (Donnelly & Boone, 2006). Also, although reported use of the standards was high, it is possible that this was not a reflection of actual usage but rather a response by the teachers to report based on two administrators and school systems pushing the teaching of the standards. Goldston and Kyzer (2009) also addressed this issue, adding that even though standards nationwide favor the inclusion and active teaching of evolution as a unifying concept in biology, other influences detract and contraindicate the

standards (p. 784). Thus, there are other social and political elements that must also be considered in addition to evolution standards.

Treatment courses, methods, and curriculum demonstrate their own limitations for generalizability and reproduction. The greatest limitation is that most of the research into treatments does not provide the detail necessary to reproduce the study (Donnelly & Boone, 2006; Robbins & Roy, 2007; Rankey, 2003), and those that do provide that detail, lack the supporting results and documentation of program success (Catley, 2006; Passmore & Stewart, 2002). Nadelson and Sinatra (2010) and Banet and Ayuso (2003) also faced the additional challenge of having investigators as teachers in their prospective treatments. Time and consistency appear to also have been concerns, especially in more longitudinal attempts to measure increases in evolution understanding and acceptance. Banet and Ayuso (2003) specifically explain that during the course of a school year, only a few weeks are generally allotted to the study of evolution, but in their treatment, they took nearly two times the allotted time to implement their treatment program. In a classroom, this would be highly unlikely.

Although a number of different limitations have been addressed in the studies that make up this analysis, it is important to note that addressing them enhances the legitimacy of the studies and their contribution to our understandings of evolution in education and the directions needed for further study. No study is without limitations; it is impossible to be completely objective when conducting any research. Researchers are led by personal interests, expectations, and beliefs as much as the participants being studied. As long as limitations are addressed, we can continue to gain greater insight into the complex processes surrounding evolution education.

Critical Analysis

Analysis of the selected published findings revealed seven categories of research regarding the teaching and learning of evolution. These categories included (1) *approach to evolution in the classroom*, (2) *knowledge, understanding, and acceptance of evolution*, (3) *attitudes and perceptions of evolution*, (4) *factors impacting the teaching and learning of evolution*, (5) *evolution conflict and coping strategies*, (6) *evolution and religiosity*, and (7) *proposed evolution teaching method, courses, and assessment*. Although these categories separate the literature into groups, there were often points of intersection and overlap that are also important to the understanding of the overall picture of evolution education.

The teaching of evolution lacks the unification required for science literacy. There exists too many conflicting facets such as pressure by standards and school boards to teach evolution but resistance and pressure to avoid evolution from parents, churches, and in some cases, states themselves (Goldston & Kyzer, 2009; Moore, 2008; Moore & Kraemer, 2005). The result is the omission of evolution in the classroom or a watering-down of the evolution topics by including non-scientific elements, such as Creationism or Intelligent Design, as scientific alternatives to evolution (Bowman, 2008; Moore, 2008), both of which have been shown to have a negative effect on evolution when students enter college (Moore, Cotner, & Bates, 2009). The inconsistency of teaching evolution persists despite numerous nationally publicized court cases that address what can and cannot be done regarding evolution in schools (Bowman, 2008; Moore, 2004). Although other religions have embraced the teaching of evolution and their scriptures can be found in textbooks side by side scientific theory, the same casual agreement cannot be found between Christian believers and evolution (Asghar, Wiles, & Alters, 2010). This conflict is prevalent across Christian denominations despite wide ranges of doctrine, practice

(Murphy, Hickey, & Beggs, 2010) and views of clergy that science and religion are both complementary and compatible (Colburn & Henriquez, 2006).

Among the hurdles present in the teaching and learning process are the methods used to teach evolution. It has been shown that making connections outside of the traditional lecture approach can help with the teaching and learning of evolution, however many teachers are unprepared to teach evolution on its own and lack the experience and background to incorporate evolution in other fields to draw those connections (Veal & Kubasko, 2003). Lack of confidence can result in a nonchalant toward the evolution controversy in the classroom, whereby teachers approach it in a playful manner, undermining the legitimacy of the topic (Oliveira, Cook, & Buck, 2010; Verhey, 2005). This shift of approach on the part of teachers can be severe enough to cause teachers to lose their effectiveness and hard earned standing in the classroom by avoiding or skirting issues in an effort to protect themselves from perceived pressures or avoid dealing with students feelings (Goldston & Kyzer, 2009; Oliveira, Cook, & Buck, 2010). This tension is exacerbated by the lack of content support in curricular materials to legitimize evolution instruction, especially in cases where the text itself holds a disclaimer contraindicative to supporting evolution (Goldston & Kyzer, 2009).

There are other intrinsic and extrinsic influences that come into play associated with understanding and acceptance of evolution. In terms of classroom experiences, we know that those students who are exposed only to evolution in their high school science classes have a higher content knowledge when they reach college than those who have been exposed to alternative theories. We also know that knowledge of evolution tends to increase the more a student is exposed to evolution (Kim & Nehm, 2011; Moore, Brooks, & Cotner, 2009), yet students are still being taught creationism in tandem with or instead of evolution (Bowman,

2008; Moore 2008). It has been suggested that including creationist studies with the teaching of evolution increased student knowledge and understanding, but that position holds a caveat since the inclusion of creationism in teaching is legally prohibited by federal law in the United States (Matthews, 2001; Moore, 2008). In general, most students know very little about evolution and tend to retain only what is necessary to pass exams, and then revert to their original beliefs (Nehm & Schonfeld, 2007). This “retain or revert back” pattern is not seen with noncontroversial science topics such as cell energy processes (Sinatra et al., 2003). Although the findings are mixed on whether acceptance is necessary to the understanding of evolution, acceptance does determine whether individuals choose to retain the concepts and transfer them beyond the classroom (Nehm & Reilly, 2007). It is further suggested that courses have the ability to increase acceptance (Nehm & Schonfeld, 2007); however, there is little longitudinal research to support whether this change lasts beyond the reporting period for courses.

The literature on current and future teachers points to more direct relationships between acceptance of evolution, knowledge, and understanding. One issue that continues to arise is the role of religion in the process of acceptance and rejection of evolution. In studies outside of the United States and where the data suggests lower levels of tensions between religion and evolution, there were significant relationships reported between acceptance of evolution and both evolution content knowledge and nature of science understanding (Akyol, Tekkaya, & Sungur, 2010; Ha, Haury, & Nehm, 2012; Kim & Nehm, 2011). However, these variables explained only 10% or less variance in acceptance of evolution, suggesting that there are other factors as yet identified that explain another 90% of variance. In similar studies in the United States, relationships were not found between the understanding of evolution and acceptance (Rutledge & Sadler, 2011; Deniz & Donnelly, 2011) and only one study showed any relationship between

nature of science understanding and acceptance (Nehm & Schonfeld, 2007), suggesting that there might exist variables outside the scientific explanation that influence acceptance of evolution.

Science teachers are expected to be experts in their field, but many lack the knowledge and confidence necessary to accurately teach evolution. It was found consistently that teachers have less than adequate understandings of the process and nature of science itself and are therefore unable to represent it in the classroom (Rutledge & Warden, 2000; Deniz, Cetin, & Yilmaz, 2011). They are also more open to allowing their religious as well as other beliefs to influence what they accept and what they teach their students (Nehm & Schonfeld, 2007; Nehm, Kim, & Sheppard, 2009; Trani, 2004). There are, however, still inconsistencies regarding whether evolution content knowledge, understanding of the nature of science, religiosity, and acceptance of evolution are significantly related, with support both for (Rutledge & Warden, 2000), and against (Trani, 2004) various combinations of the four variables.

What is consistent is that teachers teach that which aligns with their own beliefs and perceptions. Negative perceptions were often noted in connection with evolution, even among those with strong knowledge backgrounds (Brem, Ranney, & Schindel, 2003). Due to their own tensions, teachers tend to take the approach that students should be allowed to choose for themselves what to believe, and therefore, teach with little regard for the diverse backgrounds and misconceptions that accompany students into their classrooms (Brem, Ranney, & Schindel, 2003; Hokayem & BouJaoude, 2008). This approach to teaching evolution does not provide the supportive unified front necessary to move public perceptions toward understanding and perhaps accepting of evolution. Such teaching approaches are reflected in student rebuttals to evolution that are often based on misrepresentations of the nature and practice of science and incorrect

interpretations of concepts relative to evolution (Dagher & BouJaoude, 2005; Hokayem & BouJaoude, 2005).

One of the most noted conflicting factors in the teaching and learning of evolution is that of religious beliefs and doctrine, especially regarding human creation and origins (Hokayem & BouJaoude, 2008; Rutledge & Mitchell, 2002; Trani, 2004; Winslow et al., 2011). These conflicts not only affect student views of evolution but also impact teacher acceptance and the choices they make regarding curriculum and instruction (BouJaoude et al., 2011; Goldston & Kyzer, 2009; Rutledge & Mitchell, 2002). This autonomy allows teachers to pick and choose what to teach regarding evolution, with many opting to avoid the subject or completely alter their teaching identities to mediate conflict in the classroom (Goldston & Kyzer, 2009). With studies documenting as many as one third of teachers cutting evolution teaching time to less than three days of instructional time, it is little wonder that the public is misinformed about this unifying concept of biology (Rutledge & Mitchell, 2002). This undermining and omission of evolution is directly tied to teacher perceptions and has been demonstrated across grade levels from elementary to secondary education as well as across religious groups (BouJaoude et al., 2011; Nadelson & Nadelson, 2010; Schrein et al., 2009).

Ultimately, elementary and middle school teachers demonstrated greater misgivings and less support of evolution than their secondary counterparts. That is not unexpected, teachers who are not a part of content specific training often have exposure to content elements through as little as two introductory level survey courses whereas their secondary counterparts often have the equivalent of a minor or more courses in the sciences (Athanasiou & Papadopoulou, 2011; Nadelson & Nadelson, 2010; Schrein et al., 2009). To challenge the rejection of evolution, teachers must be given adequate opportunities to explore and address their own concerns,

conflicts, and deficiencies regarding evolution prior to entering the classroom. It is this experience that makes teachers more receptive to the teaching of evolution and to the needs, expectations, and beliefs of their students. Having such insight allows teachers to teach with confidence and approach difficult topics with their students in a way that facilitates critical thinking and accurately represents the practice of science (Chuang, 2003).

There were a number of factors shown to potentially influence the teaching and learning of evolution; however, the extent and consistency of these relationships have not been uniform. Interestingly, students' extant views and beliefs are resilient in their persistence and tend to revert to their original configuration despite attempts to improve acceptance of evolution (Schilders et al., 2009). This persistence can continue, even after student knowledge is increased and misconceptions are reduced (Nehm & Schonfeld, 2007). This is also true of science teachers, who have demonstrated similar acceptance and misconception issues despite having greater content and nature of science knowledge than the general public, even if it is much less than what it should be compared to the scientific community (Nehm, Kim, & Sheppard, 2009). The failure of studies to find consistent results means that there is much that is unknown about the evolution phenomenon to draw conclusions that apply to the general student, teacher, or pre-service science teacher populations (Cavallo & McCall, 2008; Nehm & Schonfeld, 2010; Rutledge & Mitchell, 2002).

To increase and improve the teaching of evolution, standards have been accepted in many states, leading to more pressure to teach evolution, at least from some state sources (Donnelly & Boone, 2006). The intent of the standards was to unify the teaching of science by providing a framework for the content to be taught and benchmarks for the learning process that would enhance teaching of science (National Research Council, 2011). Unfortunately, the intended

effect of standards as a support for teaching of evolution can be undermined by conflicting positions by state government entities, teacher autonomy, and public pressures (Goldston & Kyzer, 2009).

If we are to change how evolution is taught and public perceptions of evolution and science in general, we must provide our teachers with better training and tools to help them cope with internal and external conflict. One possible tool is to train teachers how to communicate with parent and students about the nature of science and controversial topics (Dotger, Dotger, & Tillotson, 2009). This open line of communication with support for the teachers can help them to justify their teaching and reduce their feelings of isolation when teaching topics that are contested by the public (Griffith & Brem, 2004). There is also a need for workshops and professional development to address teacher concerns such as low confidence, content knowledge, and uncertainty that are obstacles preventing them from moving to higher levels of coping (Griffith & Brem, 2004; Meadows, Doster, & Jackson, 2000; Sanders & Ngxola, 2009). Teachers should also have mentors and professors who openly model convergence of beliefs and their own coping processes. This will help them find ways to navigate their own tensions, and be less consumed by conflict and fear of retribution (Griffith & Brem, 2004).

The use of courses and curricular supplements to improve teaching and learning of evolution has shown mixed results (Wiles & Alters, 2011; Cavallo & McCall, 2008). Some reported changes in knowledge but not acceptance, even after months of intervention (Cavallo & McCall, 2008; Crawford et al., 2005). Other studies suggest that supplements as easily available as free web-based programs are enough to cause increases in acceptance of evolution even where knowledge is not changed (Nadelson & Sinatra, 2010). However, the impact on teaching preferences and acceptance is inconclusive, with some studies showing no change (Nehm, Kim,

& Sheppard, 2009) and others claiming widespread change in just a few sessions (Robbins & Ray, 2007). It has been shown that courses, from a handful of meetings to those between 12 and 15 weeks in length, can improve knowledge and nature of science understanding (Nehm, Kim, & Sheppard, 2009). What is missing from these studies is a longitudinal comprehensive assessment of conceptual change and whether the reported changes in acceptance are sustained beyond the reporting periods. It is also questionable whether simply asking students whether they accept evolution pre- and post-course gives sufficient insight into the process and level of acceptance they achieve.

One common approach to treatment that lends itself to improving understanding and acceptance of evolution is the use of discovery and inquiry style learning experiences to indirectly broach the topic (Farber, 2003; Pramling, 2008; Robbins & Ray, 2007). Inquiry, in addition to argument and counterargument exercises (Rankey, 2003) only makes sense, as they model the practice of applied science and nature of science that is often missing from direct instruction courses. Allowing students to undertake the same actions that led to original discovery gives insight into the ways of employed by laboratory scientists. This would be the strongest way to include the nature of science instruction in the classroom and is more meaningful than simply discussing the method by which scientific knowledge is generated (Passmore & Stewart, 2002). It is clear that evolution teaching is not meeting the high standards expected based on its role as a unifying concept of science. Rather than teaching evolution as disjointed concepts that exist in isolation, it needs to be approached as a unifying concept that connects principles of biology and is directly connected to physical sciences as well (Catley & Novick, 2008). It seems that, in the midst of the controversy, students are not viewing the big picture and are left with incomplete or inadequate knowledge of evolution and the role it plays in

science (Banet & Ayuso, 2003; Catley, 2006; Catley & Novick, 2008). Courses also face specific dilemmas for measurement in that they are generally elective in nature, allowing those whose beliefs conflict with the content to avoid the courses (McKeachie, Lin, & Strayer, 2002; Wiles & Alters, 2011). This means that those who most need the course will likely not take it if they believe that it will cause cognitive dissonance.

In addition to changing the approach taken to teach evolution, there are other curricular needs that should also be addressed to improve evolution instruction. Not only do texts need to be more uniformly supportive of evolution, but also they should be more conceptually rich than what has been included in the past (Goldston & Kyzer, 2009). Assessments for evolution learning have also posed a problem in determining what and how students learn. Self-assessments are often avoided in lecture-based, rushed coverage and discussions about prior knowledge, beliefs, and misconceptions are avoided to prevent conflict (Rankey, 2003; Robbins & Ray, 2007). Assessing these early ideas and using them to elucidate reasoning patterns provides a real-time tool for mapping student progression and needs (Zabel & Gropengeisser, 2011). These maps allow teachers to track student progress and adjust instructional events to facilitate progress during the learning process (Nehm & Ha, 2010). Overall, the literature on evolution points to a single common factor: that evolution is a complex topic in terms of teaching and learning and there is no one-size-fits-all approach.

Conclusion

As noted in the introduction of this study, evolution is, and continues to be, a controversial issue in the educational forum. In order to ensure that the public is scientifically literate and able to make informed choices about matters of science, they must first have adequate, meaningful, and most importantly, accurate and substantial exposure to science and

scientific practices in their school experiences. The NSES and NGSS standards discuss, in their organization and content, that evolution understanding might be improved if, indeed, they (evolution principles) are taught well and practices of the nature of science are included in instruction (National Research Council, 2013). It appears that the issue of evolution has become oversimplified by saying ‘yes’ or saying ‘no’ to a scientific theory that is unanimously accepted among scientists. Yet, to the general public it is a matter of great debate, cast, in some cultures, as an important matter forcing the choice of one’s soul or science. Perhaps Rankey (2003) best summarized the issue with evolution, stating that there are “many shades of gray between the black and white” (p. 307).

Of particular importance to the study of evolution is the role of deeply held beliefs, especially those of a religious nature. Beliefs defined differently in various studies impact how teachers approach teaching evolution as well as the thought processes surrounding the learning, acceptance, or rejection of evolution. Worldviews are not a simple or nominal events that pose an obstacle, but rather are deeply ingrained sets of beliefs, experiences, and expectations that form the framework of who we are as individuals. These beliefs exist to answer deeply personal questions, and explain to each individual that which science cannot explain. Since they begin forming long before a person takes their first step into a classroom it is not a matter of simply rewriting beliefs, but is a rather long and arduous process of self-examination, evaluation, and the restructuring of what is known. As Matthews (2001) explained, the “variety of creation stories shows human need to explain origins, therefore we can’t expect students to simply accept evolution over creation, as those religious beliefs were first” (p. 406). In light of these beliefs, it should be the goal of evolution education to examine their own worldviews, and those of their students, in order to help students understand the nature of science itself, as well as the principles

and theories that explain things in the world around them (Asghar, Wiles, & Alters, 2011; Colburn & Henriquez, 2006; Dagher & BouJaoude, 2005; Hokayem & BouJaoude, 2008; Winslow et al., 2011).

The year of this study marked not only the seventeenth year since the National Science Education standards were released, but also the year of new standards, known as the Next Generation Science Standards. Unfortunately, despite the forward progression in the implementation of strong, unified science standards, matching K -12 science classroom practices with the spirit of the national science standards is slow to occur.

The role of the science teacher in today's classroom is a complex one. As Meadows, Doster, and Jackson (2000) noted, "biology teachers face the demanding challenge of crafting a learning environment that mediates colliding agendas" (p. 102). Therefore, it is imperative that teachers enter the classroom with the best possible preparation to teach not only the widely accepted topics but the publicly controversial topics as well. To do this, we must fully understand the problems underlying the acceptance and rejection of evolution in order to construct meaningful teaching and learning strategies across levels, enhancing instruction of content and the nature of science. It is true that the battle over evolution is one found in the public forum, and that the implications of acceptance of evolution reach far into the belief spectrum of students and teachers alike (Baker, 2013). This means that we must strive to better understand beliefs and the complex interactions between these influential factors and how the processes of acceptance and rejection of evolution theory occur. A better understanding in these areas will help students, pre-service, and in-service secondary science teachers to understand better the lenses through which they view the world, allowing them to manage their inner conflicts. Only then will we begin closing the gap between what evolution is, scientifically and

what the public thinks it is thus moving closer to the level of scientific literacy embraced by the standards movement.

Implications for Teaching and Learning of Evolution

The study of evolution and the controversy surrounding evolution are not new topics in research and have been a source of intrigue for over 150 years. Leading up to the period of focus of this study, there have been decades of research on the teaching and learning of evolution, influential factors, teacher preferences, and conflict. This study simply represents contemporary studies of evolution since the creation of the National Science Education Standards. Although we have not progressed as much as we would have liked, we have gained insights that provide a precipice for moving forward. It would appear that our current approach, although winning small victories and gaining slight headway in highly-specialized settings, still is not enough to make a difference in the court of public opinion regarding evolution. There is still much research to be done regarding the teaching and learning of evolution, both to generate new data and to reproduce results at a level that would allow prospective programs and course formats to be put into action across the country.

The studies represented in this critical analysis pose a wide range of potential implications for the teaching and learning of evolution, the most prevalent is that we are not enough to increase understanding and teaching of evolution. Moore notes on multiple occasions that we are in the grips of an educational malpractice epidemic that is unlikely to change without greater concerted effort on the part of teacher education and teachers alike (Moore, 2008; Moore & Kraemer, 2005). Furthermore, in spite of widespread reform efforts and implementation of strong national standards for science previous standards only go so far as to suggest the teaching of evolution but do not require that teachers do so (Bandoli, 2008). This is especially true when

the standards are undermined by negative attitudes, mixed messages, from state and local leaders (Goldston & Kyzer, 2009). It has yet to be seen what the impact of the newly adopted Next Generation Science Standards will be, but the strong evolution component and focuses on scientific processes and the nature of science have the potential for change if implemented and taught at the level they are written (National Research Council, 2013).

Problems with the current state of evolution education include inconsistencies in the quality and quantity of instruction in the classroom, lack of understanding of the very nature of science, and ever present misconceptions. It is clear from teacher responses that they do not feel prepared or supported in many cases when it comes to teaching evolution and that more training is needed in teacher education (Moore, 2004; Nadelson & Nadelson, 2010; Nadelson & Sinatra, 2010). Another change proposed involves improvements in methods courses and, as Trani (2004) supported, possibly screening teacher candidates to ensure that they will be able to accurately and meaningfully teach science. Since evolution is a unifying topic across years of study and no longer a topic reserved for the high school biology classroom, elementary and middle school level teachers should receive the training, support, and continued professional development to meaningfully represent the nature of science and evolution in their science classrooms (Nadelson and Nadelson, 2010). As Moore, Cotner, and Bates (2009) noted, before we see changes in college courses, or the general public, we have to make changes in compulsory education so that all students are being reached.

In order to reach students, educators need to be unified in support and instruction of evolution in our schools. It has been shown that beliefs are a strong obstacle to acceptance of evolution, so teachers must keep students' beliefs in the forefront and foster mutual respect while moving toward acceptance, rather than breaching the ethical dilemma of forced belief in

evolution (Colburn & Henriquez, 2006; Meadows, Doster, & Jackson, 2000). Belief has been explained as involving an attachment for later application and transfer whereas knowledge can have less permanence (Rutledge & Warden, 2000). Although some research has suggested including creation stories in the science classroom (Matthews, 2001), this approach proves a moot point, as the teaching of creationism is not allowed in United States public school classrooms by virtue of interpretation of the Establishment Clause of the Constitution of the United States by the Supreme Court (Mount, 2010). It is possible, however, to implement other means of modeling scientific thought and practice in teaching evolution, such as debates for and against evolution (Asghar, Wiles, & Alters, 2010); learning experiences (Crawford et al., 2005); ongoing modeling of the nature of science (Dagher & BouJaoude, 2005); and through longer, more intensive evolution courses or learning modules to increase knowledge and encourage acceptance through deeper exploration of beliefs and concepts (Nadelson & Sinatra, 2010).

Perhaps the most meaningful course of action is one that encourages students to explore their own beliefs and learn to manage their knowledge and understanding of evolution in terms of those personal beliefs (Meadows, Doster, & Jackson, 2000). Since students often rely on non-scientific views, beliefs, and experiences to shape their ideas about evolution, it is not surprising that students find it difficult, if not impossible to reconcile the two (Crawford et al., 2005). Therefore, it is important that we provide teachers with the tools and opportunities to manage these tensions, as well as providing them with a model of how this can be done (Crawford et al., 2005; Meadows, Doster, & Jackson, 2000). This approach has the potential to put a more personable face on the theory of evolution, giving students guidance in positively managing the conflict they may experience rather than ignoring it while teaching it.

Suggestions for Future Research

Despite the limitations that accompany all studies involving a human element, the research reveals wide agreement that more research is needed to better understand the complexity of obstacles and issues associated with the teaching and learning of evolutionary theory. Based on the studies presented, it appears that teacher education and university course work is not adequately preparing secondary pre-service science teachers to teach evolution in ways that make teachers comfortable teaching it (Rutledge & Warden, 2000), and it cannot be assumed that having a background in science or even extensive biology background provides an adequate working knowledge of evolution (Nehm & Schonfeld, 2007). Therefore, more research is needed to determine how it is being taught (Rutledge & Mitchell, 2002); how evolution is perceived (Bowman, 2008); and the pedagogical content knowledge associated with effective evolution instruction (Veal & Kubasko, 2003).

In terms of methodology, there is a need for innovative approaches to both the prepare science teachers to teach evolution as well as the teaching of evolution in the classroom. Such approaches should span various settings such as science methods and content courses at university and secondary levels (Crawford et al., 2005); address of complex topics such as earth time (Catley & Novick, 2007); support of currently suggested approaches such as oral framing and metaphor (Oliveira, Cook, & Buck, 2011; Pramling, 2008). Further study of the complex relationships between religion and acceptance is also needed (Deniz, Cetin, & Yilmaz, 2011; Nehm & Schonfeld, 2007; Nehm, Kim, & Sheppard, 2009), especially with weak creationists, who demonstrated more issues with evolution than those with other beliefs (Brem, Raney, & Schindel, 2003), in a nation, unlike others, “where creationism is widely regarded in the public population” (Moore, 2008,p. 82).

Aside from the development of new approaches, there is also a need to better understand the processes that influences the gaining of knowledge and its association with acceptance and rejection of evolution. Schilders, Sloep, Pele, and Boersma (2009) suggest the need to explore worldviews, specifically addressing the nature of science and epistemologies of religion and science. Within the scope of worldviews, there is also a need to better understand the relationships of specific aspects such as self and non-self, space and time, and how these elements influence the process of rejection and acceptance of evolution (Hokayem & BouJaoude, 2008). Although it is suggested that worldview contributes to the acceptance or rejection of evolution, there is currently no research exploring whether it has the same effect on other non-controversial topics in the way that knowledge influenced acceptance of non-controversial issues in other studies (Sinatra et al., 2003). There is also a need for the incorporation of approaches that will encourage students and teachers alike to evaluate worldviews other than their own, thus seeing the issue of evolution through more than their own worldview lens (Hokayem & BouJaoude, 2008).

Before we can do anything to improve the instruction of evolution, we need to determine what components make up the ideal evolution learning experience. This includes gaining insight into what sets apart cultures that are accepting of evolution from those that are not, as well as which worldviews are more conducive to acceptance than rejection. This is especially true of the under-represented population of pre-service and non-tenured science teachers at both the secondary and elementary levels, both of who represent transitional positions between learner and teacher and who do not have the benefit of experience and resources gained by experienced teachers.

Finally, based on the limited research analyzed here, there is a lack of regional representation in the United States in the existing literature on evolution. A majority of studies have taken place in the Midwest and Northeast, namely Indiana, New York, and Minnesota (Matthews, 2001; Moore, 2004; Rutledge & Mitchell, 2002). Others have looked elsewhere however, the findings suggest a need for further exploration of acceptance and rejection of evolution across the nation and, especially, in the Southeastern United States where there have been demonstrated anomalies such as the use of textbook disclaimers and documentation that students in the South are 84% less likely to receive credible evolution instruction and ten times more likely to have no evolution instruction (Goldston & Kyzer, 2009; Bowman, 2008).

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Appendix A

Evolution and Pre-service Science Teachers: Categorization of Reviewed Articles

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| Approach to evolution in today's classrooms | Bowman, 2008; Goldston & Kyzer, 2009; Moore, 2004; Moore, 2008; Moore & Kraemer, 2005; Oliveira, Cook, & Buck, 2011; Veal & Kubasko, 2003 |
| Knowledge, understanding, and acceptance of evolution | Students: Martin-Hanson, 2008; Moore, Cotner, & Bates, 2009; Ingram & Nelson, 2006; Matthews, 2001; Nadelson & Sinatra, 2008; Nehm & Reilly, 2007; Nehm & Schonfeld, 2007; Rutledge & Sadler, 2011; Sinatra et al., 2003 Pre-service Teachers: Akyol, Tekkaya, & Sungur, 2010; Athanasiou & Papadopoulou, 2011; Deniz & Donnelly, 2011; Deniz, Donnelly, & Yilmaz, 2008; Ha, Haury, & Nehm, 2012; Kim & Nehm, 2011 In-service Teachers and Teaching Preferences: Deniz, Cetin, & Yilmaz, 2011; Nehm, Kim, Sheppard, 2009; Rutledge & Warden, 2000; Trani, 2004 |
| Attitudes and perceptions of evolution | Students: Brem, Ranney, & Schindel, 2003; Dagher & BouJaoude, 2005; Hokayem & BouJaoude, 2008; Winslow, Staver, & Scharmann, 2011 Teachers: BouJaoude et al., 2011; Chuang, 2003; Goldston & Kyzer, 2009; Nadelson & Nadelson, 2010; Rutledge & Mitchell, 2002; Schrein et al., 2009 |
| Factors impacting the teaching and learning of evolution | Donnelly & Boone, 2006; Moore, Brooks, & Cotner, 2011; Nehm & Schonfeld, 2007; Nehm, Kim, & Sheppard, 2009 |
| Evolution conflict and coping | Dotger, Dotger, & Tillotson, 2009; Griffith & Brem, 2004; Meadows, Doster, & Jackson, 2000; Sanders & Ngxola, 2009 |
| Evolution and religiosity | Asghar, Wiles, & Alters, 2010; Baker, 2013; Colburn & Henriquez, 2006; Moore, 2008; Moore & Kraemer, 2005; Murphy, Hickey, & Beggs, 2010; Schilders et al., 2009; Verhey, 2005 |
| Proposed evolution teaching methods, courses, and assessment | Banet & Ayuso, 2003; Catley, 2006; Catley & Novick, 2008; Cavallo & McCall, 2008; Crawford et al., 2005; Farber, 2003; McKeachie, Lin, & Strayer, 2002; Nadelson & Sinatra, 2010; Nehm & Ha, 2010; Passmore & Stewart, 2002; Pramling, 2008; Rankey, 2003; Robbins & Ray, 2007; Wiles & Alters, 2011; Zabel & Gropengeisser, 2011 |

ARTICLE TWO:
EVOLUTION AND PRE-SERVICE SCIENCE TEACHERS: FACTORS INFLUENCING
ACCEPTANCE AND REJECTION OF EVOLUTION.

Introduction

Evolution has, and will continue to be, one of the most polarizing scientific theories taught in science classrooms. Although the term evolution simply refers to the slight changes in organisms that occur over very long periods of time, evolution herein refers both to the concept definition and to the collective theories of ancestry (both human and otherwise) geologic time, and the proposed origins of life. It is in these details that the controversy of evolution begins. Now, nearly two hundred years after Darwin's observations on the *HMS Beagle*, many are still struggling to find where evolution fits within their beliefs and culture. According to Lee (1999), “some of the information sources and discourses in children’s social and cultural contexts present them with mainstream western views, whereas others present alternative views” (p. 189).

This need for alignment of information with a person’s world view appears to be crucial in the acceptance process for complex concepts such as evolution that are often found to be in conflict with the views a student brings into the classroom (Hansson & Redfors, 2007; Hansson, Andreas, & Redfors, 2010; Martin-Hanson, 2006). When students have multiple sources for beliefs that diverge, findings suggest they accept that which most closely aligns with those beliefs and views that reflect their existing cognitive worldview rather than those that are in conflict (Branch & Scott, 2008; Jakobi, 2010; Kikas, 2004; Nehm & Reilly, 2007; Rutledge & Mitchell, 2002). This does not mean students do not know the concept or cannot grasp it, but rather that they know what is required of them for whatever period it is beneficial, such as for

grading purposes, then relegate the information to a cognitive region where it is unused (Cobern, 1994b; Ingram & Nelson, 2006; McKeachie, Lin, & Strayer, 2002). As Cobern (1994b) described,

Many students, in other words, practice cognitive apartheid. Students simply wall off the concepts that do not fit their natural way of thinking. In this case, the students create a compartment for scientific knowledge from which it can be retrieved on special occasions, such as a school exam, but in everyday life, it has no effect. (p. 9)

Therefore, the issue is not that the concept of evolution is unknown to individuals but rather that they do not believe in evolution (Cobern, 1994b).

This problem applies not only to mainstream students in secondary and post-secondary school, but is of greater magnitude when the students being considered are pre-service science educators who share in the struggle for acceptance of a concept that is unanimously accepted as the unifying concept of biological science (National Academy of Sciences, 2008, 2013; National Association of Biology Teachers, 2008; National Research Council, 1996; National Science Teachers Association, 2004). Research findings posit that improving how we teach evolution is the key to increasing student acceptance of evolution (Alles, 2001; Alters & Nelson, 2002; Cobern 1994b; Scharmann, 2005). It is the position of this study that to prepare future teachers to best teach the theory of evolution, we must first understand the complex interactions that lead our future teachers to their own acceptance or rejection of evolution, a position that will strongly impact what and how they teach evolution once they are in the classroom (Bowman, 2008; Ha, Haury, & Nehm, 2011; Smith, 2010a, 2010b).

Assumptions and Limitations

For this study, it was assumed that pre-service secondary science educators are early experts in the content field of science and that they will be responsible for teaching evolution to their students. Therefore, their understanding of the nature of science and evolutionary content

knowledge should be comparable to those students who are science majors. It was also assumed that these pre-service teachers would bring with them varying degrees of acceptance of evolution, as well as varying worldviews based on their personal experiences.

Several limitations impacted the study of this topic and sample. First, a multiple regression analysis was used to provide statistical findings but is limited in its application in that it cannot determine the causality among determined related variables, only whether relationships exist. Another limitation is the use of purposive sampling in the selection of a limited sub-population of pre-service science teachers and science majors in a teaching college with less than ten thousand students. This method, as opposed to a random sample, produces results that are not as readily generalized to a greater population.

Research Questions

The following research questions were examined in this study:

1. What relationships exist between the worldview variables and acceptance of evolution among pre-service secondary science teachers; and
2. Which combination of these variables explains the most statistically significant amount of variance in acceptance of evolution among pre-service secondary science teachers?

Purpose of the Study

Despite much research seeking to identify problems, prescribe strategies for more effective teaching, and understand evolution (Alters & Alters, 2001; Alters & Nelson, 2002; Besterman & Baggott la Velle, 2007; Bowman 2008; Bleckman 2006; Butler, 2009; Cooper, 2001; Farber, 2003; Goldston & Kyzer, 2009; Hoffman & Weber, 2003; Lerner, 2000; Oliveira, Cook & Buck, 2011; Passmore & Stewart, 2002; Scharmann, 2005; Smith 2010a; Smith 2010b;

Zimmerman, 2009) the chasm between acceptance and rejection is as large today as in the past (Alters & Nelson, 2002; Gallop, 2011; McKeachie, Lin, & Strayer, 2002; Miller, Scott, & Okamoto, 2006; Rutledge & Warden, 2000; Wiles & Branch, 2008).

These studies, and others, have taken on many directions for exploring evolution and teaching but lacked a key component relevant to acceptance of evolution, the premise that understanding of a topic and belief in its premises are not one in the same (Cobern, 2000; Cooper, 2001; Davson-Galle, 2004; Hoy, Davis, & Pape, 2006; Southerland, 2000). Knowledge, in this study, refers to the key concepts and factual information presented as a part of evolutionary theory. To know something, one must first accept something as factual; therefore, knowledge and acceptance cannot occur one without the other (Cobern, 2004). Understanding, however, is the “process of thought leading to conceptual comprehension” of a topic, representing the ability to connect fact and concept in such a way as to apply it to the world (Cobern, 1994, p. 586). Whereas knowledge and understanding are divided based on the ability to use the information at hand, acceptance and belief are differentiated by rationality. As Southerland and Sinatra (2003) and Nehm and Schonfeld (2007) redressed, “acceptance may be considered recognition of a theory’s validity based on rational systematic review of the evidence, belief is based on personal convictions, opinion, and extrarational (sic) criteria” (p. 719). Since most individuals do not differentiate between the academic definitions of acceptance and belief, or evaluate whether their strongly held convictions are based on factual evidence or irrational ideas, an approach similar to that taken by Nehm, Kim, and Sheppard (2009) was taken and the two terms were considered interchangeable. Inevitably, there is, within each student, a complex interaction of internal and external factors that influence that which we accept and reject in terms of belief. External factors, such as cultural and social influences on science education and its

teaching, have not been well addressed in the realms of conceptual change and cognitive learning theory that are often applied as a means to explore evolutionary belief and acceptance (Lee, 1999).

According to Cobern (1994b), there are three things to remember when addressing acceptance of a concept: “our knowledge is based on what we experience, it is subjective, and it is painted in our prior experiences” (p. 586). The existing body of research on the acceptance of evolution addresses some of the aforementioned factors, while others address influences such as religiosity, content knowledge on evolution, and understanding the nature of science. However, most research findings address these factors as individual influences rather than looking at the possible interactions among factors that influence acceptance or rejection of evolution.

The purpose of this study was to better uncover and clarify the process of the acceptance and rejection of evolution by looking for relationships between acceptance and factors that influence a person's worldview—the set of beliefs, expectations, experiences, and ideas by which a person evaluates all other events and information—or their scientific understanding. This was done by quantitatively examining participants' responses to a combination survey to determine whether possible factors were statistically significant predictors of acceptance or rejection of evolution and whether the identified independent variables adequately explained the variance in acceptance of evolution among pre-service science educators. A worldview framework was used to explain how these variables would collectively contribute to the participants' perspectives and learning of evolution. Identifying variables that explained a great amount of variance enabled the determination of which, internal or external factors, were of greater influence on acceptance of evolution. This distinction provided critical insight about how one may reform and modify pre-service science teachers' preparation to address these influences in acceptance of evolution.

Significance of the Study

Understanding the process by which an individual elects to accept or reject evolution enables a more research-driven approach to the teaching of evolution at the secondary level as well as higher education in the preparation of pre-service teachers relative to evolution. Since this study focused on the acceptance or rejection among pre-service science teachers, it gives insight not only into how teachers have been prepared and make their decisions, but also the changes that are necessary to encourage these teachers to include evolution in their classroom curriculum.

Theoretical Framework

The lens through which this research was viewed was that of worldview (Cobern, 1994a, 1994b, 2000; Cobern & Loving, 2000, 2002; Koltko-Rivera, 2004). It is important to note here that the foundational theory was “world view” whereas the modern theory is written as “worldview,” referring to a more formal set of beliefs and interactions rather than the general picture that would be a person's view of the world. Cobern (1994a, 2000) describes “worldview” as “a comprehensive concept about the tacit dimensions of cognition subsuming both epistemology and metaphysics” (p. 14). Shumba (1999) simplifies this by defining the worldview as “fairly stable and consistent values, beliefs, and frame of reference about the universe” (p. 334).

Worldview is not a new concept; its early foundations are the German concept of *weltanschauung*, which refers to the opinion through which a person's collective experiences hold judgment over all new experiences. Ashmore (1966) noted, “a weltanschauung may function as a kind of prejudiced tribunal, before which issues that confront the mind appear for adjudication and are resolved according to the character of the prevailing weltanschauung” (p.

216). These concepts, in addition to the premises of cultural anthropology, have been elucidated and formalized in the research of Kearney (1975; 1984) and Cobern (1991, 1993, 1994a, 1994b). Kearney (1984) defined world view as “culturally organized macrothought: those dynamically inter-related basic assumptions (i.e., presuppositions) of a people that determine much of their behavior and decision making, as well as organizing much of their body of symbolic creations...and ethnophilosophy” (p. 1).

Worldview is rooted in anthropology (Kearney, 1975) and “consists of basic assumptions and images that provide a more or less coherent, though, not necessarily accurate, way of thinking about the world” (Kearney, 1984, p. 41). It is a combination of all factors that converge in an individual to create a fixed, lasting perspective through which they will view and interpret all other interactions in their world (Cobern, 2000; Koltko-Rivera, 2004). Ashmore (1966) explained the concept of *weltanschauung*, an early component of worldview, as an amalgam of factors that include “temperament, disposition, morals (i.e. morals, habits, and manners), organizations of thought, class, etc.” (p. 216-220). Kearney (1975) built upon this by adding that “a formulation of world view should express the implicit conception of the natural and social universe which exists at a subconscious cognitive level such that information are not normally able to articulate it” (p. 248). He later clarified that it is the existing web of assumptions and preconceptions that individuals use to determine how they behave and choices they make (Kearney, 1984). Cobern (1994a) added to this, changing “world view” to “worldview” in order to reflect the shift from a simple interpretation of the world around to his “sum of whatever number of cultural components (e.g., religion, aesthetics, ideology) a person embraces” (p. 8).

World view addresses the cumulative influence of “notions about the self, the other, time, space, the natural and supernatural, and the sacred and profane” (Kearney, 1975, p. 248). This

considers both environmental influences and the internal processes within the individual that become the fixed set of beliefs and notions about the world of which they are a part (Heibert, 2008; Koltko-Rivera, 2004). Cobern (1994a) gives a representative equation for the formulation of worldview in which there are any possible number of contexts and cultural variables whose sum, ultimately, results in worldview. It is not assumed that the power of these variables are equal, rather they fluctuate both across a group and within the individual based on ongoing experiences with their surroundings.

In addressing the power of the concept of worldview, Cobern (1991) explains, “specifically, a worldview defines the self... it sets the boundaries of who and what I am... it also defines everything that is not me, including my relationships to the human and non-human environments. It shapes my view of the universe, my conception of time and of space” (p. 3). A person’s worldview becomes an internal normative value by which all other things are judged and either accepted or rejected (Ashmore, 1966; Heibert, 2008; Johnson, Hill, & Cohen, 2011).

Review of Literature

Thagard and Findlay (2010) stated, "unfortunately, for science students and the population in general, there are major psychological obstacles to accepting Darwin's theory" (p. 626). The question of acceptance of evolution is one made with great influence by external and internal factors on the individual (Osif, 2007). Unlike most concepts in science, evolution has proven controversial from its inception and continues to be a topic fraught with negative perceptions and conflict. Unlike neutral topics, such as photosynthesis and respiration, evolution faces rejection despite vast amounts of evidence and the unanimous backing by the scientific community (Sinatra, Southerland, McConaughy, & Demastes, 2003). Thagard and Findlay’s

(2010) findings further support the tensions associated with the chasm between knowing and accepting:

Rationally, people are supposed to form their beliefs on the basis of evidence, not according to what they want to be true. But it would be naive to ignore the fact that people often shape their beliefs in part by their goals. (p. 630)

These personal goals, they earlier explained, are psychological, emotional, and cognitive obstacles, including “conflict with valued beliefs about God, souls, and morality,” among others (Thagard & Findlay, 2010, p. 626).

Although some studies argue that understanding is more important than acceptance among students (Ingram & Nelson, 2006), acceptance is also important when discussing students in pre-service programs as it influences teacher topic preferences such as durations, coverage, and depth once they enter the classroom (Deniz, Cetin, & Yilmaz, 2011). The idea of acceptance of evolution as a point of study comes from data supporting only moderate levels of acceptance of evolution among both students and teachers, even in the field of biology (Fahrenwald, 1999; Johnson, 1986; Nehm, Kim, & Sheppard, 2009; Rutledge & Warden, 2000). It is for this reason that study regarding the acceptance of evolution has become a prevalent topic in the literature over the past two decades.

Much of the existing literature on acceptance of evolution is focused on the factors influencing the level of acceptance among students in colleges and universities (Alters, 1996; Ingram & Nelson, 2006; Johnson, 1986; Nadelson & Sinatra, 2010; Osif, 1997; Rice, 2007; Sinatra, Southerland, McConaughy, & Demastes, 2003) or in-service teachers of science at the secondary level (Fahrenwald, 1999; Nadelson & Sinatra, 2009; Nehm, Kim, Sheppard, 2009; Rutledge & Mitchell, 2002; Rutledge & Warden, 2000). These studies look at evolution through the teaching and learning lens but do not take into account the gray area in which pre-service

teachers exist, that state of being a student striving to become a science teacher. The least explored group, the one being explored in this study, is that of pre-service secondary science teachers and their acceptance of evolution (Akyol, Tekkaya, & Sungur, 2010; Deniz, Cetin, & Yilmaz, 2011; Deniz, Donnelly, & Yilmaz, 2008).

Not only is there little research exploring the acceptance of evolution among pre-service secondary science teachers, there is equally little research done in the Southern United States, a location with a history of contention with evolution and evolutionary instruction (Goldston & Kyzer, 1999). Many studies on evolution can be located primarily in the Mid-western and New England regions of the United States, including Pennsylvania (Osif, 1997), South Dakota (Fahrenwald, 1999), Indiana (Rutledge & Sadler, 2007; Rutledge & Warden, 2000), and New York (Nehm, Kim, & Sheppard, 2009). Furthermore, the related studies involving the target population, pre-service secondary science teachers, (Deniz, Cetin & Yilmaz, 2011; Deniz, Donnelly, & Yilmaz, 2008) took place among small groups of pre-service science teachers in Turkey and are not readily applicable to the sample in this study.

Several factors influencing acceptance of evolution are recurrent in the existing literature and are considered in this study based on the recurrence. These include knowledge and/or understanding of evolutionary theory (Akyol, Tekkaya & Sungur, 2010; Deniz, Donnelly, & Yilmaz, 2008; Ingram & Nelson, 2006; Rutledge & Warden, 2000), religion or religiosity (Deniz, Cetin, & Yilmaz, 2011; Nehm, Kim, & Sheppard, 2009), critical thinking and similar dispositions (Deniz, Donnelly, & Yilmaz, 2008; Sinatra, Southerland, McConaughy, & Demastes, 2003; Wiles, 2008), understanding of the nature of science (Fahrenwald, 1999; Rutledge & Warden, 2000), and other background factors explored below (Deniz, Donnelly, & Yilmaz, 2008; Nadelson & Sinatra, 2010; Nehm, Kim, & Sheppard, 2009; Rutledge & Mitchell;

2002). The existing literature reveals a lack of consistency in the findings within the aforementioned groupings.

A number of studies have looked either directly at the influence of knowledge and understanding on acceptance (Akyol, Tekkaya, & Sungur, 2010; Deniz, Cetin, & Yilmaz, 2011; Deniz, Donnelly, & Yilmaz, 2008; Rice, 2007; Sinatra, Southerland, McConaughy, & Demastes, 2003), indirectly at the two based on measures such as achievement in an evolution-related course (Ingram & Nelson, 2006), or after completion of other related treatments, such as interactive websites (Nadelson & Sinatra, 2010). Regarding most subjects, acceptance is directly related to a student's or teacher's knowledge in conjunction with understanding core facts and principles behind the subject, as evidenced in the study by Sinatra, Southerland, McConaughy, and Demastes (2003). It is naturally assumed that greater knowledge and understanding will lead to higher acceptance, as is the case with general topics such as photosynthesis (Sinatra et al., 2003). However, when applied to evolution among different groups different results have been reported (Deniz, Cetin, & Yilmaz, 2011; Deniz, Donnelly, & Yilmaz, 2008; Donnelly, Kazempour, & Amirshokohi, 2009; Rutledge & Mitchell, 2002; Rutledge & Warden, 2000; Wiles, 2008). Ingram and Nelson (2006) reported no statistical relationship between acceptance of evolution and achievement in evolutionary studies, explaining that student participants were able to score in the high achievement range, despite having low levels of acceptance of evolution (p. 16). Conversely, Rutledge and Warden (2000) reported that "significant relationships were found between teacher acceptance of evolutionary theory and both teacher understanding of evolutionary theory and teacher understanding of the nature of science" (p. 28). Fahrenwald (1999) showed similar results among teachers in South Dakota, noting "a correlation between an understanding of evolution and acceptance of evolution" (p. 66). Deniz, Donnelly, and Yilmaz

(2008) reported similar results in pre-service secondary science teachers, finding “significant correlations between participants' knowledge of evolution and their acceptance of evolution” (p. 432). The study reveals different dynamics may be involved with different groups of individuals, lending further support for studies among groups such as pre-service secondary science teachers.

Several of the studies evaluating knowledge and/or understanding the nature of science suggest it as a potential variable influencing acceptance or rejection of evolution (Fahrenwald, 1999; Rutledge & Warden, 2000). There is, again, an inconsistency between the results of the studies. In Fahrenwald's (1999) study, the sample demonstrated a “moderately high level of understanding of nature of science” but only a “moderate acceptance of evolution” (p. 63). Correlation of the data showed “weak to moderate correlations between all of the combinations of variables” but “no significant relationship between an understanding of the nature of science and an acceptance of evolution” (p. 66) in teachers. Rutledge and Warden (2000) found the opposite to be true with Indiana teachers recording “a direct significant relationship between acceptance and nature of science” (p. 28). Two other studies (Deniz, Donnelly, & Yilmaz, 2008; Sinatra, Southerland, McConaughy, & Demastes, 2003) did not specifically look at the nature of science, but the studies focused on the openness to belief change, dispositions, and cognitive flexibility as traits aligned with the concept of the nature of science described by Lederman and Zeidler (1987). In their study, Deniz, Donnelly, and Yilmaz (2008) found that those pre-service teachers who were open-minded and flexible cognitively were more likely to accept evolutionary theory (p. 432). Sinatra, Southerland, McConaughy also reached this conclusion, and Demastes (2003) who stated those with more “open minded thinking” in terms of disposition were more likely to accept evolution (p. 519).

In terms of religion and religiosity, the research suggests that subjects are influenced by religion when deciding whether to accept or reject evolutionary theory (Wiles, 2008). Wiles' study was based on self-reporting of perceived religious influence on personal choice by the individuals studied and did not empirically test for significance. Nehm, Kim and Sheppard (2009) suggest that "religiosity per se is not the most salient descriptor of teacher concern with evolution" (p. 1132) but it is one influential factor.

Deniz, Cetin, and Yilmaz (2011) empirically found that there is a "significant negative correlation between acceptance of evolutionary theory and religiosity" (p. 4). Not only did the results suggest that higher levels of religiosity were correlated to lower acceptance levels, but religiosity also influenced the pre-service secondary science teachers' preferences for teaching evolution. Deniz and colleagues study involved using pre-service secondary science teachers in Turkey, a location with a mixed religious heritage including Christian and Islamic tradition, among others. It has yet to be seen whether similar empirical evidence will be derived in a location with more fundamental Christian beliefs. This direction is supported by Johnson's (1986) finding that there were significant variations in level of acceptance of evolution among subjects of different religious backgrounds, denominational in this case.

In addition to the aforementioned findings, a number of studies sought to define some additional variables that are of interest in this research. This includes family scientific background, degree history, or science course history of students or teachers (Deniz, Donnelly, & Yilmaz, 2008; Rutledge & Mitchell, 2002; Nehm, Kim, & Sheppard, 2009; Osif, 1997). Findings in these studies suggest that "educational sophistication is positively correlated with participants' acceptance of evolutionary theory" (Deniz, Donnelly, & Yilmaz, 2008, p. 432). Rutledge and Mitchell (2002) found "significant correlations between teacher acceptance of

evolutionary theory and overall number of credit hours in biology, completion of a course in evolution, and completion of a course in the nature or philosophy of science” (p. 22). It is noted, that, although courses in science have been shown to significantly impact acceptance of evolution, Johnson (1986) shows that only certain courses in science were influential. It is also shown that although biology majors were more open to acceptance than non-biology majors to acceptance (Johnson, 1986, p. 74) the result for biology teachers “barely differed from a comparable sample with little or no undergraduate biology coursework” (Nehm, Kim, & Sheppard, 2009, 1128).

The findings documented in the literature suggest that there exists some fundamental difference between students and teachers of science that result in different influences of significance in their acceptance and rejection of evolution. This difference has led to greatly varying results being found when testing teachers than those found in science majors. It is this lack of solidarity in results that makes it necessary to further examine the relationships between these variables and the acceptance of evolution in pre-service secondary science teachers in the southeastern United States.

Methodology

Research Design

A quantitative methodology was selected for this study based on the nature of the research questions:

1. What relationships exist between the independent variables and acceptance of evolution among pre-service secondary science teachers;
and

2. Which combination of variables explains the most statistically significant amount of variance in acceptance of evolution among pre-service secondary science teachers?

To determine the answers, a survey document was deployed that generated data for the regression model.

The document included a demographic section, the Measure of Acceptance of Theories of Evolution (MATE) test, a Nature of Science (NOS) test, and Evolution Content Knowledge (ECK) test. These instruments were used to determine level of acceptance of evolution, understanding of science as an ambiguous and changing discipline and practice, and the understanding of key concepts of evolution. The demographics section served to identify general categorical variables such as the students' year of study, completed science courses, number of friends and family members in STEM careers or study, their perceived level of religiosity, and how important they felt beliefs were to their decision-making processes.

Multiple regression analysis was employed to determine relationships and the best model for explaining variance in acceptance of evolution. Multiple regression, an appropriate form of univariate analysis, was used to simultaneously study the relationships between several explanatory and independent variables with a single dependent variable (Pedhazur, 1997, p. 5). It can be used both to explain the relationships that exist among variables and to predict outcomes in individual variables based on the changes in others.

Setting and Population

This study took place at a state university in the southeastern United States, an area defined as including Louisiana, Mississippi, Alabama, Georgia, and Tennessee. This state university is situated in a rural community located within sixty miles of two major cities. The

school houses just under ten-thousand students and is Carnegie classified as a medium, full-time, four-year, inclusive school that is primarily non-residential (Carnegie 2011). It is a co-educational institution with both undergraduate and graduate programs and is regionally accredited by the Southern Association of Colleges and Schools (SACS). In addition to institutional accreditation, the National Council for Accreditation of Teacher Education (NCATE) accredits the education program at the school. The population of interest is that of pre-service science teachers who are enrolled in teaching colleges with less than 10,000 total students. These schools are traditionally found in rural or metropolitan areas that border large rural zones and reflect a more homogeneous population from local areas than what is found at larger research universities.

Instrumentation

The instrument employed in this study was multi-section document consisting of a detailed demographic section and three aspect specific surveys. These instruments are the MATE survey, a modified version of that created by Johnson (1986) and used by Rutledge & Warden (2000), a survey of the nature of science modified from that created by Rutledge & Warden (2000), and a multiple selection evolutionary content knowledge test developed by Johnson (1986). Each section was selected based on the existing support for validity and reliability regarding the purported measurements generated. The survey document in its entirety can be found in Appendix A with the scoring document following in Appendix B.

Demographics. The demographics portion of the survey incorporated traditional demographics such as gender, age, and race for the purpose of examining whether demographics were possible variables of influence acceptance of evolution. The study also included specific background information such as college major, class level, parents' education levels, and

exposure to science, math, and technology fields through family and friends. Finally, there were a number of questions that related to participant's perceptions of religiosity and the perceived impact of their beliefs on choices they make, including those about evolution.

Measure of acceptance of evolutionary theory survey. The Measure of Acceptance of Theories of Evolution, or MATE, instrument was first conceptualized as the "acceptance of evolution survey" by Johnson (1986) and later modified slightly by Rutledge and Warden (2000). The MATE has been used primarily with biological science students in secondary and higher education (Butler, 2009; Donnelly, Kazempour, & Amirshokoochi 2008; Johnson, 1986; Moore, Brooks, & Cotner, 2011; Nehm, Kim, & Sheppard, 2009; Rutledge & Warden, 2000; Rutledge & Sadler, 2007; Wiles & Alters, 2011; Wylie, 2003) but is widely accepted across fields due to high levels of reliability and validity (Johnson, 1986; Rutledge & Sadler, 2007).

The MATE was initially tested by Johnson (1986) with a reported Chronbach alpha score of .77 (p. 50). Following modification by Rutledge and Warden (2000), a re-test of the document, now identified as the MATE, resulted in a Pearson coefficient of .92 when given twice to the same population of biology students, and a Chronbach alpha value of .94 (Rutledge & Sadler, 2007, p. 333). When tested for reliability as a measure of acceptance among secondary educators, the reliability coefficient was .84 (Rutledge & Warden, 2000). Internal validity of the MATE was established by review of the instrument by professors, classroom teachers, and other field specialists (Rutledge & Warden, 2000).

Scores for the MATE are reported on a scale of 20-100 with 20 being the lowest possible score achievable with all questions attempted. Scores are classified as very high (89-100), high (77-88), moderate (65-76), low (53-64), or very low (20-52), based on the value obtained (Rutledge & Sadler, 2007).

Nature of science survey. The Nature of Science, or NOS, instrument by Rutledge and Warden (2000) accompanies the MATE and measures a subject's understanding of the practice and principles of scientific thought and process. As stated before, it is widely noted (Abd-el-Khalik & Lederman, 2000; Akyol, Tekkaya, & Sungur, 2010; Cobern, 2000; Farber, 2003; Griffiths & Thompson, 1993; Lederman & Zeidler, 1987; McComas, 2003; Morrison, Raab, & Ingram, 2009; Rudolph & Stewart, 1998; Scharmann & Harris, 1992; Southerland, Johnston, & Sowell, 2006) that an understanding, or lack of understanding of the nature of science is a key factor in understanding why teachers teach what they do and likely why students, teachers, and pre-service secondary science teachers do or do not accept evolution. The nature of science survey measures an individual's understanding of the processes by which scientific research is conducted, replicated, and laws or theories are derived. Like the MATE, the NOS survey was tested for validity by members of a panel of regarded scientists and science instructors (Rutledge & Warden, 2000) with an initial Chronbach alpha reliability value of .78 (Johnson, 1986) when administered to biology students. When administered to secondary science teachers it had a .94 reliability coefficient (Rutledge & Warden, 2000).

Evolutionary content knowledge test. Johnson (1986) incorporated a short, theory-based evolution content knowledge examination to determine whether students were able to learn and later recall information about the theory of evolution. The evolutionary content knowledge test, or ECK, used is a recounting of key principles, discoveries, and facts relevant to evolution and is valued solely on correct responses to questions. Based upon this scoring method, a total of 21 points would indicate perfect understanding of the content and a score of 0 representing no understanding of the content. According to Johnson (1986) the reliability, measured by the Kuder-Richardson formula 20, was .73 (p. 50) when given to biology students and .84 when

administered to secondary science teachers (Rutledge & Warden, 2000). This document was also evaluated and accepted as valid by the research panel of experts selected by Rutledge & Warden (2000) to review their questionnaire.

The evolutionary content knowledge test scores were reported as the percent of questions answered correctly with grade scale ranges representing the student's level of knowledge: very high (90-100), high (80-89), moderate (70-79), low (60-69), and very low (59 or less). In this study, the numerical value will be used for statistical analysis.

Procedures

The briefing of potential subjects took place in the students' upper-level biology courses on site at the university. With approval from the department, I arranged to meet with classes and, during each meeting, briefed all students in attendance to request participation and secure consent. The instructors for the courses were excused from the classroom to discourage students from feeling coerced or judged regarding their choice whether to consent. Those students who elected not to participate in the study were released following the briefing session. All who elected to participate were asked to sign a consent form and completed the survey on site during the same class session. Forms were collected in such a way as to separate the names from the collected data and ensure anonymity. At no time were subjects' names used on the survey documents, nor was the department notified of participant or non-participant identities. Upon completion, all surveys were scored by hand to determine the score for the MATE, NOS, and ECK. All data was then input into PASW/SPSS 18 data form for analysis.

Sample

The sample for this study was one of convenience in that it was a sub-set of the overall population selected based on their enrollment and declared major. The original sample consisted

of 148 undergraduate college students who were declared majors in either biology or secondary science education with a concentration in biology or general science. The minimum number of cases required for the first part of the study was 148 based on the sample formula $n \geq 50 + 8m$, for multiple correlations, and $n \geq (104 + m)$, for individual predictions, with $m=11$, representing the number of variables being initially tested (Tabachnick & Fidell, 2007, p. 123). The final number of cases used was $n=116$, with $m=5$ following removal of incomplete survey documents and outliers from the original sample group.

Data Analysis

Data collected from the survey instrument was sorted into measured variable sets and prepared for analysis using the PASW/SPSS 18 data program. Demographic information was compiled using either ordinal totals, such as the number of science courses passed and STEM influences; or categorical data, including both education levels, gender, major, year of study, religiosity, influence of beliefs, and background. Scores were generated for the nature of science, content knowledge, and acceptance portions of the survey document for each participant based on the scoring guidelines in Appendix B.

Initial review of the variables indicated a need to simplify the categorical variables. Therefore, the variables representing education levels were dichotomized into groups representing completion of middle school to some college or completed degree to professional level. This was also done for background, making the options urban or non-urban rather than urban, metropolitan, or rural. Further data clean-up involved cross-checking the input data with original data for accuracy and determination of linearity between the dependent variable and each possible explanatory variable.

The initial evaluation of the dependent variable acceptance of evolution (MATE), and the explanatory variables that include: a) nature of science understanding (NOS), b) content understanding (ECK), c) gender (GEN), d) completed science courses (SCI), e) mother's education (MED), f) father's education (DED), g) STEM influences (STEM), h) background (BG), i) year of study (YR), j) religiosity (REL), and k) influence of religious beliefs (RINF), was done by generating a full regression model in SPSS and requesting residuals to identify and address possible outliers in the sample. This was done by requesting standardized residuals (*zres*), studentized residuals (*sre*), and studentized deleted residuals (*sdr*). Those scores with *zre* values greater than $|2|$, or *sre/sdr* values greater than $t^*(125) = 1.980$ were set aside for further evaluation. Upon review of these residuals, seven cases were removed from the 126 sample cases based on their position as outliers in at least two of the three categories.

Following removal of outliers, a correlation analysis was conducted to determine what relationships exist among the possible explanatory variables and the dependent variable (see Appendix C). Those variables displaying Pearson correlation coefficient values above $|0.1|$, which were selected for multiple regression model testing, included nature of science (NOS) with a Pearson value of .296; evolution content knowledge (ECK), with a Pearson value of .402; STEM influences (STEM), with a Pearson value of -.133; religiosity (REL), with a Pearson value of -.371; and influence of beliefs (RINF), with a Pearson value of -.443. All respective Pearson product moment values can be seen in Table 3.1.

Table 3.1

Evolution and Pre-service Science Teachers: Correlations and Descriptive Statistics (N = 119)

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|--|---------|--------|--------|-------|-------|--------|--------|-------|-------|
| 1. Measure of Acceptance | – | | | | | | | | |
| 2. Nature of Science | .296** | – | | | | | | | |
| 3. Evolution Knowledge | .402** | .350** | – | | | | | | |
| 4. Major ^a | -.046 | .069 | .099 | – | | | | | |
| 5. Gender ^b | .062 | -.061 | .252** | .194* | – | | | | |
| 6. Science Background | .061 | .139 | .232* | .011 | .125 | – | | | |
| 7. Mother's Education ^c | -.065 | .088 | -.004 | -.183 | .147 | .133 | – | | |
| 8. Father's Education ^d | .034 | -.064 | .038 | -.091 | .085 | .045 | .542** | – | |
| 9. STEM Influences | -.133 | .287** | .028 | -.025 | .029 | .072 | .128 | .041 | – |
| 10. Background ^e | -.009 | -.027 | -.027 | -.065 | -.095 | -.121 | .092 | .003 | .219* |
| 11. Year of Study ^f | .073 | .188* | .138 | .178 | .066 | .493** | .036 | -.035 | .030 |
| 12. Religiosity ^g | -.371** | -.034 | -.222* | .078 | -.063 | .017 | .147 | -.007 | .032 |
| 13. Influence of Religion ^h | -.443** | .059 | -.089 | .191* | .025 | .132 | .035 | -.035 | -.006 |

Table 3.1

Continued

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|--------------|--------|--------|--------|------|------|-------|------|------|-------|
| <i>M</i> | 70.45 | 65.45 | 37.72 | 1.25 | 1.38 | 6.05 | 1.38 | 1.33 | .38 |
| <i>SD</i> | 13.231 | 7.974 | 17.284 | .435 | .489 | 2.785 | .486 | .472 | 1.016 |
| <i>Range</i> | 20-100 | 20-100 | 0-100 | 1-2 | 1-2 | 2-16 | 1-2 | 1-2 | 0-6 |

^aMajor: 1 = *sciences*, 2 = *science education*. ^bGender: 1 = *female*, 2 = *male*. ^cMother's Education: 1 = *secondary to some college*, 2 = *college to professional*. ^dFather's Education: 1 = *secondary to some college*, 2 = *college to professional*. ^eBackground: 1 = *non-urban*, 2 = *urban*. ^fYear of Study: 1 = *freshman*, 2 = *sophomore*, 3 = *junior*, 4 = *senior*, 5 = *graduate*. ^gReligiosity: 1 = *non-religious*, 2 = *religious*. ^hInfluence of Religion: 1 = *low*, 2 = *medium*, 3 = *high*.

* $p < .05$. ** $p < .01$.

Table 3.1

Continued

| Variables | 10 | 11 | 12 | 13 |
|--|-------|------|--------|------|
| 10. Background ^e | – | | | |
| 11. Year of Study ^f | .155 | – | | |
| 12. Religiosity ^g | .038 | .005 | – | |
| 13. Influence of Religion ^h | -.006 | .085 | .526** | – |
| <i>M</i> | 1.18 | 3.17 | 1.77 | 2.41 |
| <i>SD</i> | .385 | .926 | .425 | .746 |
| Range | 1-2 | 1-5 | 1-2 | 1-3 |

^aMajor: 1 = *sciences*, 2 = *science education*. ^bGender: 1 = *female*, 2 = *male*. ^cMother's Education: 1 = *secondary to some college*, 2 = *college to professional*. ^dFather's Education: 1 = *secondary to some college*, 2 = *college to professional*. ^eBackground: 1 = *non-urban*, 2 = *urban*. ^fYear of Study: 1 = *freshman*, 2 = *sophomore*, 3 = *junior*, 4 = *senior*, 5 = *graduate*. ^gReligiosity: 1 = *non-religious*, 2 = *religious*. ^hInfluence of Religion: 1 = *low*, 2 = *medium*, 3 = *high*.

* $p < .05$. ** $p < .01$.

All possible partial models were then systematically tested to determine the model with the least number of variables that explained the most variance in acceptance of evolution. In each case where more than two variables were involved, religiosity demonstrated no statistical significance as an explanatory variable for acceptance of evolution; therefore, religiosity was removed from the analysis. After testing, it was determined that the most explanatory line included nature of science, evolution content knowledge, STEM influences, and influence of religious beliefs with an $R^2=.413$, and adjusted $R^2=.391$. Evaluation of plotted residuals indicated possible outliers and required further evaluation.

The best-fit model and residuals were again calculated to identify outliers or variables of influence. Upon review of residuals, four cases were found to have values for $zre>|2|$ and/or $sre/sdr>t^*(120) = 1.984$, and were removed from the data set. Descriptive statistics, correlation analysis, and multiple regression analysis were then conducted using the remaining 116 cases, with the inclusion of residuals, part and partial correlations, and a plot of the predicted and standardized residuals to test assumptions. Table 2 shows the regression summary for the best-fit model, which explained 45.4% of variance in acceptance of evolution following adjustment.

Table 3.2

Evolution and Pre-service Science Teachers: Predictor Model Summary (n=116)

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|-------------------|----------|-------------------|----------------------------|
| 1 | .689 ^a | .475 | .454 | 9.265 |

a. Predictors: (Constant), Influence of Beliefs, Nature of Science, STEM Influences, Evolution Content Knowledge

b. Dependent Variable: Measure of Acceptance

For the final model (n=116) the correlation analysis demonstrated Pearson coefficients of .354 for nature of science, .481 for evolution content knowledge, -.127 for STEM influences, and -.432 for influence of beliefs. Table 3.3 demonstrates the predictive equation values for the best-fit model.

Table 3.3

Evolution and Pre-service Science Teachers: Best Fit Model

Coefficients^a

| Model | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | |
|-------|-----------------------------|------------|---------------------------|-------|--------|------|
| | B | Std. Error | Beta | | | |
| 1 | (Constant) | 41.399 | 8.261 | | 5.011 | .000 |
| | Nature of Science | .569 | .126 | .364 | 4.507 | .000 |
| | Evolution Content Knowledge | .216 | .058 | .293 | 3.744 | .000 |
| | STEM Influences | -2.227 | .908 | -.186 | -2.454 | .016 |
| | Influence of Beliefs | -6.454 | 1.242 | -.382 | -5.197 | .000 |

a. Dependent Variable: Measure of Acceptance

Further analysis provided part and partial correlations for each of the independent variables as well as upper and lower bounds for a confidence interval set at 95%. The data are shown in Table 3.4.

Table 3.4

Evolution and Pre-service Science Teachers: Confidence, Part, and Partial Correlations

Coefficients^a

| Model | | 95.0% Confidence Interval for B | | Correlations | | |
|-------|-----------------------------|---------------------------------|-------------|--------------|---------|-------|
| | | Lower Bound | Upper Bound | Zero-order | Partial | Part |
| 1 | (Constant) | 25.010 | 57.787 | | | |
| | Nature of Science | .319 | .820 | .406 | .409 | .325 |
| | Evolution Content Knowledge | .102 | .331 | .469 | .349 | .270 |
| | STEM Influences | -4.028 | -.427 | -.136 | -.237 | -.177 |
| | Influence of Beliefs | -8.918 | -3.991 | -.432 | -.459 | -.375 |

a. Dependent Variable: Measure of Acceptance

An analysis of co-linearity showed that there were no VIF values greater than 10 and no tolerance values less than .10, therefore there were no co-linearity issues present in the model.

The regression analysis in its entirety can be found in Appendix D.

Research Findings

Based on the regression analysis, it was determined that there were significant relationships between acceptance of evolution and the explanatory variables of the nature of science, evolution content knowledge, STEM influences, and influence of religious beliefs. There was sufficient evidence to indicate that these variables explain a statistically significant amount of variance in acceptance of evolution, based on $F=22.844$ and $p=.001$, with a two-tailed $\alpha=.05$. It was also determined that the model described explains 45.4% of the variance in acceptance of evolution based on an adjusted $R^2=.454$. Part correlations were squared to determine the unique variance explained by each variable. It was found that 10.5% of variance is uniquely explained by nature of science, 7.3% by evolution content knowledge, 3.1% by STEM influences, and 14.0% by influence of beliefs. This indicates that the greatest influence on

acceptance of evolution is explained by influence of beliefs and nature of science. The four variables in this model explain 34.9% unique variance in acceptance of evolution with 10.5% shared variance explained.

Correlation analysis demonstrated that, as the nature of science understanding or evolution content knowledge increase, acceptance of evolution also increased. It further indicated that as STEM influences or the student's perceived influence of their beliefs increase, the level of acceptance decreases. This is supported by the prediction equation for the model: y (predicted) = 41.399 + .569(NOS) + .216(ECK) - 2.227(STEM) - 6.454(RINF). Therefore, acceptance increases .569 points for each point increase in nature of science, or .216 points for each point increase in evolution content knowledge, controlling for the other variables. Furthermore, acceptance decreases 2.227 points for each additional STEM influence, or decreases 6.454 points for each level of increase in religious beliefs, when controlling for the other variables.

Critical Assumptions

The following assumptions were made regarding the regression analysis: (1) that x was a fixed variable, (2) the relationship between x and y was linear, (3) that x was measured without errors, (4) that at each value of x the mean of distribution of errors is zero, (5) at each value of x , variance is constant, (6) at each value of x distribution of errors is normal, and (7) that errors are independent of one another (Pedhazur, 1997).

For this study, all values for explanatory (x) variables existed within a set range of scores. All explanatory variables were plotting against acceptance of rejection and all were linear in relation. Although it is impossible to prove with certainty that the explanatory variables were measured without error, measures were taken regarding instrumentation to ensure that reliability

and validity were reasonable. The standardized predicted residual for the regression line was plotted against the standardized residual to determine whether assumptions for distribution of errors, constant variance, normal distribution, and homoscedasticity.

Conclusion

It is evident, based on the findings, that there are elements beyond classroom control, such as influence of religious beliefs and exposure to others in STEM fields, that have at least moderate influence in the acceptance and rejection of evolution. Whereas some elements, such as the nature of science and evolutionary content knowledge can be taught, improved upon, and continually evaluated for growth within science classrooms and teacher training programs; others, such as a student's personal beliefs and worldview, cannot.

Ingram and Nelson (2006) argue a point that understanding of evolution is more important than accepting it, but in the context of pre-service teachers, there is a consideration that calls this into question. In the general public, knowledge and understanding lead to a more literate society. However, in pre-service teachers, it is their internal belief system that leads them in what and how they choose to teach in their classrooms (Deniz, Cetin, & Yilmaz, 2011).

This study supports the suggestion of Wiles (2008) that religious beliefs, as reported by the participants, are influential in whether they accept or reject evolution. Although his findings were not statistically tested, the findings in his sample show a moderately significant relationship between acceptance and the influence of religious beliefs on decision-making. Furthermore, the results here contradict the statement by Nehm, Kim, and Sheppard (2009) that religious beliefs are not the most influential factors, as, in fact, within this sample, religious beliefs were the most statistically significant predictor of acceptance of evolution. This further supports findings by Deniz, Cetin, & Yilmaz, 2011) in non-Christian populations abroad, and various denominations

of Christianity (Johnson, 1986) suggesting that religious beliefs, in traditionally fundamentalist cultures, are significant predictors of acceptance of evolution regardless of location or practice.

The finding of a moderate mean acceptance in this sample is in line with prior studies on acceptance in teachers in the United States (Akyol, Tekkaya, & Sungur, 2010; Rutledge & Warden, 2000) suggesting that some future teachers accept only small parts of the theory of evolution and not the theory as a whole. The impact of this in the classroom might be a lack of comfort in teaching the topic, a feeling of conflict in teaching what they do not accept, a choice to teach only parts of the theory or additional non-scientific ideas to ease their discomfort, or avoidance of teaching the theory altogether.

The findings of this study align with those demonstrating relationships between acceptance and knowledge and/or understanding of evolution content knowledge (Deniz, Donnelly, & Yilmaz, 2008) and nature of science (Akyol, Tekkaya, & Sungur, 2010; Rutledge & Warden, 2000). Although the actual strength of the relationships were different in the respective samples, all demonstrated higher correlations between nature of science understanding and acceptance as an influential factor than those for content knowledge and acceptance (Akyol, Tekkaya, & Sungur, 2010; Rutledge & Warden, 2000) in both pre-service and in-service science teachers. This was different in the students studied by Ingram and Nelson (2006) who showed the ability to demonstrate higher knowledge of evolution with lower acceptance levels, suggesting that, although knowledge is a predictor of acceptance in pre-service teachers, it might be possible, for the purpose of examinations, for students to have minimal acceptance with temporary retention. Further testing is required to understand this phenomenon. This also differs from the findings of Fahrenwald (1999) who failed to show a significant relationship between nature of science and acceptance in teachers.

In addition to the confirmations of existing studies, there were contraindications found in the data. Unlike other studies (Nehm, Kim, & Sheppard, 2009), this study found no relationship of significance between a person's major--science education or science--and acceptance of evolution. It is noted that, in this study setting, biology majors and all science education majors are required to take the same courses with the exception of the elective courses of choice. Contrary to existing research, the study demonstrated no relationship between acceptance of evolution and education level (Deniz, Donnelly, & Yilmaz, 2008) or between acceptance and the number of science courses completed (Rutledge & Mitchell, 2002). This is perhaps due to a lack of specific courses on evolution and/or the nature of science at the study location. This lends further support to Johnson's (1986) conclusion that only certain courses are of influence regarding the acceptance and rejection of evolution rather than the total of courses completed. The finding that parents' education levels are not related to acceptance was contradictory to findings by Deniz, Donnelly, and Yilmaz (2008) in pre-service science teachers in Turkey.

In this study, Thagard and Findlay (2010) were further supported in their assertion that there are internal obstacles that influence acceptance of evolution. The role of religion in the Southeastern United States is that of a Christian fundamentalist foundation to many individuals. The conflict between religious beliefs, an internal factor, and scientific knowledge causes the individual to make difficult personal decisions regarding controversial topics such as evolution. Those who place high value on their religious beliefs in decision-making appear less able to cope with the conflict between their religious beliefs and evolution, and are therefore more likely to reject evolution as false in part or entirety. Although their content knowledge of evolution is a statistically significant influence on acceptance, it does not have the strength of influence that one would expect would follow a strong background in a topic (Sinatra et al., 2003).

As science teacher educators, knowing these relationships exist, we must determine how to best prepare pre-service science teachers to teach the next generations of students. This means accepting that what we do in the classroom is but one element that comes into play when a topic causes conflict with existing ideas and beliefs in our students. We must, therefore, decide whether our goal in teaching is strong content knowledge and understanding of evolution or acceptance of evolution, and therefore structure our teacher education programs to provide a strong foundation in either case.

Suggestions for Future Research

Based on the outcome of this study, there are several possible directions for further research and understanding. It is suggested that additional studies be conducted in similar settings, both within and outside of the region, to determine whether the outcomes of this study could be applied to a greater population than that provided by this purposive sample. Based on the results, it is also apparent that more study needs to be done regarding the teaching of the nature of science and how this element plays such a significant role in the understanding and acceptance of controversial scientific theories such as evolution. It is further suggested that research be done in similar sample groups once they have completed their programs and entered the teaching field to determine what impact, if any, it had on their students regarding the teaching and learning of evolution.

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Appendix A
Survey Instrument

Name _____
Email _____

What is your gender? ___ Male ___ Female

What is your age? ___ 19-21 ___ 22-24 ___ 25-27 ___ 28-30 ___ over 30

What is your student level (junior, senior, graduate, etc) ? _____

What is your content major? ___ Biology ___ General Science ___ Physics
___ Chemistry ___ Secondary Education (circle concentration) GS BIO

Please check the box beside each science course you have passed:

___ BIO 101/103 ___ BIO 102/104 ___ BIO 323(Genetics) ___ BIO 332 (Ecology)
___ BIO 373 (Cell) ___ CHEM 105/107 ___ CHEM 106/108 ___ PHS 201/203
___ PHS 202/204 ___ GY 210/220 ___ Other Biology courses above 300 level:

___ Other Science Courses (non-biology) _____

Which science courses did you take in high school? ___ Biology ___ Chemistry ___ Physics
___ Anatomy/Physiology ___ Earth/Environmental Science ___ General
___ Other (Please list) _____

What is the highest level of education your parents have completed?

Mother _____
Father _____

Do you have any friends or family in STEM fields or careers, if yes, which and how many?
(Math, Science, Engineering, Technology)

What is your race?

___ American Indian or Alaskan Native
___ Asian or Pacific Islander
___ Black/African American
___ Hispanic/Latino
___ White/Caucasian
___ Other (Please Specify) _____

How would you describe where you grew up? ___ Rural (less than 5,000 people)
___ Metropolitan (5,000-20,000 people) ___ Urban (>20,000) *if you are not sure you can
name your town and state here: _____

Which of the following media outlets do you use as a source of information (please rank your top three by marking them with a 1, 2, or 3): ___ major newspapers (USA Today, NYTimes) ___ Internet (Yahoo, MSN) ___ Social Media (Facebook, etc) ___ local newspapers ___ television news ___ scholarly journals ___ tabloids (US Weekly, etc) ___ Religious publications (Christian Science Monitor, etc) ___ Friends/family ___ Other (please explain) _____

Do you consider yourself one of the following: ___ religious ___ spiritual ___ agnostic ___ other (specify) _____

Do you affiliate yourself with a particular set of beliefs? ___ If yes, which _____

Please rate the importance of these beliefs in your decision making: ___ low ___ mid ___ high

For each of the following statements, mark your answer document with one of the following:

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

11. Organisms existing today are the result of evolutionary processes that have occurred over millions of years.
12. The theory of evolution is incapable of being scientifically tested.
13. Modern humans are the product of evolutionary processes that have occurred over millions of years.
14. The theory of evolution is based on speculation and not valid scientific observation and testing.
15. Most scientists accept evolutionary theory to be a scientifically valid theory.
16. The available data are ambiguous (unclear) as to whether evolution actually occurs.
17. The age of the earth is less than 20,000 years.
18. There is a significant body of data that supports evolutionary theory.
19. Organisms exist today in essentially the same form in which they always have.
20. Evolution is not a scientifically valid theory.
21. The age of the earth is at least 4 billion years.
22. Current evolutionary theory is the result of sound scientific research and methodology.
23. Evolutionary theory generates testable predictions with respect to the characteristics of life.
24. The theory of evolution cannot be correct since it disagrees with religious accounts of creation.
25. Humans exist today in essentially the same form in which they always have.
26. Evolutionary theory is supported by factual historical and laboratory data.
27. Much of the scientific community doubts if evolution occurs.
28. The theory of evolution brings meaning to the diverse characteristics and behaviors observed in living forms.
29. With few exceptions, organisms on earth came into existence at about the same time.
30. Evolution is a scientifically valid theory.

31. The goal of science is the improvement of man's quality of life.
32. Scientists must limit their investigations to the natural world.
33. The scientist is limited to the investigation of phenomena which are directly observable by the senses.
34. A theory has been corroborated by many scientific facts.
35. Scientists must be accepting of all findings of their fellow researchers.
36. If an experiment yields results which are contradictory to one's hypothesis, one should find other ways to corroborate the hypothesis.
37. The theory of evolution must deny the existence of a creator.
38. A hypothesis is a guess based on a premonition.
39. Scientific experiments must be repeatedly performed to be considered valid.
40. Any scientific finding that contradicts religious doctrine should be discarded.
41. A hypothesis must be capable of being tested in order for it to be in the realm of science.
42. To make any scientific determinations about historic occurrences in nature, there must be direct human observation.
43. As a result of scientific methods, definite conclusions can be made to the absolute and ultimate cause behind an event.
44. Science can never reach absolute truth about a particular phenomenon in nature.
45. Science is well-prepared to investigate the validity of miracles.
46. A hypothesis which has been validated by an experiment is elevated to the level of theory.
47. A fact in science is a truth which can never be changed.

For each of the following questions, select the correct answer:

38. The evolutionary theory proposed by Charles Darwin was:
 - A. Change in populations through time as a result of mutations
 - B. The spontaneous generation of new organisms
 - C. The passing on of genes from one generation to the next
 - D. Change in populations through time as a response to environmental change
 - E. The development of characteristics by organisms in response to need

39. The wing of the bat and the fore-limb of the dog are said to be homologous structures. This indicates that:
 - A. They have the same function
 - B. Bats evolved from a lineage of dogs
 - C. They are structures which are similar due to common ancestry
 - D. The limb bones of each are anatomically identical
 - E. They have a different ancestry but a common function

40. Using radioactive dating techniques, the first life seems to have appeared on the earth about:
 - A. 10 thousand years ago

- B. 270 million years ago
- C. 3.3 billion years ago
- D. 4.5 million years ago
- E. 10 billion years ago

41. Which of the following phrases best describes the process of evolution?

- A. The development of man from monkey-life ancestors
- B. The change of simple to complex organisms
- C. The development of characteristics in response to need
- D. Change of populations through time
- E. The change of populations solely in response to natural selection

42. Marine mammals have many structural characteristics in common with fishes. The explanation that evolutionary theory would give for this similarity is:

- A. Fish and mammals are closely related
- B. Fish evolved structures similar to those already existing in mammals
- C. Marine mammals evolved directly from the fishes
- D. Marine mammals never developed use of limbs
- E. Marine mammals adapted to an environment similar to that of the fishes

43. An alternation in the arrangement of nucleotides in a chromosome, possibly resulting in either a structural or physiological change in the organism, is called:

- A. Genetic drift
- B. Gene flow
- C. A mutation
- D. Natural selection
- E. A recessive gene

44. It is thought that there was a rapid evolutionary rate once animal life invaded land from the oceans. The explanation given for this rapid evolution is:

- A. There were many potential habitats for new forms to fill
- B. The land was a perfect haven for life
- C. There were many climatic changes occurring at that time
- D. Radiation from the sun caused many mutations
- E. The ocean was too stable and limited to allow for evolution to occur

45. The first animals to settle on land probably had which one of the following characteristics?

- A. They were quite mobile to escape from predators
- B. They were partially dependent upon water for survival
- C. They were capable of completely adapting to the terrestrial environment in their life span

- D. They had wings for flight from one habitat to another
- E. They were quite adept at feeding on specific terrestrial plants

46. Two islands are found in the middle of the Pacific Ocean, isolated from any other land mass. These two islands were at one time connected by a land bridge and are of recent origin. They have identical plant and animal life and are separated by 50 miles of ocean. Assuming different selection pressures, which of these island populations would be most likely to be reproductively isolated, possibly allowing for species divergence?

- A. Dandelions, with airborne seeds
- B. Coconuts with floating seeds
- C. Birds
- D. Butterflies
- E. Mice

47. The population of Florida panthers has been drastically reduced by the actions of man. Which of the following most likely threatens their ability to continue to evolve in response to the pressures of their environment:

- A. There is no longer the prospect of over-reproduction
- B. There is no longer the prospect of a struggle for limited resources
- C. There is a lack of genetic variation for selection to act upon
- D. There is no longer the prospect of a trait conferring a reproductive advantage
- E. There is no longer the prospect of genetic drift occurring

48. A sudden major climatic change would most likely initially result in:

- A. A rapid increase in adaptive radiation
- B. A rapid increase in extinction rates
- C. A sharp increase in numbers of species
- D. An increase in mutation rates
- E. Plants and animals developing new characteristics in order to cope with environmental changes

49. The most compelling evidence for large-scale evolutionary change or macroevolution is:

- A. Kettlewell's release-recapture experiment with peppered moths
- B. The fossil record
- C. The occurrence of mass extinctions
- D. Domestication of plants and animals
- E. The observed increase of mutation rates across all species

50. When first proposed, Darwin's theory of natural selection did not fully explain how evolution could occur. This was due to:

- A. Darwin's failure to recognize the tendency of organisms to over-reproduce

- B. Darwin's initial overemphasis of the significance of genetic drift
- C. The fact that accurate mechanisms explaining genetic inheritance were not widely known
- D. The absence of accurate descriptions of the embryological development of most plants and animals
- E. The absence of biochemical techniques to determine the genetic similarities between 5 species

51. The presence of tropical rain forest fossil forms in Canada can best be explained by:

- A. A shifting of environmental requirements by these types of species
- B. A major climatic shift on the earth
- C. A drifting of continents in a northward direction
- D. An uplifting of lowland areas
- E. A long term, constant climate

52. Individuals within a species tend to be genetically different. The primary mechanism generating this individual variability is:

- A. meiosis
- B. mitosis
- C. polyploidy
- D. duplications
- E. asexual reproduction

53. The extinct species Archaeopteryx had characteristics of both birds and reptiles. This is an example of a(n):

- A. convergent species
- B. trace fossil
- C. archetype
- D. intermediate form
- E. polymorphic species

54. The earliest fossils found in the geologic record are:

- A. fungi
- B. bacteria
- C. small photosynthesizing plants
- D. seed plants
- E. protozoa

55. Radiometric dating techniques rely on the fact that:

- A. The bony portions of organisms decompose at a known rate

- B. Organisms which lived earlier in time will tend to be found in sediments below organisms which lived more recently
- C. The magnetic field of the earth has reversed its polarity at known time intervals in geological time
- D. The earth contains elements which change into other elements at a constant known rate
- E. During the decomposition process organic matter is converted into radioactive elements at a known rate

56. Which of the following best represents Lamarck's ideas on the evolutionary process?

- A. Survival of the fittest
- B. Inheritance of acquired characteristics
- C. Neutral drift
- D. Punctuated equilibrium
- E. Assortive mating

57. Which of the following is not a part of Darwin's theory of natural selection?

- A. Individuals of a population vary
- B. Organisms tend to over-reproduce themselves
- C. There are limited resources for which individuals compete
- D. Modifications an organism acquires during its lifetime can be passed to its offspring
- E. Variations possessed by individuals of a population are heritable

58. The life histories of five birds of the same species are listed below. The most evolutionally successful bird is the one that:

- A. Lives 5 years, lays 12 eggs in a lifetime, 4 hatch
- B. Lives 2 years, lays 8 eggs in a lifetime, 5 hatch
- C. Lives 6 years, lays 2 eggs in a lifetime, 2 hatch
- D. Lives 4 years, lays 7 eggs in a lifetime, 6 hatch
- E. Lives 5 years, lays 4 eggs in a lifetime, 3 hatch

Appendix B

Survey Scoring

Scoring Instructions for the MATE (Questions 1-20)

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.

1. Step 1. Scoring of items 1, 3, 5, 8, 11, 12, 13, 16, 18 and 20 is as follows:
 1. Strongly Agree = 5
 2. Agree = 4
 3. Undecided = 3
 4. Disagree = 2
 5. Strongly Disagree = 1

2. Step 2. Scoring of items 2, 4, 6, 7, 9, 10, 14, 15, 17, and 19 is as follows:
 1. Strongly Agree = 1
 2. Agree = 2
 3. Undecided = 3
 4. Disagree = 4
 5. Strongly Disagree = 5

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

Scoring for Nature of Science Survey (Questions 21-37)

The nature of science survey was scored using a likert score value of five points for the most accurate response down to one point for the least accurate response. This resulted in each student generating a score value between twenty and one-hundred points which was then assigned a level of understanding based on the score received (Johnson, 1986).

Johnson's (1986) original levels were retained for scoring, those levels were: "very high

understanding (89-100), high understanding (75-88), moderate understanding (65-74), low understanding (45-64), and very low understanding (20-24) (p. 49).

Scoring for Content Knowledge Examination (Questions 38-58)

- 38. D
- 39. C
- 40. C
- 41. D
- 42. E
- 43. C
- 44. A
- 45. B
- 46. E
- 47. C
- 48. B
- 49. B
- 50. C
- 51. B
- 52. A
- 53. D
- 54. B
- 55. D
- 56. B
- 57. D
- 58. D

Appendix C

Operational Definitions

Acceptance of evolution. Acceptance of evolution is conceptually defined as the ability of a person to internalize information regarding biological evolution and accept the theory and accept such as factual and real. It is measured as a score range on the Measure of Acceptance of Theories of Evolution (MATE) survey (Rutledge & Warden, 2000).

Background. Demographic background is defined as a generalized description of the size of the place, as measured by population, a person spent most of their lifetime prior to college, namely whether it is rural (less than 10000) , metropolitan (10,000-20,000) or urban (30,000 or greater) in size.

Completed courses. This refers to a simple range measure of the number of science courses that have been successfully completed by each individual in their undergraduate (and graduate, where applicable) coursework.

Content major. Students were identified by their major as either biology education; general science education, which included biology, chemistry, and physics; or other science, for those who are science majors but not in the college of education. This distinction was based on the students' reported majors on file at the university.

Evolution content knowledge. Evolution content knowledge is defined as the accurate knowledge of basic concepts, theories, and facts associated with biological evolution as accepted by scientists. Content knowledge is measured as a score on the evolution content knowledge test created by Johnson (1986).

Father's education. This refers to the completed education of the participant's father or male guardian at the time of the study. Options range from middle school to professional level of study.

Nature of science understanding. As Lederman and Zeidler (1987) explain, it "refers to the values and assumptions inherent to the development of scientific knowledge" (p. 721). Understanding of the nature of science (NOS) involves the understanding of the ambiguity of science, scientific practices, goals of science, scientific theories and laws, and how science works. Each person's perception of the nature of science is a reflection of their "beliefs concerning whether scientific knowledge is amoral, tentative, empirically based, a product of human creativity, or parsimonious" (Lederman & Zeidler, 1987, p. 721). It is measured by a slightly modified version of the nature of science Likert survey created by Johnson (1986) and tested by Rutledge and Warden (2000).

Mother's education level. This refers to the level of educational study completed by the mother, or female guardian, of the participant at the time of the study. The range for this variable is from middle school to professional level of study.

Religiosity. For the purpose of this study, religiosity is a general term referring to the perceived religious classification of the participant as religious or not-religious. Students were presented with multiple options for their personal beliefs, including being religious, spiritual, devout, atheist, agnostic, or other. Those students who reported religious preference were categorized as religious, meaning that they have some involvement with religious beliefs. Those who identified in the other categories were grouped as non-religious.

STEM influences. This referred to any person in fields of math, science, technology, or engineering in the peer or family group of the participants. Students were asked how many

family members or friends were involved in these careers and the number value was reported as a score.

Year of study. This referred to the credit-hour classification of the participant as sophomore, junior, senior, or graduate.

Worldview. Worldview refers to the set of beliefs, expectations, experiences, and ideas by which a person uses to evaluate all other events and information. It is further discussed and described below.

Appendix D

Descriptive Statistics

Statistics

| | | Measure of Acceptance | Nature of Science | Evolution Content Knowledge | Science Courses Completed |
|------------------------|---------|--------------------------|----------------------|-----------------------------------|---------------------------------|
| N | Valid | 115 | 115 | 115 | 113 |
| | Missing | 5 | 5 | 5 | 7 |
| Mean | | 70.90 | 65.45 | 37.63 | 6.04 |
| Std. Error of Mean | | 1.165 | .747 | 1.608 | .265 |
| Median | | 71.00 | 65.00 | 38.00 | 6.00 |
| Std. Deviation | | 12.491 | 8.016 | 17.239 | 2.819 |
| Variance | | 156.035 | 64.250 | 297.184 | 7.945 |
| Skewness | | .376 | .302 | .303 | .506 |
| Std. Error of Skewness | | .226 | .226 | .226 | .227 |
| Kurtosis | | -.263 | .668 | .174 | .105 |
| Std. Error of Kurtosis | | .447 | .447 | .447 | .451 |
| Range | | 52 | 46 | 95 | 14 |
| Minimum | | 48 | 45 | 0 | 2 |
| Maximum | | 100 | 91 | 95 | 16 |

Statistics

| | | STEM Influences | Influence of Beliefs |
|------------------------|---------|-----------------|----------------------|
| N | Valid | 113 | 106 |
| | Missing | 7 | 14 |
| Mean | | .38 | 2.42 |
| Std. Error of Mean | | .096 | .072 |
| Median | | .00 | 3.00 |
| Std. Deviation | | 1.020 | .742 |
| Variance | | 1.041 | .550 |
| Skewness | | 3.384 | -.845 |
| Std. Error of Skewness | | .227 | .235 |
| Kurtosis | | 12.579 | -.684 |
| Std. Error of Kurtosis | | .451 | .465 |
| Range | | 6 | 2 |
| Minimum | | 0 | 1 |
| Maximum | | 6 | 3 |

ARTICLE THREE

EVOLUTION AND PRE-SERVICE SCIENCE TEACHERS: A THEORETICAL PROCESS MODEL OF ACCEPTANCE AND REJECTION OF EVOLUTION.

Introduction

William Cobern (1994a) once stated, “All knowledge entails ambiguity” (p. 12). This is especially true in science, where the very nature of theory and discovery is one of ambiguous temporary proof, valid only until one can provide contrary evidence to that which exists or new technology expands the paradigm of interest. When one looks at the controversy that is evolution, this becomes most apparent in the misinterpretation of facts, integration of fiction, and the solid rejection of the theory despite overwhelming evidence. Evolution, in this study, includes origins of life, earth history, and ancestry of both humans and other organisms. The evolution conflict is rooted in the contest between the scientific world and the internal worldview held by an individual (Ogunleye, 2009). Shuumba (1999) reminds us that “worldview is the overall perspective from which one sees and interprets the world” (p. 333). Thus, it is solely in the mind of the individual that these conflicts between science and the internal world are resolved.

In referencing students and how they learn, it is important to note a precarious relationship that exists but is seldom addressed in research: that of the pre-service teacher as a transitory position between that of student and teacher.

Students have their own world views that support the ideas that they bring to science classes. It is, therefore, necessary that science teachers understand these world views if they are to help students to come to an understanding of scientific world views that may be different from their own. (George, 1999; p. 79; Hanson & Lindahl, 2010; Titrek & Cobern, 2010)

It is understanding the worldview of pre-service secondary teachers, those who will impart the knowledge upon their students that is least understood. However, it is important to understand how pre-service teachers make decisions to either accept or reject evolution and how that choice influences both their teaching of evolution and the learning of evolution for future generations.

This study took place in a four-year teaching college situated among several rural townships, a once-bustling urban center, and a growing metropolitan outpost along a major interstate corridor that connects two very populous cities. The school and contributing counties are located within the Southeastern United States, an area defined as including the states of Louisiana, Mississippi, Alabama, Georgia, and Tennessee. The college draws the vast majority of its student population from local communities and adjacent counties of the base state and abutting state. The college shares the city limits with 38 churches of varying Christian denominations, one mosque, and one Jewish Temple, facts of importance to the outcome of this study. Furthermore, because of this location in the Southeastern United States, student understanding and dispositions toward evolution may be pronounced given “epistemology of place” reflected in the following:

Not only does the South find itself inhabited by the living presence of a unique history, a peculiar literary tradition, and an unusual set of social relationships but Southerners might also be said to possess a distinctive way of knowing, an epistemology of place. (Kincheloe & Pinar, 1991, p. 10)

It was, in fact, the unique nature of this setting and the difficulty of any generalizations outside of the geographical area that made it so enticing for study. The concept of “place” and this study of evolution is addressed by Kincheloe and Pinar (1991) as an element of social and cultural influence that guides each individual's learning and development. Furthermore, the unique history of the South, the depth of the Southern identity, and the highly evident “power of place as a category of social and personal experience” makes it all the more important to

understand the place of evolution in this region (Kincheloe & Pinar, 1991, p. 167; Pinar, 2008). Bowman (2008) supports the need for research into this microcosm of evolutionary discord, noting that in her study, students in the South were 84% less likely to receive accurate instruction regarding evolution and ten times more likely not to have any evolution instruction.

The South provides a unique venue to study the perspectives of pre-service teachers regarding the controversial topic of evolution. One of the most powerful aspects of this unique regional identity is that of Southern religion, which the research notes should neither be ignored nor be viewed as a mere obstacle to be overcome, as it is as much a part of the Southern existence as is oxygen for survival (Kincheloe, 2011; Kincheloe & Pinar, 1991; Kincheloe, Pinar & Slattery, 1994; Pinar, 2008; Sauser, 1999; Urban, 1992). It is important to note that religion is but one aspect of focus for this study, but it is taken into account from a perspective responsive to the nature of religiosity and religious fundamentalism, specifically Christian Fundamentalism, as found in the southeastern United States, neither of which can be cognitively divorced from any study on acceptance of evolution (Kincheloe & Pinar, 1991; Whittaker, 2010).

Religion in the South, even today, is not simply a set of beliefs in a higher power, or attendance at functions of a church, it is deeply ingrained in the behaviors and customs of the region. These deeply seeded roots guide everything from manners and hospitality to interpretation of topics in the classroom. Kincheloe, Pinar, and Slattery (1994) stated, “The idea of a socially constituted individual is not only unimaginable to the southern fundamentalist, it is unchristian. God is an individual. The Bible is not viewed as a historical document to be interpreted; it is the divinely inspired and inerrant code of behavior” (p. 418). It is thus up to the individual to police both self and others based on this fixed code, and failure to do so ultimately results in the damnation of the soul, a fear with such power that even now is visible in standards,

classrooms, and continued defiance of federal mandates regarding prayer, religious celebration, and of course, teaching of evolution and creationism in schools (Kincheloe & Pinar, 1991). It is noted, again, that religion is not the focus of this study; however, religious influence on the social, political, and cultural climate of the region cannot be separated from any discussion of evolution that is in direct conflict with these entrenched cultural aspects.

Research Questions

This study focused on identifying factors that influence acceptance or rejection of evolution as a scientific theory in pre-service secondary science teachers and identify, as appropriate, substantive categories of influence. It was anticipated that identification of individual variables and their respective categories would allow for the creation of a theoretical process model for acceptance or rejection of evolution. To do so, this study sought to answer the following questions:

- (1) What factors influence the acceptance or rejection of evolution among pre-service secondary science teachers; and
- (2) What process model of acceptance and rejection of evolution among pre-service science teachers emerges through a lens of worldview in the rural Southeastern United States?

Review of Literature

Theoretical Framework

The goal of science education today is the establishment of a scientifically literate society (Cavagnetto, 2010; Dillon, 2009; Laugksch, 2000; National Research Council, 2011; Zeidler & Sadler, 2011). Cobern (1994a) points out that you cannot have literacy without consideration of the worldview. “No person, including any scientist or science educator, and no segment of

culture, including the community of scientists and educators, uses a single knowledge source” (Cobern, 1994a, p. 15). These internal and external sources join together to form an individual's worldview. According to Cobern (1991), “worldview refers to the culturally-dependent, generally sub-conscious, fundamental organization of the mind. The organization of a person’s worldview manifests itself as a set of presuppositions or assumptions, which predispose one to feel, think, and act in predictable patterns” (p. 3). This is to say, the worldview is the lens through which we view the world, as well as the filter through which we process all other information that comes into our realm of discovery. It allows us to evaluate new information and organize what we experience in a continuum with that which has already been experienced. These existing beliefs and understandings are fairly consistent through a person’s lifetime and, as such, “exert a powerful influence on how sense is made of events in the world” (Cobern, 1993, p. 2).

Where does one's worldview come from? According to Lee (1999), “knowledge and world views are products of socio-cultural influences as well as individual construction, in light of the fact that every child is exposed to multiple information sources and discourses in social and cultural contexts” (p. 188). The formulation of a worldview is one that takes place from birth and is deeply rooted in the surroundings of the individual including existing cultural practices, interactions with family and peers, development of identity and the incorporation of knowledge into this closely held belief system (Beauchamp & Thomas, 2009; Sfard & Prusak, 2005). It is for this reason that concepts, like evolution, that come into direct conflict with a person's worldview are often rejected based on incongruence rather than upon a preponderance of the evidence. To accept a conflicting and even offending theory would be to directly reject ones most closely held beliefs and, in turn, the identity that defines the self.

As Hansson and Lindahl (2010) posited, “school and home have different cultures that interact within the student; when they align we get acceptance, when they diverge we get rejection” (p. 899). This acceptance or rejection is especially important regarding foundational theories such as evolution. The concepts of evolution are not difficult nor are they so abstract as to be so widely misunderstood on face value. The problem with evolution lies in the fact that even if people know and understand the concepts and supporting evidence, they may simply reject the theory based on the dissonance it causes with their accepted worldview. Cobern (1994a) states that *thinking* is what brings comprehension of a topic, and *knowing* is what allows us to accept or reject the topic, but the two are not mutually exclusive. We can reject things and still understand them; likewise, we can accept things we do not truly understand (p. 12-13).

Aikenhead and Jegede (1999) addressed this issue of divergence as related to science, noting, “Cultural clashes between students' life-worlds and the world of western science challenge science educators who embrace science for all, and the clashes define an emerging priority for the 21st century” (p. 269). It is for these reasons that an understanding of the acceptance and rejection of evolution is not sufficient unless it takes into account the myriad factors that are inherent in each student who enters a classroom to learn (Hanson, Redfors, & Rosberg, 2010). Likewise, it is essential that we understand how those who will teach students evolution theory come to their own acceptance or rejection of evolution.

Hansson and Lindahl (2010) remind us that worldview can be an important tool when seeking to understand why students do or do not relate to or participate in scientific study. When faced with these conflicts that take on such a personal position, it is imperative to remember that what seems to be harmless scientific theory in the mind of scientists can in fact, trigger deeply rooted inner conflict within the student. As Cobern (1991) noted, “students bring with them ideas

and values about the natural world that they have formulated on based on their own socio-cultural environment or from previous educational experiences” (p. 1). Confrontation with de facto information that clashes with these ideas and values results in rejection and revolt. A key to understanding is the identification of the factors in a person's worldview which enable or encumber the acceptance of evolution and which have the great power over individual decisions (Cobern & Loving, 2000; Cobern & Loving, 2002).

It is noted that, although there are many variables that make up an individual's worldview, not all components are empowered or activated in the same way and many are only enabled regarding specific topics and events. Anderson (2007) reminds us to consider that each person has their own understanding of reality as well, meaning that each person's influences will interact with one another and be empowered in ways different from the next person. It is important to add that worldview is not concerned with matters of fact or fiction, but rather matters of convergence and divergence with the norms held by the individual. According to Cobern (1994a), a “worldview provides a non-rational foundation for thought, emotion, and behavior. Worldview provides a person with presuppositions about what the world is really like and what constitutes valid and important knowledge about the world” (p. 5). This does not imply that what a person accepts or believes is in any way grounded in evidence; rather it is equally possible that the beliefs, values, and accepted facts taken by an individual are grounded in misconceptions, farce, and information that is partially or completely incorrect. The importance is the perception of the individual making the choice as to what they will and will not accept (Aikenhead, 2006).

Worldview, as the lens by which information is processed and conflicts resolved, is key to understanding the acceptance of evolution (Anderson, 2007; Hansson & Lindahl, 2010;

Hokayem & BouJaoude, 2008). As Cobern stated, “nowhere in science is the overlap between scientific ideas and other ideas in society more clear than with the theory of evolution. Evolution has acceptance problems because it is hard for students to accommodate the concepts of this theory within their cognitive culture” (1994b, p. 584). The reason suggested for the difficulty lies in the overlap of some ideas that the theory “advocates with other social, epistemological, and religious beliefs” (Hokayem & BouJaoude, 2008, p. 395). These deeply held core beliefs make conflict resolution among existing and new information very difficult. Shuumba (1999) explains that the acceptance of a conflicting idea involves the restructuring of the very foundations of a person's beliefs and identity. It is therefore understandable that so many people elect to reject evolution rather than completely replace their existing worldview (Aikenhead, 2006; Hanson et al., 2010; Shuumba, 1999).

Worldview varies based on the individual but it is expected that there would be certain patterns or themes found across the worldviews of individuals in shared circumstances such as location, background, education, and religion. The identification of these themes is an important part of understanding but as George (1999) noted “it is not sufficient to know the content of a world view only; the structure is also of extreme importance” (p. 78). For that reason, in this study, interviews were used to identify components of worldview but the main focus will be the placement of an individual within these realms of influence for the purpose of creating a process model for acceptance of evolution. By examining the acceptance or the rejection of evolution in pre-service secondary science teachers by sorting them based on their acceptance level and conducting extensive interviews, a picture may emerge demonstrating the process by which acceptance or rejection is made derived from the body of influence that is worldview.

Factors Influencing Evolutionary Decision-Making

The existing literature exploring views on evolution by teachers or pre-service teachers is wide in scope but lacks strong unification. Examining studies as parts of a whole reveals a number of influential factors involved in choices regarding acceptance of evolution among in-service science teachers and students, both secondary and post-secondary. These internal and external influences interact, diverge, and intersect within each individual where the factors are then evaluated and repackaged to make up that individual's world view. Prior research centers on confirmation of these influences with little focus on seeking patterns that may exist among these factors in terms of acceptance or rejection of evolution (Bowman, 2008; Ha, Haury, & Nehm, 2011; Hoy, Davis, & Pape, 2006; Moore, 2002; Nehm & Schonfeld, 2007). What follows is a discussion of several key studies regarding the existence and elucidation of these factors.

Much of the literature on evolution examines students (Donnelly, Kazempour, & Amirshokoochi, 2009; Fowler, 2009, Ingram & Nelson, 2006; Nehm, Kim, & Sheppard, 2009) and in-service teachers (Jorstad, 2002; Rutledge & Mitchell, 2002; Rutledge & Warden, 2000). These studies can also be used to identify possible factors that may apply to pre-service teachers based on their position between the two groups (Deniz, Cetin, & Yilmaz, 2011, Deniz, Donnelly, & Yilmaz, 2008). One thing that is known about people and evolution is that an individual's choice to accept evolution as well as how they teach or will teach evolution is complicated (Smith, 2010b). Griffith and Brem (2004) explain that "there is evidence that teachers experience internal and external conflict over teaching evolution" (p. 792) and Smith (2010b) adds that "each individual-both teacher and learner-entering the classroom bring with him or her a personal naive psychology, a cognitive ecology of factors that impact learning" (p. 544). These

factors are likely to vary based on the individuals involved, but there should be some sharing of culture among persons from similar backgrounds.

It has been documented that evolution is either not covered at all in many classrooms or it is not taught well, whether due to lack of background by the teacher, misconceptions, or negative perceptions (Alters & Alters, 2001; Catley, 2006). This could be a result of pressures such as those found by Scharmann and Harris (1992) who reported that science teachers often find evolution to be “frustrating and challenging” as well as a source of criticism (p. 375). Criticism as a factor is explained by Van Koevering (1999), who looked at the impact of external influences on how or if a teacher taught evolution, finding that many teachers reported being approached by family or community members regarding what they taught (Van Koevering, 1999). This criticism, or fear of impending criticism based on family background, community, and existing beliefs is likely to influence whether a person accepts evolution as well (Brem, Ranney, & Schindel, 2003; Fowler & Meisels, 2010; Griffith & Brem, 2004; Sanders & Ngxola, 2008).

Sinatra, Southerland, McConaughy, and Demastes (2003) noted that, traditionally, “learners are not overly rational” (p. 511) meaning that acceptance of evolution is not based on knowledge alone but on a choice made by the individual in light of reconciliation of the knowledge with their own beliefs and expectations. It can be added that some teachers feel pressure due to what Shankar and Skoog (1993) refer to as “persistent and publicly sanctioned hostility” regarding the teaching of evolution. From this angle, evolution is not just a topic, it is a cultural taboo, a phenomenon defined by McGinnis and Simmons (1999) as “beliefs that constrain action by making those behaviors perceived as threatening by the members of the social group forbidden and improper for discussion” (p. 183).

It has also been noted that evolution is even more problematic when “teachers perceive the topic of evolution to be in direct conflict with either their own or their students’ personal beliefs” (Goldston & Kyzer, 2009). Meadows, Doster, and Jackson (2000) also address this stating that when beliefs are in opposition to the curriculum, internal conflict occurs. This internal conflict, in combination with other factors is likely to also influence whether the teacher and/or students accept evolution (Chinn & Samarapungavan, 2001; Davson-Galle, 2004; Jones & Carter, 2007). Due to these issues, McGinnis and Simmons (1999) say that we must “focus on the explanatory power of socio-cultural perspectives,” not just curriculum to understand the influences upon teacher choices regarding evolution (p. 180).

Previous studies have examined specific factors that influence the teaching of evolution (Aguillard, 1998; Bowman, 2008; Ha, Haury, & Nehm, 2011; Hoy, Davis, & Pape, 2006; Jorstad, 2002; Nehm & Schonfeld, 2007) that include misconceptions regarding evolution (Nadelson, 2007), or those that influence acceptance or rejection of evolution (Wiles, 2008). In his study of Louisiana classroom teachers, Aguillard (1998) identified educational background as a factor, noting that “subjects were often critical of their college biology training” and that they had less than three classes in biology where they specifically address evolution (p. 172). Science background is further supported as a factor in Wile’s (2008) study, where many of the subjects specifically stated that religion was the most important factor in their choice to accept or reject evolution (p. 78). They further explained that conflict with their religion was a primary reason for their rejection of evolution and their ability to go from rejection to acceptance relied upon their ability to reconcile their religion with evolutionary concepts (Meadows, Doster, & Jackson, 2000; Shipman, Brickhouse, Dagher, & Letts, 2002; Trani, 2004; Wiles, 2008; Woods & Scharmann, 2001). The most influential factors outside of religion are rooted in the evidence for

evolution which is related to content knowledge and understanding of evolution by the individual (Jorstad, 2002; Nadelson, 2007; Wiles, 2008; Woods & Scharmann, 2001). This suggests that strong content background, understanding of the nature of science, science background in general, and open-mindedness in regards to religion and scientific issues may be factors identified by participants as influential to their acceptance or rejection of evolution.

Another realm of possible influence is found in exploring external socio-cultural relationships with those they interact with regularly, such as parents, friends, church and community members (Demastes, Good, & Peebles, 1995; Woods & Scharmann, 2001). Aguillard (1998) looked at a number of other external influences that affected in-service teachers' choices when teaching evolution. These included support within the system and the school itself, district and school guidelines for teaching of evolution, knowledge of legal cases regarding the teaching of evolution, membership in professional organizations, and the textbooks used to teach biology (Aguillard, 1998). The findings of that study point to powerful influences such as parent attitudes and perceptions of support or discord from others related to their stance on evolution (Aguillard, 1998). This is further supported by Brem, Ranney, and Schindel (2003) who found that similar negative influences on evolutionary thought occurred in subjects when there were negative perceptions of evolution by others leading to an outcast-like status. These studies may lend themselves to the anticipation of similar identified factors among the group of pre-service science teachers in this study.

In the literature, there is a plethora of parallel and sometimes contradictory data as to what is influential to an individual's decision regarding acceptance, rejection, teaching, and learning evolution, but the results vary based on whether the participant is a teacher (Fahrenwald, 1999; Jorstad 2002; Kim & Nehm, 2012; Rutledge & Warden, 2000; Shuumba, 1999; Wiles,

2008), pre-service teacher (Abd-el-Khalik & Akerson, 2004; Akyol, Tekkaya, & Sungur, 2010; Athanasiou & Papadopoulou, 2011), or student (Alters, 1996; Butler, 2009; Donnelly, 2007; Fowler, 2009; Johnson, 1986; Moore, Brooks, & Cotner, 2011; Rice, 2007; Wiles & Alters, 2011). Smith (2010a) asks, in light of this difference, what makes one group more likely to accept or have a relationship between acceptance and understanding than the others (p. 539)? What is missing from the research is a model that helps to explain the process of acceptance or rejection, in particular, one that explains how pre-service teachers use their knowledge, understandings, and beliefs, in combination with other self-identified factors of influence in their personal decision to accept or reject evolution. It is clear that the differences in acceptance or rejection fall within the interpretation of the individual and the interactions that take place between a person's world view and the specific factors they choose to let influence that world view. It is this process of choice regarding acceptance and rejection that will be explored with this study.

Methodology

A grounded-theory qualitative methodology was selected for this study based on compatibility with the research questions. This approach enabled description of influences and portrayal of the intricate nature of the process of acceptance and rejection of evolution. The study was further framed using the theoretical underpinning of worldview. Originally designed to fill the gap between qualitative interpretations and empirical research (Glaser & Strauss, 1967), grounded theory provides a method in social science and humanities research that enables “discovery of theory from data systematically obtained from social research” (p.3) and it “is regarded by Glaser and Strauss as a general theory of scientific method concerned with the generation, elaboration, and validation of social science theory” (Haig, 2006, p. 1).

In his study, Haig (2006) compared grounded theory to the scientific method by systematically reviewing the process from problem formulation to the “emergence of theory from the data” (p. 1). In terms of grounded theory, the phenomena itself—in this case acceptance or rejection of evolution—serves as the foundation for problem-based investigation of the data, therefore it is “typically phenomena, not data, that our theories are constructed to explain and predict” (Haig, 2006, p. 4). It is important to note that phenomena, in terms of social research, are defined as “relatively stable, recurrent general features of the world that we seek to explain” (Haig, 2006, p. 4). This allows for the collection of data relative to a given phenomenon, in this case the acceptance or rejection of evolution, and lays a framework for the systematic analysis and coding of data to pick up inherent themes or patterns, and contributing factors relative to the phenomenon itself in order to reveal the development of a theoretical model regarding the phenomenon.

Interviews were selected for use in this study based on the need to understand the lived experiences surrounding influential variables identified in prior studies with this population. Interview protocols involved exploring the following: evolution content knowledge, understanding of the nature of science, STEM influences (Science Technology Engineering and Math), and religious influence. It was through interview data that I gained insights for category building necessary in theoretical model building. Grounded theory calls for the use of open-ended interview questions in an effort to allow the participants' experiences, viewpoints, and positions to emerge rather than be forced. The addition of field notes and investigator memos added further to the depth of data interpretation.

Interviews and surveys have been widely used for studies of acceptance of evolution (Aguillard, 1998; Alters, 1996; Butler, 2009; Donnelly, 2007; Fahrenwald, 1999; Fowler, 2009;

Johnson, 1986; Jorstad, 2002; Rice, 2007; Rutledge & Warden, 2000; Shankar, 1989; Troost, 1966; Wiles, 2008). This is due, in part, to the ability to measure a wide range of emotions and body language, in addition to describing concepts and interactions through the words of those who are experiencing the process. Interviews allow the investigator to give direction to the conversation (e.g., religiosity, background, socio-cultural influences) but have the benefit of allowing the participant to respond in their own words, clarification questions on the part of each party, and the introduction of variables that might not have been expected by the investigator. Thus, this study used a combination of semi-structured and open-ended questions in an effort to explore lived experiences of the participants relevant to evolution.

Positionality

I brought a multi-dimensional perspective into this study in my vantage point across the spectrum of experiences. I was born and reared in the South, attending both urban and rural public schools. I was a secondary science educator and a post-secondary biology instructor, a researcher in education, and instructor of secondary education pre-service teachers. As a member of many of the groups that are being examined, I became aware of my own biases, maintaining a research journal throughout the process in order to identify, and track, the progression of my personal position throughout the study from inception to final conclusion.

It is this position as an insider-researcher that initiated my interest in the study of evolution in this unique setting. It is this status that enables an authentic sensitivity, both during the interview process and throughout the analysis of data, while recognizing possible nuances of conflict that the participants encounter while establishing shared rapport with participants on the basis of insider understanding.

My goal was to be aware of my own personal positions, biases, and assumptions and to explore how those attributes interact with, and influence, interpretation of the outcomes. Since the purpose of grounded theory methodology is to allow the data to lead us to conclusions, rather than to push our conclusions on the data, it is imperative that the researcher track his or her thought and belief processes throughout research (Charmaz, 2006). The so-named “audit trail” (Birks & Mills, 2011, p. 53) provides a method by which the thoughts, assumptions, interactions, and behaviors of the researcher can be charted as a research history, providing insight into the internal and external processes of the research study.

Study Site and Participants

This study took place at a mid-sized teaching college in the heart of the Southeastern region of the United States. The students served by this institution tend to come from relatively local communities and nearby small cities. Although the university houses an international program and draws some students from outside of the state, a majority of those in attendance come from a seven county area surrounding the university itself. The community where the school is located has a population of less than 20,000 including the students matriculating. There are two major cities within 100 miles of the study site and a number of smaller urban centers that offer entertainment, shopping, and other social opportunities for students.

Participants in this study, upper-level undergraduate students, had completed their core courses and had begun study in the college of education. Their age range was wide, falling between 20 and 50 years of age. Participants were pre-practicum, meaning that they had no independent classroom experience at the time the study was conducted.

Participant Selection

Purposive sampling was used to identify and select participants from a specific population. General study information and researcher contact information was sent to the participants through the science advisory email list generated by the secondary education departments. The email included the informed consent document and an electronic link to the online consent request and survey document.

Students who completed the online survey had the opportunity to be chosen for interview if they met the following criteria: (1) they must be undergraduates, formally admitted to the college of education, (2) their content major is either general science or biology, (3) they have completed their first block of education courses but were pre-internship at the time of the interview, and (4) they have completed the following science courses-BIO 101/103 (Introduction to Biology I), 102/104 (Introduction to Biology II), 322 (Genetics) or 332 (Ecology), and 373 (Cell Biology).

To ensure a representative interview sample across the continuum of evolutionary acceptance, the Measure of Acceptance of Theories of Evolution (MATE) survey was employed to determine the levels of acceptance of the consenting pre-service teacher population. The MATE survey was chosen, in part, due to its wide acceptance among scientists and science education researchers (see Appendices A and B). The validity of the MATE was established by a panel of experts in the fields of science and education and reliability was statistically high when administered to similar student populations (Rutledge & Warden, 2000).

The initial pool of pre-service science teachers enrolled at the university consisted of 94 individuals. After review, it was determined that only 79 of these individuals were eligible for participation. The other 14 individuals were removed from the list because they were not

members of the desired study population in that they were either classified as in-service teachers or were pre-majors not yet admitted as pre-service teachers. Of the 79 students who received the request to complete the survey, 44 students responded.

Five acceptance groups were created based on participant MATE scores: very high (89-100), high (77-88), moderate (65-76), low (53-64), or very low (52 or lower). The MATE scores were collected and participants were grouped by level of acceptance with five scoring *very high*, ten *high*, nine *moderate*, seven *low*, and six *very low*. Another individual withdrew consent, and six others were eliminated due to incomplete responses on the MATE that rendered the score invalid. After adjustment, removing the six invalid scores and all withdrawn consent values, 37 participants were available for interview. Lists were created for each of the five levels of acceptance represented by the MATE scores. In the theoretical model, the primary focus is on the process of the average pre-service science teacher, therefore the focus is on the experiences at the moderate range, however, there are specific elements that emerged relative to the higher and lower acceptance participants that are addressed in the model as well. Names in each list were numbered and randomly drawn to determine which participants from each group would be interviewed. In the case that a selected participant was not willing to complete the interview, additional numbers were drawn. Two individuals were randomly selected from each group for the initial set of interviews.

Data Collection

The data collection consisted of primary interviews and follow-up interviews where needed for clarification of responses. The primary interview protocol consisted of questions that explored religiosity, family background, socio-cultural constructs, and individual's perceptions, as well as content knowledge and understanding of the nature of science (see Appendix C). The

semi-structured interviews were audio taped for transcription and took place in the weeks following consent and the completion of the survey, allowing time for the survey responses to be sorted and participants to be selected.

The interview selection process brought up a number of concerns relative to the topic of evolution. First, many students were unwilling to share their views about, or even discuss, evolution when asked to participate in the interview portion. Of the 37 students who responded completely to the MATE survey, only 24 provided their contact information when asked whether they would be willing to be interviewed regarding their ideas about evolution. Of those twenty-four, ten were initially contacted for interview but only six responded. After three rounds of contacts with substitute interview candidates, ten candidates were interviewed.

After the interview process and initial review of data, it was determined that additional participants at the moderate level would best inform the creation of a process model for the average pre-service science teacher. This was done to increase the richness of the data representative of the average experiences of pre-service science teachers. Upon review of the original interview data, it was determined that the experiences separating the very high from the very low acceptance groups were unique enough in nature that the most representative model would be based on the moderate, or average acceptance level, participant experiences. To do so, three additional interviews were conducted with participants at the moderate level, again randomly selected by number from the participant pool. The initial interviews were approximately one hour long, with fifteen to twenty minute follow up sessions as needed. For most participants, there was a single follow up interview, however, some cases led to multiple follow up sessions with the greatest being four. Interviews were conducted at neutral off-campus locations selected by the participants.

Data Analysis

Interviews were transcribed and coded using grounded theory practices and methodology. An essential part of this methodology was the various levels of coding, memo construction, and "theoretical integration" (Birks & Mills, 2011, p. 9; Bryant & Charmaz, 2007). In a grounded theory methodological approach there are multiple levels of coding that inform the process. For instance, initial coding focuses on the sorting of words and phrases within the data. An example in this study is "*my parents' guidance*" labeled *parents*, "*My girlfriend and her family influenced me to become saved*" labeled *peers*, and other codes such as *mentors*, and *coaches* being combined with other like codes to create categories such as *influential people* in this work. Another example would be the codes *urban*, *rural*, and *community* that contributed to the category, *background*. Some initial codes are labels in and of themselves, for example the code *creationism* refers to both the mention of the term itself as well as the collection of other concepts, such as *seven days*, *creation*, and *genesis* that are directly contribute to it as a category. This served as an *in vivo* category (Birks & Mills, 2011, p. 10). The coding process was undertaken to identify all possible phrases and terms mentioned by the participants in their interviews. From these interview transcripts, 603 codes were initially identified. This number was scaled back to 537 following review of the codes to merge those that had duplicate labels, such as *belief* and *beliefs* and combine codes that were co-descriptive such as *emotion* and *feeling*. Through an evaluation and sorting of these codes, twelve initial categories emerged, with multiple codes nested within. The coding process continued until all 537 remaining codes fit into emerging categories, a state referred to as "saturation" of the category (Birks & Mills, 2011, p. 10; Charmaz, 2006, p. 97).

Following initial coding, intermediate coding was used, in combination with the collection of memos recorded throughout the data review process, to fully develop and connect the identified categories through ongoing comparative analysis of the data (Birks & Mills, 2011; Bryant & Charmaz, 2007; Charmaz, 2006). Reviewing all the codes and quotations, while using concept mapping, revealed connections within and across the emergent categories. This process allowed possible identification of interactions and influences that might inform the process of acceptance and rejection. Mapping essentially began creating a storyline of the process of acceptance and evolution by looking at the patterns inherent in the responses given by the participants. Twelve initial categories emerged from the data: *background, creationism, critical incidents, conflict, evolution ideology, evolution teaching, influential people, misconceptions, nature of science, reconciliation, religiosity, and sources*. Following review and consolidation, these twelve were condensed to seven categories: *background*, absorbing influential people and sources; *religiosity*, absorbing creationism, *nature of science, evolution background, conflict and reconciliation, misconceptions about evolution*, and *teaching evolution*.

Final coding used a storyline method to “provide a comprehensive explanation of a process or scheme apparent in relation to a particular phenomenon,” in this case, the acceptance or rejection of evolution (Birks & Mills, 2011, p. 12; Charmaz, 2006). The storyline moved toward a progression of influences from parents and religion to peers, followed in some cases by divergence from original belief sets or persistence of original belief sets in others. A complex pattern of critical incidents emerged in those who demonstrated higher acceptance of evolution than those with lower acceptance. There was also a strong storyline connection between many participants and their religious identities and their approaches, beliefs, ideas, and rationalization relative to evolution.

An important discovery was that of distinct storylines for those at the highest and lowest levels of acceptance of evolution that set them apart from the average experience, noted by those with moderate acceptance. Since this study sought to create a process model that was more highly applicable to the average student, the focus was shifted to the storylines that intersected among those at the moderate level of acceptance while considering the extraneous events that cause divergence toward greater or lesser levels of acceptance. These overlapping storylines were then used to construct a process model by outlining the intrinsic and extrinsic factors that influence a pre-service secondary science teacher's acceptance of evolution.

Results

The results below are divided into two sections. The first section provides a breakdown of the participant interviews into categories that were developed through the grounded theory coding process. The final section provides a summary overview of the levels of acceptance based on the shared characteristics of individuals in each level.

Interviews

Background. A majority of the students who were interviewed reported growing up in areas within 100 miles of the study setting where they now attend college. Of the remaining students, one grew up in the Northeast and two others reported transient upbringing in that they moved very often, one within the state, the other across states with the military. Only three participants reported growing up in urban settings where the population was greater than 20,000 people. Most described smaller metropolitan or rural hometowns with populations ranging from a few hundred to less than 20,000. The idea of everyone knowing everyone was a common theme among participants, as most were involved deeply in the community through church activities as they were growing up. This experience was viewed both as positive and negative in

that the participants noted a feeling of closeness and support from those around them but a lack of anonymity based on the small-town dynamic as well. Many of the participants reflect Emile's view: "I grew up in a small town. There are approximately less than 5,000 people who reside in my hometown. With this size population, there is the typical everyone knows everyone."

All of the participants reported some aspect of family as influential factors in their beliefs, behaviors, and decision-making processes. In each case, it was the events that transpired within the family that drove the individual to particular beliefs or behaviors. For all but one participant, family influences included being pushed to excel, encouraged to do well in school, to be an active part of their church family, and to value moral and religious beliefs. For one participant, family took on a different context involving abuse by alcoholic parents who were very religious. This familial context led to the participant's move away from organized religion and toward self-determined moral judgment as a factor in beliefs. When asked what they felt were the strongest influences on the person they are today, many students mentioned their families. Jake said, "Largely any decision I make is affected by the consequences that it might have on the ones I hold dear." Lukas added that his church family was as much an influence on him as his home family. This puts a focus on external factors in the decision-making process, namely how one's actions impact those they hold dear.

Several noted that peers hold strong regard in their choices and interactions. This group includes friends, girl/boyfriends, school, community, sports and other group-related interactions. In each case, great value was placed by the individual on the opinions of and their acceptance by these influences. Emily noted that her school experiences "were very important in her development of ideas as an individual." Shannon agreed, adding that his experiences in "sports and with coaches had a strong impact on his life." For others, like Maddox, certain friends were

of greatest influence and became stronger than earlier influences on their choices. As he noted, “the biggest thing for me was my best friend, Heath. We met when we were little kids and were always curious and experimenting and asking questions. Before that I think religion, well, church had the biggest impact on me, but not anymore.”

For many, religion was a major influence in their daily lives and the choices made regarding what they accept or reject in science. When asked what influences they felt made them the people they are today, many students looked back at their family and religious experiences as a shaping factor as powerful. Brandon said, “The influences that I feel are most important being brought up in church and being pushed academically, both at school and at home.” Others, noted this such as AJ, who noted that his biggest influences were “faith in God, my parents’ guidance, and my social interactions through sports while growing up.”

It was expected that those whom the participants were closest to would be the most influential forces in their decision making and this was reflected in the interviews. The most common mentions were parents and church experiences. Only a few students mentioned teachers, school, peers, or coaches as strong influences in their lives. Not all of the experiences with these influences were positive and, in some cases, the negative experience with one influential person pushed the participant to be influenced by other entities, such as replacing a parent with a coach or church mentor with a friend.

The interactions and connections between the participants and these people whom they regard as influences informed the process of acceptance and rejection by framing a set of expectations by which the participant judges all other knowledge and experiences. In cases where there was agreement between the major influences, such as parents and church, peers and family, there tended to be a higher occurrence of rejection of evolution where the church, family,

and peers were all in agreement that the acceptance of evolution, or discussion of evolution, was taboo. In some instances there was conflict among influences, generally an agreement between church and family and a disagreement with those elements and peers, school, or mentors. In these cases, the participant tended to side with what they reported as their oldest held belief systems, that of church and parents, addressing the conflict by management, ignoring it, or trying to find reconciliation. In cases where the participant sided with the newer experiences and beliefs, there existed a critical incident, such as abuse, that generated the distance from the expectations.

Religiosity. When asked whether they were religious and what religion meant or represented to them, the participants had many shared experiences and beliefs. Each of the participants, with one exception, shared backgrounds rooted deeply in attendance in church and participation in church-sponsored or related events. In their experiences, it was common to be in church each time there was a service, which often meant three or more times a week. This included actual church services on Sundays, additional services on Sunday evenings or other evenings during the week, weekly study groups, church league sports, and other events. In fact, many noted the church as the cornerstone of their childhood experiences. When asked about their experiences with religion, many either are or have been personally involved at high level. As Jonathan explained,

I'm a pretty devout Christian. I'm a deacon in my church and I also sing and travel around singing at different churches and stuff like that. So I would say that most of my community involvement is through my church and working with the people of my community with my church.

Maddox shared similar experiences growing up where church was, as he described, a “major social venue” like school. He further noted, “My particular church was very large for the area. It was and still is the largest building in the town. There were no outlets that I was aware of for

kids interested in science.” This social connection was shared by Jimmy, whose childhood and youth involved moving often and attending many different schools, some for very short periods of time. As he explained,

The interactions I had with my community were actually kind of shallow, I made no long term friends that I kept in contact with until I was a teen. Most of my friends were not from school. They were from church, especially in the rural areas. No matter where we lived there was always a church and I found myself involved there more.

Only two participants reported being without a religious background from a young age, with becoming spiritual and finding religion at a later point in life and the other reporting actively searching for religion. In both cases, belief in a higher power was seen as guidance for how to live a good life, with a set of values or morals that dictated thought and behavior. There were also areas revealing intersections of influence between family, peers, personal experiences and church, for instance Shannon, recently became involved in religious practice as a result of persons of influence coming into his life. As he acknowledged, “I am new at this because I really didn’t grow up in church when I was young. My girlfriend and her family influenced me to become saved and learn about the Bible.” Wilkes too expressed,

No, I do not consider myself religious; but I am actively looking for a religion that fits me. I’m looking for one who welcomes everyone and anyone who walks in the doors. Makes me feel good about the way I already am as a person. The religion would tolerate any mistake; turn around and make that mistake-- growth. But, I do feel that the Bible is the best handbook on how to be a well-rounded person with good morals.

As to their current religious background, most participants identified, at varying levels of intensity, with being either religious or spiritual. It was noted that, when asked about the difference between being religious and spiritual, students responded with different ideas about the practice of organized religion as opposed to personal feelings. The delineation between religion and spirituality was equally difficult to distinguish in academic context. Webster defined religion as “the service and worship of God or the supernatural; a commitment or devotion to

religious faith or observance; and a cause, principle, or system of beliefs held to with ardor and faith (Webster, 2012). Spirituality is defined as something “of, relating to, consisting of, or affecting the spirit; relating to sacred matters, concerned with religious values, and relating to supernatural beings or phenomena (Webster, 2012). In this study, participants generally viewed being religious as a practice and tradition with expected behaviors, as opposed to feelings or beliefs they held which were considered much more personal and spiritual in nature. Others saw religion as an all-encompassing term to mean the beliefs and practices of one who believes in a certain deity and the principles included therein. This differentiation can be seen with Emile, who said, “Well, I would consider myself to be a Christian-- more than being religious. To me, being religious or spiritual is just going through the motions.” This was countered by Maddox’s statement,

So you can say, you know, you're not religious and maybe you don't participate in the formal activities of an organized religion. But ...a simple dictionary definition of religion is what it is. It is the belief in a god and whether you practice with a specific organization or ceremonies or not you're still religious, in my opinion.

In many cases, the term Christian, born-again Christian, or Believer were specifically used by participants to self-identify not only as religious or spiritual, but as a certain type of believer, namely that of fundamentalist Christianity attributed by Kincheloe and Pinar (1992) to the Southern region of the United States and supported by Baker (2013) as being evangelical and literalist in dogmatic view. AJ, Jonathan, and Shannon, who all referred to themselves as being “saved” or “born-again” Christians, can see this identity differentiation in statements. As AJ stated, “My beliefs are not caught up in religion so to speak, but rather revolve around the fact that I am a born again Christian saved by the power of Jesus Christ.”

In each case, the secondary science pre-service participants articulated strong personal stances regarding the role of religious beliefs or religion in their lives as a part of who they are,

rather than just something about them. Their self-defined religious beliefs centrally serve as a moral compass that directs their decisions and actions. For some, like Josh, this includes a literal interpretation of religious text as a foundation of his belief system. When probed regarding his statement about Biblical fact, he responded, “I don't try to question the Bible because that is how I was brought up. We believe that the Bible is the trust and you shouldn't question things in the Bible.” Lukas and AJ further personified this in their mention of the Bible as “God’s word” or the “word of God.” For them, this was taken to mean that God himself as a rule of law constructed the text for true believers and that it was meant to be taken literally. As AJ elaborated, “God wrote the Bible and meant what was said in it.” This thought is extended when evolution is specifically addressed in church settings, as it was in the case of Jonathan:

I know it has been talked about in church. I don't know if that was the first time that I've heard about evolution though. But it was looked upon in church like it was a ridiculous idea. Like it was, you, you were unintelligent if you actually could possibly believe that human beings came from monkeys.

In contrast, Jimmy and Jonathan both noted being brought up in churches that believed in a literal interpretation of the Bible as well, however, their experiences led them to conclude that the text was meant as a metaphor, or best explanation for the time in which it was written. These two, as well as Robin, noted that the literal interpretation of events in the Bible, namely that of Genesis and the seven days of creation and rest, pose the greatest conflict with evolution. This was confirmed by Lukas, who noted that he can't believe in evolution because “the Bible obviously tells us something different from evolution” and Josh adds, “you don't question things in the Bible.”

Nature of science. In regard to the nature of science, students had varying levels of understanding of how science itself works. When asked questions about science and their understanding of the nature of science, there were many important points of agreement but also

many misconceptions. All participants defined science as the explanation of natural events, some adding that it is supported by evidence or that it is a part of our daily lives. However, the ideas about level of proof, behaviors, and evidence in scientific discovery varied greatly across participants.

Laws and theories. In science, laws are defined as explanations among events or phenomena that occur in nature, such as gravity; and theory is defined as a “widely accepted explanatory idea that is broad in scope and supported by a large body of evidence” of a phenomena (McComas, 2003; Simon, Dickey, & Reece, 2013). Only one participant in this study held a personal definition that was similar to this interpretation. As Robin shared, “Theories are what we believe based on the evidence available to us. These may change with new evidence. Laws are basic observations of what happens in nature.” The definition and application of these concepts, and confusion with the everyday use of law and theory, make them a common source of misconceptions and confusion (McComas, 1998). Furthermore, understanding these scientific terms are exacerbated by the misrepresentation of religious beliefs as scientific alternatives to evolution as seen in these responses:

Shannon: Religion has laws and theories that shapes them around the views of that religion.

Jonathan: There are other elements that are important in the decision process, like the theory of creation.

All participants agreed that laws and theories were an integral part of science, the participant’s knowledge of each was inaccurate, incomplete and varied. For instance Lukas commented, “Scientific law has been proven and can be repeated to show that it exists or that it is factual, and theory is something that has yet to be proven.” This differs from Wilkes’ explanation of a theory as “just someone's prediction of events” and Josh’s conceptualization of

theories as a sort of practice attempt whereby after multiple uses and testing, a theory becomes a law. This is a common misconception about the nature of science that was also mentioned by Jimmy and Emile (McComas, 1998). Perhaps what is most interesting about this misconception is the fact that participants held it from the lowest to the highest level of acceptance. This is not surprising; students begin memorizing the scientific method in textbooks throughout their schooling. The scientific method is presented as a set of organized steps in the scientific process and suggests that continued testing results in theory and that eventually becomes law. However, that is not what happens in science practice, theories explain phenomena and laws describe the relationships among phenomena, but they are neither interchangeable nor developmentally progressive to one another.

Ambiguity of science. The nature of science requires the understanding that science is ambiguous, self-correcting as technology and methodology improves, and not able to provide complete, un-yielding proof of any event. As seen in previous literature, the participants in this study also struggled with their definitions and expectations of proof, evidence, and truth in terms of science. Some students made statements regarding the ambiguous and always-changing nature of science, as noted by Brandon who said, “science is always changing and other fields of study are basically set in stone.” Josh stated, “Basically, science is always changing and other fields of study are basically set in stone; like in math, two plus two is always four, and is always going to be.” However, some students found the idea that science was about proof, rather than explanation of phenomena with current tools and technology. A range of responses by the participants revealed common misconceptions as well as more accurate conceptions.

Emile: I would make sure they (students) know that a theory has not been proven. It is a proposition to explain something. However, a law has been proven and can apply under the same circumstances each time. (Misconception)

AJ: I believe both a theory and a law can change if it can be disproven, but a law and theory can be really hard to disprove because of the ample evidence that supports each before they become a law or theory. (Misconception)

Jonathan: Well, theory is something that hasn't been proven by fact over and over again. A law is something that is consistently reproduced, consistently backed up by fact. In my mind a law is something that you can't question. (Misconception)

Jimmy: You can never prove anything beyond a shadow of a doubt. There is always speculation, you know, built into that. (Conception)

The idea of change and proof is critical to evolution, where evidence or proof is often given as support for rejection or acceptance seen in the following statements:

AJ: Science does not prove nor accept creation as a plausible means of how the world began nor how all the organisms ended up where they are.

Lukas: They say that evolution has been proven, when it hasn't, they just try to bring up arguments to do with that.

Dagher and BouJaoude (2005) addressed these ideas stating that “students use a generic understanding of the nature of science as ammunition to dismiss evolutionary theory” (p. 387).

Generation of scientific knowledge. When asked about experiments, data collection, analysis, and reporting, there were a wide range of ideas concerning how science is practiced. This included several misconceptions about how and where scientific knowledge is generated and supported including that scientific knowledge is only generated through direct experimentation, that scientists either do not use creativity or they misuse it to manipulate data, and that there are science entities that conduct biased research to manipulate the public. For example, Jimmy commented that “in today’s age, we do have people using science to further political and social agendas.” Jake shared similar reservations, explaining that “statistics can be bent to go along with a hypothesis, which is not ethical but it does indeed happen.” AJ also

demonstrated a mistrust of scientific findings, stating that “evidence is needed proving a situation before it can become a theory or law so that manipulative data will not become a theory or law.” Shannon and Wilkes both felt that scientific knowledge must come from experiments, as did AJ who said “without experiments, scientific knowledge would be based solely on interpreted opinions of scientists which could not be proven.”

Robin disagreed with the idea that experiments were the only method of generating scientific knowledge, stating that sometimes simple, unplanned observation of events would suffice in providing meaning. Many students still held the view that science only occurs in light of a set scientific method, an order of events and expectations that must be followed precisely to be legitimate research, a misconception previously identified by McComas (1998). In other words, for some, objectivity is a highly entrenched part of their view of the nature of science, whereas others are more aware of the subjective nature of interpretation. The polar positions on this point were evidenced in comments made by Brandon and Lukas regarding how scientists can be looking at the same occurrence and have differing explanations for the events they are observing:

Lukas: If those people are looking at it and get completely different answers then obviously, we don't have all the information we need.

Brandon: I think this is just part of the process of discovery. Hopefully over time with more research these different conclusions will be either proven, disproven, or new conclusions will be formed. There is so much that we do not yet understand about our universe and we would be ignorant to think that the current way of thinking will eventually lead to all the answers.

There were also disagreements as to whether and when scientists should use creativity. Wilkes felt that scientists should use their imagination before, during and after they collect data, but others, such as AJ, felt that using imagination to interpret data can result in the manipulation of the data instead of reporting the facts.

Shannon: I don't believe scientists use their imagination during and after data collection. I think they go with what they see. If it fails it fails, if it is successful it is successful. I believe different scientist just have different viewpoints on how they look at it.

AJ: When the data are then interpreted and analyzed, scientists may be able to construct it in such a way that they are actually being creative and imaginative with it to prove what they want to prove. I feel that the data from their experiments should show exactly what happened during the experiment.

Jimmy agreed with this, adding that whether experiments were considered a success or failure, scientists should report the facts of what happened.

How scientists practice science. When discussing scientific practices, all participants agree that science itself is universal and should be treated as such. However, several were willing to admit that conflicts between science and cultural and social norms are not uncommon.

Robin: Some people are not accepting of scientific theories that contradict with their religious beliefs, so that is imposing social and cultural values. But I think everyone accepts that gravity works.

Emile: Sometimes people with a limited educational background have very narrow views and are not open to learning new things, especially, a controversial topic like evolution.

In spite of these issues, Brandon felt that "science should be able to be free of any cultural or social contexts to prevent bias from altering the results or its interpretation." Jake felt that science should be universal, but added, "I have witnessed people who do not believe in dinosaurs because it does not mention them in a specific religious book," therefore science, at the individual level, is not free of cultural and social influences. While most pre-service secondary teachers were not supportive of the filtering of science information as a general rule, there were some exceptions considered and still others experienced first-hand. This includes intentional filtering, such as Wilkes' support of choosing what to teach and not teach in science based on

age appropriate ideas. It also included cultural and social filtering, where outside influences determine what is and is not taught to students, such as the choice whether to teach evolution.

The idea that cultural beliefs and social expectations also function in how scientists internally approach their practice was also voiced:

Jonathan: I think that culture can affect the way that we believe and the things that we believe about science and the things that we research in science. You know, people do research based on the problems that they have and the questions that they want answered and those questions are pretty dependent on your culture.

Shannon: People look at data differently. Scientists have different backgrounds. In their past, they have had different teachers, and different school that taught them different ways. This is how people come up with different viewpoints.

Evolution. When asked about their experiences with science prior to attending college, all students reported having several science courses in high school with most reporting having at least one positive experience. In some cases, like with Shannon and Jimmy, teachers were leading influences in the life of the student or their choice to become a science teacher. When asked about their early experiences with evolution, students displayed a wide variety of exposure both in and out of school. Jonathan, Robin, and Jake recalled hearing about evolution as young as elementary age in school or other settings but were not sure of the details other than it was negative when outside of school. Maddox, on the other hand, recalled having detailed discussions with a friend about how organisms change:

I remember talking about it around nine years old with my friend and he explained it so simply, and I looked at this as he's explaining it and I thought, "You know what? That makes sense." He said, "Ok, you have two dogs and there are these two dogs and they have kids, those puppies have these characteristics, these have these characteristics, and he actually went through and showed me how animals could change over a long, long period of time.

Another participant, Jimmy, first experienced evolution in life science classes in middle school along with Jonathan who said, “Yea, I was taught about evolution in 8th grade and I went into it thinking that this is not what I was supposed to believe, that I wasn’t supposed to believe in what my teacher was telling me.”

However, AJ, Lukas, and Shannon were in high school before they were exposed to evolution in the classroom and all reported that it was barely covered, with the topic of evolution being limited to explanations of change over time, somewhat vague definitions of adaptation and fitness, and avoidance of discussion of human origins.

AJ: In high school, I learned that evolution is just when organisms or populations change over time. Evolution is essentially heritable changes that occur in species and populations over a period of time. Since the beginning time, species have died off due to lack of adapting to climate change, adapted to climate changes to survive, or evolution to produce offspring better equipped for the region in which the population lives. In other words, macro-evolution was briefly discussed and then we focused in on micro-evolution subjects.

Lukas: I think evolution is when organisms start from more basic cellular makeup and go to more advanced cellular makeup. That applies to all living things according to science books but I was taught that believing evolution means the Bible is not real.

None of the participants reported extensive study of evolution in their middle or high school years, nor had any taken an evolution-specific science course in their university study. Within the context of this study, the participants could take an upper level course on evolutionary biology, but the course was not required for education majors.

A majority of the participants recalled some negative connotation in what they were taught in school or heard outside of school. One participant recalls a sticker being placed in the beginning of the biology textbook as a disclaimer regarding the teaching of evolution, also noted in a study by Goldston and Kyzer (2009). Maddox commented,

Yeah, there was a preface in the beginning of the book on evolution that stated that the book was going to talk about evolution. I guess it was to prepare students. To let them know that they were going to hear about these topics in this class and that the state did not support them.

Others, like Emile, noted, “I first heard about the idea of evolution in high school. It was when my teacher said she refused to teach it. I was formally introduced to evolution in college.” Several noted that evolution was directly addressed as it related to church or church-related groups, each time with negative implications. Some even reported their being classes offered in their church that specifically addressed evolution in regards to their religious beliefs and expectations. Such was the implication that a number of students responded that they would rather not further discuss the events. Jimmy explained,

Every time I ever heard of evolution, it was referred to in a negative way. You know, like, this is Satan’s plans to you know, discredit the Bible and stuff like that. So I really didn’t have a good understanding of it till later on when I started reading.

Maddox reflected, “I know it has been talked about in church. I don’t know if that was the first time that I’ve heard about evolution though. But it was looked upon in church like it was a ridiculous idea.” AJ added that evolution was discussed in his church but stopped, saying “I would rather not talk about it.”

Still others recall having discussions with family or friends regarding evolution at varying times in their lives. Most were in the context of parents teaching their children based on their own closely-held beliefs and expectations. Others were more clandestine discussions held with close friends regarding questions and conflict between beliefs and readings, or teachings of the individual. For Robin, the idea of evolution is seen in her statement, “I’m pretty sure [I heard about evolution] from my parents or church, so it wasn’t an accepted idea at all. It did come up in church, but I really remember my mom, who is very religious, talking about it --- always negatively. Jonathan also reflects a negative intergenerational view of evolution,

Yeah, she (my mom), she told me this story about when she was in school and how they taught evolution...she came home from school and told her mother what she had learned in school and her mother, my grandmother, chastised her and told her that she shouldn't talk about that and that that was wrong. And so, my mother told me that story. And my mother isn't as closed off as my grandmother is, but she did say that evolution is not right and that it'll, um, it's not what we believe and, yeah, that's the first thing I ever heard about evolution. I didn't know what evolution was until she told me that because I hadn't learned about it in school yet. That was in elementary school, in like 5th grade.

Many participants specifically addressed difficulty or unwillingness to discuss evolution with peers, family, or others due to the controversial nature of the topic or a desire to avoid conflict with those they know oppose evolution (Dotger, Dotger, & Tillotson, 2009; Griffith & Brem, 2004; McGinnis & Simmons, 1999). Emile stated, "I have never talked with my family about evolution. It would be a difficult conversation because they would have such narrow thoughts on it." Maddox shared a particularly enlightening view of the taboo nature of asking hard to answer questions that challenge the status quo, sharing that

In Sunday school, when I would ask the hard questions, I can't think of anything specifically about evolution but just questions in general, I was actually pulled into my pastor's office once when I was a kid and was told I need to stop asking questions like that in Sunday school because I'm being a disturbance.

Another student, Wilkes revealed, "I have not discussed this topic with many people. One peer I talked to told me that it takes more faith to believe in evolution than man from God and women from a rib."

Probing the participants ideas of evolution, all described evolution as a process of changes occurring in a population over a period of time but, beyond that, the definitions were limited, incomplete, and replete with misconceptions regarding when, to whom, and how evolution occurs (Bishop & Anderson, 1990; McComas, 1998; Rutledge & Warden, 2000). When probed regarding their knowledge and beliefs about evolution, several misconceptions specific to evolutionary theory were brought to my attention. This included misconceptions with

respect to ancestry with particular emphasis on humans, monkeys and apes, adaptation as an individual response to changes to the environment, and evolution as an unsupported idea (Bishop & Anderson, 1990; Rutledge & Warden, 2000).

The human ancestry issue was addressed by Jonathan who said, “Do I believe in that little picture that they show you in middle school about how man evolved from other species. I don’t. I don’t believe that, but I do believe in natural selection as a means to produce a fit species.” Shannon and Jake hold ideas that are reminiscent of Lamarck. Shannon says, “Evolution is about organisms adapting to their environment and changing their physical appearances in order to adapt over time.” Jake finds evolution, “The measureable changes that an animal makes due to environmental stimuli, and the changes that the animal passes on to its offspring.” Some students challenge evolution as unsupported, as seen in Lukas’ words, “They say that evolution has been proven, when it hasn’t and they just, you know, try to bring up arguments to do with that.”

None of the participants disagreed with the concept of evolution as change over time; however, there was variation regarding human evolution including the ideas of common ancestry seen in the following:

Robin: I’m not convinced people eventually evolved from amoebas.

Jake: My feelings about evolution are that, besides the fossil record, there is no absolute concrete evidence that cross species evolution has occurred, or at least not to my current knowledge.

Emile: The only part of evolution that conflicts with my personal beliefs is that all species of life descends from common ancestry.

Although each of the participants described science itself as universal and should be free of social and cultural influence, many reported personal conflict with concepts of evolution as well as the influence of their religious beliefs and cultural implications on their ideas about evolution.

Brandon: I have had a personal struggle with evolution; biblically you are taught the story of creation and the finite number of days it took God to create the earth and all of its inhabitants. I generally try to keep the two things separate in order to try not to apply science to my religious beliefs.

Jake: In some areas it does not matter if there is a hybrid species between ape and man, and a scientist named him Joe, evolution would not be accepted.

Conflict and reconciliation. The most prevalent recurring theme in the interviews was the existence of conflict between religious beliefs and evolutionary concepts, whether observed or personally experienced. The participants in this study demonstrated similar levels to the three explained by Griffith and Brem (2004). These included scientist teachers, selective teachers, and conflicted teachers, as well as individuals with shared traits of two or more of the categories. Many students in the lower range of acceptance of evolution expressed greater levels of conflict between evolution and their personally held religious beliefs. These individuals agreed that issues of religion and evolution are too contentious to be reconciled.

Emile: I do not think evolution and religion should be mixed. I have experienced a lot of tensions when the two are combined.

Lukas: I think that (pause) they cannot coexist, as far as, the Christian belief and evolution. Because the Bible obviously tells us something different than evolution.

The lowest acceptance group bore remarkable differences from the higher level groups in that they rejected most of the aspects of evolutionary theory. According to their reports, this was driven by a literal interpretation of religious texts, such as the Christian Bible, which, to them, meant a direct conflict not just with their beliefs, but also with what they accept as the direct word of God. This group reported more conflict and less ability to reconcile beliefs than any other groups.

Lukas: Well, there are just people who say that, you know, the Bible is obviously not real because of evolution.

AJ: I believe that the Bible should be interpreted literally. God wrote the Bible and meant what was said in it.

Some examples of conflicting ideas the students personally held were such a fundamental part of their closely-held religious belief system that acceptance of evolution would mean no choice but to reject their faith and personal beliefs (Baker, 2013; Kincheloe & Pinar, 1991). The greatest obstacle among participants was that of biblical creation and its direct contradiction to evolutionary accounts of creation and, especially, human origins. As Brem, Ranney, and Schindel (2003) noted, creationists, especially those who were considered weak creationists, meaning that they were not completely literal in their interpretation, had the strongest issues relative to evolution.

AJ: Macro-evolution conflicts with my personal beliefs because I believe that God created this universe and also created us and the other organisms that live here...I'm sticking to my belief that evolution occurs for survival to take place among the populations and species that God placed here on this earth.

Jonathan: You know, in Christianity the reason that there is death, the reason that people die is because of sin, because of Adam and Eve's first sin. It was God's original plan to never have death and... the Bible says because of sin there is death. So, if all of that is true, and there was millions of years before man even came and dinosaurs or you know, whoever was before man that would mean that there was a death before there was ever sin and I don't, I don't believe that there was death before there was sin.

AJ: Evolution in the sense of organisms coming into existence from a common ancestor is false and God created the earth and its creatures.

Brandon: Biblically you are taught the story of creation and the finite number of days it took God to create the earth and all of its inhabitants. I feel that if God created us in a manner that was free of change, we would have had no way of surviving and thriving on a planet in which we would be at the bottom of the food chain.

These statements are demonstrative of the level of conflict that surrounds evolution on a very personal basis among some participants in this study. The division between evolution and religion is so powerful that to embrace evolution would mean the dissolution of the religious

belief system and part of their identity. Therefore, it is not a question of scientific evidence supporting evolution so much as it is seen as disproving what they have accepted as a literal fact in their religious beliefs. This problem is not unique to the Southern United States, but with the larger following of evangelical Christian Fundamentalism, it is more prevalent than other areas of the nation (Baker, 2013; Bowman, 2007). Even clergy have noted the difficulty in transitioning individuals from this concrete interpretation to a non-literal interpretation of biblical events (Colburn & Henriquez, 2006). Baker (2013) further explains that these “conflicts between religion and science are about morality and public influence rather than formal epistemology” (p. 217).

Contrasting with this position is that of the higher acceptance participants, whose ability to reconcile their personal beliefs with their knowledge of evolution appeared to be the key to their acceptance of evolution. This openness or willingness to explore other worldviews aligns with recommendations by Dagher and BouJaoude (2005) and Asghar, Wiles, and Alters (2010) who support the use of similar techniques in the teaching of evolution. With the exception of one participant, who reported nearly complete division of himself from his prior beliefs to a position of atheism, the higher acceptance participants managed to maintain both sets of beliefs. These individuals displayed two main coping strategies when it came to dealing with conflicting beliefs.

In some cases, the participant simply chose to believe both while keeping them in separate cognitive domains divided by their definitions of science and religion. In each of these cases, the students saw science as applying only to the natural world and supported by physical evidence; and religion to the supernatural, based solely in faith in the unseen. As Shannon noted, “I am a believer in evolution and religion. I don’t really have tension or conflicts between them. I

try to look at them as coexisting without hurting my belief in God.” This allowed him to believe in both, and justify it as two different entities occupying two totally different realms. As Brandon stated, “Science is a method of examining the universe, although it cannot be used to examine religion because science cannot examine the supernatural, like religion.”

In other cases, students demonstrated a high capacity for rationalization of the conflicts between their belief systems that allowed them to use science as a supporting factor to their personal religious beliefs. These were often very detailed and thought provoking explanations that demonstrated a great deal of thought and reflection on the part of the participant.

Jimmy: The conflict I had was only due to the literal interpretations of my earlier religious beliefs. When you are taught at a young age that the earth was made in 7 days, you take it as it is. The theory of relativity explains that all matter is linked to time and space and that the universe is between 13-14 billion years old. The fact that particles can be in two places at the same time, made me think that if a particle is not bound by the same perception as me when considering time then everything is based on perception. I then began to realize that the Bible was not based on the same perception that I now have. You know, starting off with Genesis, you know seven days to create the earth? And all that is in, or 6 days and a day to rest. Ok, first of all, no man knows God’s mind. No man knows what day it was to God and I believe that, you know, God... basically, created us. I believe that this planet was created but I don’t subscribe to the belief that it was less than, you know, five thousand years old. Or twenty-thousand years old now. It is, you know, 4.6 or 5.7 billion years old. And, I just believe that, you know, people just subscribe to literal interpretation. You know, because they want to say the manifestation of the miracle and life in itself is a miracle. You don’t have to subscribe to some mystical component. You just look at all the factors that have gone on in creating what we are today, and you can’t deny that it is a miracle that we exist.

Robin: I think evolution and religion are not mutually exclusive. I don't think "7 days" has to be our 7 days. I think animals could have (and still do) evolve, but I don't think we all evolved from an amoeba. God could have still created man in His image. Conflicts come when people refuse to reconcile the two.

The ability to reconcile is different for those who embrace a literal interpretation of biblical events as opposed to scientific explanations of events leading to evolution (Catley &

Novick, 2008, p. 17). We can see, in these two participants, a view of the role of religion and acceptance of the practices and tenants of their beliefs as stories meant to explain events of the time rather than a factual account of pre-human history.

Misconceptions about evolution. Common among participants relative to the nature of science and evolution were misconceptions across all levels of acceptance. This lends further support to findings that evolution content knowledge is not an adequate predictor of acceptance of evolution (Akyol, Tekkaya, & Sungur, 2010; Deniz & Donnelly, 2011; Nehm & Schonfeld 2007) and contradicts that of Rutledge and Warden (2000) who found that content knowledge on evolution did predict acceptance in their study. The commonly shared misconceptions held by the participants in this study were similar to the misconceptions previously noted by McComas (1998). Some of the misconceptions relate to whether there is evidence of evolution (Alters, 1996); fitness meaning stronger or bigger (Alters & Nelson, 2002); evolution as a result of need, use, or disuse (Bishop & Anderson, 1990); failure to consider the importance of reproduction in evolution (Rutledge & Warden, 2000), and viewing evolution as modification of traits rather than shifting proportions (Bishop & Anderson, 1990; Rutledge & Warden, 2000). These comments provide a snapshot of these common misconceptions noted by participants:

- Jimmy: Individuals don't evolve except for mentally and psychologically, but not physically. Evolution is usually brought on by a need or some outside force that forces an evolutionary change or adaptation.
- AJ: It just means that over time populations adapt to circumstances to survive, which then leads to the evolution of that particular population in their genetic inheritance to be better suited for the changes they are facing in order to survive. All organisms evolve to be better suited for the ecosystem in which they live.

Teaching evolution in their future classrooms. A common thread among many of the participants was that they are already thinking about what and how they will deal with evolution

in their own classrooms. Many of them suggested that students should be allowed to choose for themselves what to believe, regardless of their (the participants) beliefs, after exploring multiple sides, either in class or independently. It is also clear that the participants had little understanding of the legal issue that prevents the teaching of creationism in classrooms in the United States:

AJ: They [students] can choose to believe that evolution is the way we were created or they can believe in creation and that from that point evolution happens among populations of organisms to become better suited to survive where they live.

Jonathan: Like I said, I think that you should let students decide what they want to believe and show all evidence for each theory. You know, show the evidence for evolutionary theory and show the evidence for the creation theory.
Emile: They (students) should have the freedom to make educated conclusions.

Their teaching preferences and concerns are best demonstrated by the range comments they made about teaching evolution that demonstrates the varying levels of concern and confidence they held:

Jake: I want to be the scientist teacher in my school, I will teach evolution just like every other scientifically valid theory.

Emile: If given the opportunity, I will teach evolution. Like I mentioned earlier, I think that evolution is a change over time. I will teach my students about natural selection and species diversity. If I expose them to Darwin's theory that we all have a common ancestry, I will make sure students understand the differences between a scientific theory and scientific law. The only concern is that I will have students trying to unify evolution and religion because of their cognitive development.

Brandon: Well, since I am planning on teaching at a public school I hopefully will not have to compare evolution to creationism.

Shannon: I will teach evolution, but I will not make it a Creation conflict. I'll teach it to the book. If Creation comes up I will say I cannot answer that in school.

Robin: It can be taught without stepping on religious toes. It's just genetics and selection for or against traits. Teach it that way and give solid examples those students already accept.

Jonathan: I would tell them the scientific theories of today, how old the earth is and I would tell them that I'm not sure about evolution.

AJ: Evolution in the sense of organisms coming into existence from a common ancestor is false and that God created the earth and its creatures.

Lukas: I won't teach evolution if there is not any time allowed for it in the course of study or whenever we're going over it.

These statements range from hopeful and prepared to wholly resistant, lacking the unified support of evolution that exists in the scientific community.

One point to note is that, at no time, did the participants mention alternatives to evolution that were not directly tied to creationism. One participant, Wilkes, mentioned that Young Earth Creationism was something she might examine in her science classes with students as an alternative, but Intelligent Design, Morphic Resonance, Punctuated Equilibrium, or Theistic Evolution were not addressed by any participants. This omission of common alternative explanations suggests that the culture of the participants was more deeply connected to religion than other sources.

Summary of Levels of Acceptance

Grouping of participants by levels of acceptance provided a means for viewing attributes of the participants that reveal their thoughts and expectations. Those who had the greatest levels of acceptance of evolution based on their MATE scores were Jimmy and Maddox. Their scores were both above 95% on a 100% scale, which would imply greater knowledge and understanding of both evolution and the nature of science. Despite this, they still had misconceptions that were similar, if not the same as, individuals at the other levels of acceptance (Nehm, Kim, & Sheppard, 2009). An interesting commonality within this group was that both noted being able to separate their scientific knowledge of evolution from their religious beliefs. As seen in Griffith and Brem's (2004) study Jimmy and Maddox fall into the scientist teachers'

category in coping with teaching evolution. This was a common category but held distinct sub-categories--critical incidents--that caused them to break from their family cultures with respect to religion. In both cases, they were brought up as highly engaged and active participants within the Christian Fundamentalist religious culture of the Southern United States; however, both experienced distancing events that pushed them to adopt anti-fundamentalist beliefs as adults.

Those in the high acceptance group demonstrated an ability to reconcile or manage their personal beliefs and their scientific beliefs, at least in part. In effect, they straddled the line between being scientists and selective teachers (Griffith & Brem, 2004). They both embraced science and were supportive of the teaching of evolution, yet they still had questions due to their experiences with religion and beliefs about God. Two high acceptance participants, Wilkes and Brandon, reported being religious or in search of an active religion but did not report being literalists in terms of their religious practice. This position allowed them to either find ways to support their personal beliefs with evolution as evidence, or completely separate the two as being parts of two separate entities. The high acceptance participants in this study are characterized by the acknowledgement of the presence and interjection of a higher power in the process of evolution while still accepting evolution as truth, which is illogical and creates a state of permanent disequilibrium among beliefs.

The moderate range of acceptance included Emile, Robin, Jake, Jonathan, and Shannon. These participants seemed to rationalize some belief in evolution with their religious beliefs, however, there were more instances of selective belief in aspects of evolutionary theory with much less certainty than the higher acceptance groups. The moderate acceptance group exhibits similar attributes to that of Brem, Ranney, and Schindel's (2003) weak creationists and were more likely to explore all sides of the evolution argument than any other group. Most notably,

they self-reported to be highly involved in family, church, and community and were more likely to report having mentors or peers to whom they looked for answers about matters of science and religion. Another trait in this group was the ability to believe in creationism as well as some accepting of aspects of evolution. An exception to the co-belief in religion and evolution held by these participants is human evolution, where the participants explained human origins with creation stories, specifically Genesis creation. This group tended to see science and religion as complimentary to one another, where the two fit together to provide explanation. Like selective teachers, they chose to believe parts, but not all, of evolution (Griffith & Brem, 2004). A common theme was the explanation of creation through scientific terms, such as the belief that a “day” to a higher being does not have to be twenty-four hours, that the events of the seven day creation follow the same pattern as scientific explanations of the origins of the universe and life, and that evolution is the mechanism by which God changes life on Earth. This group was also more likely to see creationism as an equal to scientific evolution, both in their own beliefs and in the classroom.

The low acceptance level group, Stacey and AJ, tended to be more deeply conscious of the conflict between their own religious beliefs and their understanding of science. Stacey especially occupied a precarious position between science and religion, as she was the daughter of a minister in a Baptist church. Although these participants accept science as universal and evidence driven, many comments were made regarding the lack of proof for evolution, especially the concept of evolution as “only a theory,” drawing on the lay term of *theory* as something that is not necessarily based on evidence. These individuals were more likely to avoid teaching evolution unless required by the school itself and made more comments about teaching creation stories to help students decide what to believe. In terms of conflict, those in the low acceptance

level struggled more with the concepts of evolution and had a higher occurrence of conflicting comments regarding evolution, like AJ who mentions that laws and theories are well proven in one statement, then notes that evolution is a theory without evidence or support in another. This group demonstrated the most acknowledged internal conflict and seemed more eager to explore the different avenues of discussion of beliefs than other groups. Like the high acceptance group, these members tended to straddle the line between coping styles, only in this case, the line was between being selective and being conflicted (Griffith & Brem, 2004).

The group rated very low in acceptance of evolution based on their scores, Lukas and Josh, both felt that a literal interpretation of their religious text was not only warranted, but a primary tenet of their core beliefs. They both made comments regarding the Bible not as a book written by men to explain God, but written by God as the living Word of God, through which they were given instructions about all that has been and will be in this world. This caused direct conflict between what they accepted in their religious beliefs and what they had been taught about evolution. They both appeared unable to reconcile or manage their religious and scientific beliefs, therefore they wholly rejected evolution as false and were highly conflicted (Griffith and Brem, 2004). For them, there was no other option for belief or acceptance and they were highly aware of the internal tension between the two. For the most part they coped with the tension by ignoring the conflict and avoiding evolution altogether, even in discussion.

Theoretical Modeling

Process models come from the realms of engineering and business and are traditionally used to demonstrate a complex pattern of steps while noting the various possible options, interactions, and influences at the different stages. The key to process modeling is the establishment of networks between various components rather than a step-by-step, single level,

or unidirectional approach (Schacchi, 2001). Although process modeling originated in business, it is key to theoretical and substantive modeling in grounded theory, giving “priority to the studied phenomenon or process-rather than just a description of a setting” (Charmaz, 2006; p. 22). At the heart of grounded theory research is the creation of “conceptual renderings” of the processes inherent to what is taking place in any given research setting (Charmaz, 2006). These early connections, in addition to the aforementioned initial, intermediate, and advanced coding, allow for the creation of models of relationships among categories that emerge from the data (p. 62-63).

To understand how a person moves to accept or reject evolution, it is necessary to look not just at variables but also at the complex interactions between each of those variables and the learner in addition to the constructive and destructive interactions that can occur among the variables themselves. For this reason, a process model approach was selected to demonstrate the complexity of relationships and how they come together within the individual to lead to their dispositions toward the acceptance or rejection of evolution.

A Process Model of Acceptance and Rejection

This study undertook modeling the complex process of individual’s acceptance and rejection of evolution. To create a model, it was determined that more participants were needed from the moderate level based on the assumption that the moderate participants represent the average position of pre-service teachers in the test population based on the MATE results. Upon analysis of the interviews from the moderate participants, a pattern of interactions became apparent with each sharing very similar experiences and worldview constructs. A simple model of worldview would appear as a sphere of influence through which ideas and experiences pass for evaluation. As information is presented to an individual that information essentially enters the

worldview sphere and is, in a way, digested, with some negotiable parts being reconstructed to fit to the worldview, those that fit being accepted into the sphere to expand the worldview, and others being rejected, and thus pushed out of the sphere.

The worldview is not a static entity but is rather dynamic, morphing with the individual through each and every experience, some with greater power than others to impact the sphere of one's worldview. At the heart of the worldview, where the various influencing factors intersect, is the core of beliefs that are at the center of the individual experience. These are more fixed through time and serve as the foundation by which all other events are judged. It is this core of interactions where much of the conflict with evolution occurs. Although some people do reject evolution without consideration, for those study participants in the moderate range, a good deal of thought may have been put into the process and their weighing of the evidence against their existing worldview becomes quite evident through the statements they made regarding their worldview and the conflict they have experienced.

The initial purpose of this study was to develop a process model of the acceptance or rejection of evolution by preservice secondary science teachers. As seen in the following visual (see Figure 4.1), there are patterns of interactions between concepts of evolution and the components that encompass pre-service science teachers' worldviews. The first set of interactions that emerged from the study participants was that between the concepts of evolution and their family experiences with religion being a close, if not intertwined, second. Similar to findings by Winslow et al. (2011) for instance, if their family had negative attitudes toward evolution, they were more likely to reject evolution as a whole without further consideration. Those family attitudes were most often rooted in religious beliefs; therefore the second level of consideration often provided a secondary support if the participant had any question about

rejection based on their family experiences. Those participants whose family experiences were either positive or neutral regarding evolution applied further evaluation of their intrinsic beliefs to determine their position about evolution and move to the next stage of influences.

The next stage of influence was that of religion, which, as mentioned before, an integral part of the familial culture was for those participants who rejected evolution. The role of religion in evolution has been widely explored and shown to be a statistically significant predictor of evolutionary acceptance among both students and teachers (Rutledge & Mitchell, 2002) and a strong influence on expectations and attitudes about evolution (Baker, 2013; Moore & Kraemer, 2005; Schilders et al., 2009). Those participants who had, directly or indirectly, been exposed to negative perceptions of evolution by members of their clergy, Sunday school, or church family members, were more likely to reject evolution. Those whose interpretation of the Bible was literal rejected evolution in every case of the study while those who had neutral or no church dispositions toward evolution, and those who had diverged from their beliefs due to critical incidents, were more likely to continue to additional levels of influence regarding evolution. In only two cases, participants who came from devout Christian Fundamentalist backgrounds elected to further explore evolution in spite of the negative connotations expressed by their family and church. Beyond family and religion, there were other elements that were present in the interviews but they could not be clearly defined as either a positive or negative influences on the acceptance and rejection process.

The understanding of the nature of science is a key avenue of exploration in evolution literature (Dagher & BouJaoude, 2005; Rutledge & Mitchell, 2002; Rutledge & Warden, 2000); however, participants in this study demonstrated a very wide range of conceptions and misconceptions about the nature of science regardless of their level of acceptance according to

MATE. This range of misconceptions about NOS is seen in the participant's comments that theories are or are not proven, theories become law, science proves things beyond a doubt, creativity is not part of science, and the idea that scientists make up data and experiments in addition to the numerous misconceptions held about evolution itself (McComas, 1998). The fact that both Jimmy, who had a nearly perfect acceptance score, and AJ, who was at the lower range of scores, both shared fears of scientific malpractice and misconceptions about the nature of theories and laws, speaks more toward an overall view and understanding of the nature of science that is not based in fact. In essence, aspects of the nature of science were just as likely to be misused to justify rejection of evolution as they were to support acceptance in the participants' accounts.

The process of acceptance and rejection of evolution is, by no means, a simplistic process, however, the narratives provided an emergent storyline demonstrated by paths of experiences and expectations leading to the levels of acceptance and rejection of evolution. This process model, therefore, cannot be generalized and applied to any population with expectation of a fit. However, understanding the process in this group of individuals in this setting suggests what could occur in a similar culture and subpopulation . Understanding the process among these more highly resistant populations might serve to improve the teaching of evolution and teacher training for it (Baker, 2013).

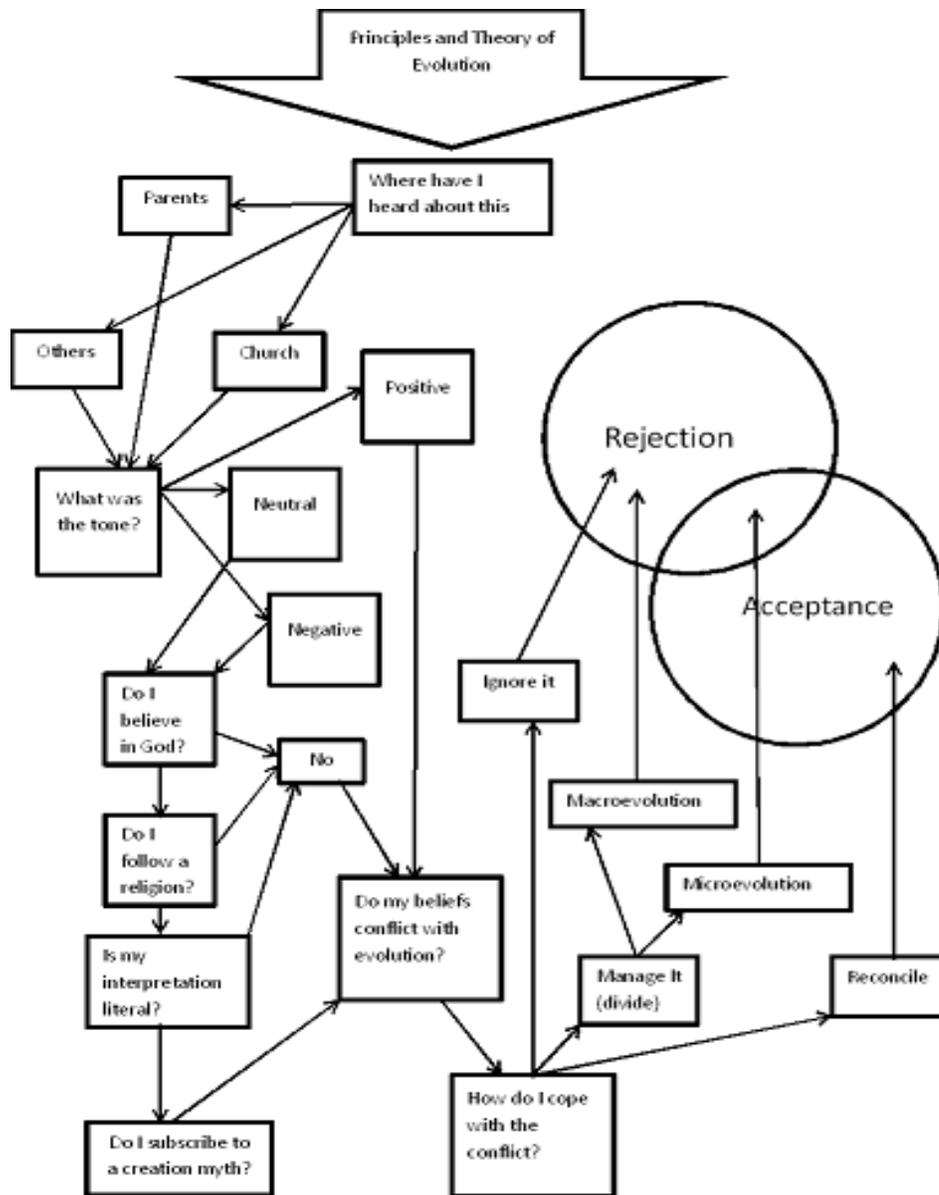


Figure 4.1. Evolution and Pre-service Science Teachers. Theoretical process model of acceptance and rejection of evolution among pre-service science teachers in a teaching college in the Southeastern United States.

Conclusion

Discussion

Scientific literacy within our society is, and will continue to be, the goal of science education for the future (Association for Science Teacher Education, 2013; National Academy of Sciences, 2008; National Research Council, 2011). What is often overlooked is that, to build a

scientifically literate society, we must assess the scientific health of those who will be on the front lines of preparing that society. There is no better place to begin than with pre-service secondary science teachers whose ideas about teaching and learning will influence students they teach. Understanding the lived experiences that contribute to pre-service secondary science teachers' worldviews enables understanding of the processes by which students make decisions about science that impact their scientific literacy and that of their future students. Charting the thought processes of each individual is imperative to understanding whether they accept or reject evolution, why they accept or reject, and where they fall in the continuum between the two poles.

The literature has shown that acceptance and rejection of evolution influence what and how teachers address the topic in their classrooms (Alters & Alters, 2001; Bowman, 2008; Catley, 2006; Veal & Kubasko, 2003). Entering this study, it was expected that there would be factors influencing pre-service science teachers regarding their ideas about evolution (Goldston & Kyzer, 2009; Griffith & Brem, 2004; Moore & Kraemer, 2005; Trani, 2004). In keeping with prior studies in teachers, the pre-service secondary science teachers in this study who had high acceptance expressed more inclination to teach evolution in its entirety and teach it with the same fervor as other topics in biology such as cells and genetics (Griffith & Brem, 2004). Those on the opposite end of the spectrum noted reluctance to teach evolution and noted that it would only be taught if mandated by state requirements (Goldston & Kyzer, 2009).

Van Koevering's (1999) findings of criticism by outside sources such as administrators, family, and community were also supported by this study. Although these pre-service teachers have yet to enter the classroom they already reported feeling pressure to teach or not teach evolution and pressure regarding their own ideas and acceptance of evolution. It was also found that the pressure to fit in with the overarching ideals and expectations of their worldview realms

often led them away from acceptance to avoid fear and conflict (Brem, Ranney, & Schindel, 2003; Fowler & Meisels, 2010).

In keeping with statements made by Sinatra et al. (2003), rationality often had no place in the process of acceptance and rejection of evolution among participants in this study. Many participants who were low or very low in the spectrum of acceptance were still very knowledgeable about the concepts relative to evolution. Therefore, it cannot be assumed that those who do not accept rejection are in some way uninformed or conceptually illiterate (Nehm & Schonfeld, 2007). Knowledge alone does not warrant acceptance, rather worldview is used to sort and sift that knowledge so that segments that are in agreement can be saved while those that conflict can be ignored or discarded (Akyol, Tekkaya, & Sungur, 2010; Deniz & Donnelly, 2011). In retrospect, worldview does not have to be built with truth; rather truth is whatever is accepted as such by the individual, regardless of whether it is externally accepted. As Sinatra et al. (2003) explained, the difference between belief and acceptance is that beliefs can be based on fact or fiction, it is a matter of what the individual believes or feels based on their experiences. Conversely, acceptance is based solely on the evaluation of extant evidence and should occur despite emotion. Therefore, people are neither easily able to differentiate between that they accept nor what they believe, nor are they willing to admit that their beliefs might be based on something other than fact (Sinatra et al., 2003). Despite scientific evidence and clear personal definitions held about science, religion and the separation of the two, most often religious conflict held the greatest impact on acceptance and rejection, a result similar to those reported by Wiles (2008).

Studies by Goldston and Kyzer (2009) and Meadows, Doster, and Jackson (2000) found that teacher acceptance played a role in what would be taught in that teacher's classroom. This

finding was paralleled by participants in this study who were already thinking of how their own ideas about evolution, and those held by their students, would come to light in the classroom. Comments were often made regarding not only personal conflicts with evolution, but also expected conflicts that future students might have with evolution and how the pre-service secondary science teacher would deal with those conflicts. This included conflicts with religious beliefs and ideas such as creationism and led some to express willingness to teach both evolution and other, non-scientific ideas relative to evolution to allow students to choose what to believe. Although many expressed that they would be willing to teach evolution if mandated as part of the curriculum, there was reluctance on the part of many of the participants based solely on their own perspectives, supporting similar results found by McGinnis and Simmons (1999).

Regarding their science training, all the participant pre-service teachers recalled being taught at least some aspects of evolution in their educational careers, mostly at the high school level and only mentioned in their university science courses. Like the findings reported by Aguilard (1998), several of the participants were critical of what they were being taught, especially at post-secondary level, some seeing the information they were given as little more than scientific propaganda meant to discredit religious ideas. What was not supported was the idea that more science meant greater acceptance (Rutledge & Warden, 2000). All the pre-service teachers in this study shared very similar science-heavy backgrounds and, in the case of their post-secondary experiences, had the same professors and many of the same classes; however their range of acceptance was wide.

Much like the participants in past studies (Jorstad, 2002; Nadelson, 2007; Wiles 2008; Woods & Scharmann, 2001), the pre-service teachers in this study often justified their acceptance or rejection of evolution based on ideas about evidence. Many wrote evolution off as

just a theory, suggesting that it is little more than an idea that has no support while others accepted evolution as an evidence-backed model that explains things to the best of modern science's current ability (Bishop & Anderson, 1990). Although understandings of science and the nature of science, how science is done, were discussed they were often ignored in part or whole when in contention with the more deeply held beliefs associated with the participants' worldviews. Unlike participants in some reported studies (Aguillard, 1998), students in this setting had no required courses that specifically covered evolution, rather, it was a side discussion that was surveyed only briefly during other courses such as genetics.

Reconciliation of personal religious beliefs was a key coping mechanism for many of the pre-service science teachers that allowed them to accept parts or, in two cases, all of evolutionary theory (Dotger, Dotger, & Tillotson, 2009; Sanders & Ngxola, 2009). This mirrored results recorded in a number of studies on religion and evolution (Meadows, Doster, & Jackson, 2000; Shipman et al., 2002; Trani, 2004). Those participants who were able to approach the topic with an open-mind and use their reasoning skills to negotiate conflicts with their beliefs and scientific understandings were more likely to accept evolution than their peers who were unable to meld the two into a complimentary set of ideas (Griffith & Brem, 2004).

In this study, pre-service teacher worldview centered mostly on family and religious experiences, which were often viewed as inseparable. This supports similar findings about the power of these relationships in the literature (Demastes, Good, & Peebles, 1995; Woods & Scharmann, 2001). As Winslow et al. (2011) noted, "acceptance of evolution is an extended journey of discovery, not just a matter of presenting facts and evidence" (p. 1040). Pre-service teachers held fast to the lessons and ideals of their parents, friends, and mentors who, in most cases, held strong negative opinions about evolution. In some cases, the conflict between the

worldview and evolutionary ideas was strong enough that the entire foundation of the worldview would be called into question for acceptance to occur, forcing rejection as suggested by Hansson and Lindahl (2010). These findings further support the idea of worldview as the experiences that define people and as a major force in decision-making as the lens through which the world is evaluated and judgment made (Beauchamp & Thomas, 2009; Sfard & Prusak, 2005).

Implications for Teacher Education and Teaching

The aspects of worldview play an important role in our understanding of whether individuals, in this case pre-service secondary science teachers, accept or reject evolution. Whenever an individual has a new experience or encounters new knowledge, this information must pass through these spheres, changing as it goes to fit into the existing ecology of the worldview. It is for this very reason that we cannot ignore the presence and power of beliefs in the classroom, especially in regards to evolution (Hokayem & BouJaoude, 2008, p. 395). The results of this study also suggest that we cannot pretend that religion does not play an integral role in the acceptance and rejection of evolution. It was aspects of religiosity that proved to be barriers to acceptance of all, or parts of, evolutionary theory, namely human evolution. The conflict between science and religion is strongly internal but is pushed by external forces.

Pre-service secondary science teachers represent a unique position in the spectrum of teaching and learning science, occupying a space somewhere between that of teacher and student. Based on the interviews with these future teachers, it is clear that there is a need of further training and support for teaching topics such as evolution. Although some demonstrated moments of confidence and strong acceptance of evolution, the prevalence of misconceptions about evolution, and the nature of science represent a gap in their scientific understanding that has the possibility to be transferred into the classroom. If teachers are to serve as the mediators

between science and the general public, it is of greatest importance that the science they represent is accurate.

In order to make changes in the perception of evolution and science by the general public, we have to reach them in the court of public opinion with a unified front. More instruction is needed for future teachers to improve their knowledge and pedagogy of evolution, as well as more ongoing support for them in the classroom in the form of professional workshops and outreach. Pre-service preparation should include greater discussion of the socio-cultural nature of learning, with a focus on helping students see things through the worldviews of others rather than simply contradicting their beliefs and labeling them as wrong. As Asghar, Wiles, and Alters (2010) noted, “science teachers must be aware of broader social, philosophical, and religious contexts that may influence student thinking about evolution” (p. 68). They should also be made aware, in their methods courses, of the legal precedent surrounding the teaching of evolution and creationism in public schools so that they know what boundaries exist (Moore, 2004; 2007). Finally, the teaching of evolution should be done, at all levels, and with respect for the different beliefs held by students and teachers alike. Only by negotiating the conflict, rather than exacerbating or ignoring it will there ever be a widespread change with respect teaching and learning evolution in the classroom.

Suggestions for Further Study

This study, like most, has limitations that impact generalizability to other populations including sample selection, researcher subjectivity, interpretation of meaning and inferences. Therefore, it is important that further studies be conducted with similar samples to provide additional support for the findings reported here. It would also be interesting to see how this sample of preservice secondary science differs from samples of pre-service science teachers at

larger public universities, in urban settings, in different regions of the United States, and those with more diverse student populations. It is clear that there are needs in our teacher preparation programs as evidenced by the misconceptions recorded about evolution and the nature of science. This suggests the need for methods and science courses that better illustrate the nature of science as well as evolution courses that address these misconceptions through interactive approaches that will allow students to explore their own beliefs while following similar paths of scientific discovery regarding evolution (Catley & Novick, 2008; Dagher & BouJaoude, 2005; Colburn & Henriquez, 2006). It is also important that these programs be assessed to determine whether they work and how they work to improve understanding and acceptance of evolution while minimizing misconceptions (Crawford et al., 2005; McKeachie, Lin, & Strayer, 2002).

This study gave insights into the lived experiences of pre-service science teachers in the rural Southern United States regarding evolution. This was one of only three studies that have specifically explored aspects of evolution in the Southeastern United States. The South has demonstrated unique characteristics that warrant further study, including disturbing statistics regarding the likelihood of educational misinformation and lack of instruction regarding evolution (Bowman, 2008). It is also home to the largest group of Fundamentalist Christians in the United States (Kincheloe & Pinar, 1991) whose literalist interpretation of the Christian Bible and evangelical dogma make them less likely than all other Christian groups to accept evolution (Baker, 2013). It is likely that the different regions of the United States have differences, further detracting from the generalizability of results from one region or setting to another. For this reason, further study of evolution across the regions of the country is needed to clarify the picture of evolution in the United States. There is also a need for further study of the treatment of evolution and perceptions of evolution among private school students and teachers, especially in

religious schools, and how they approach the teaching of evolution. Every study we make at clarifying our understanding serves to provide one step closer to untangling the complexity of teaching and learning evolution.

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Appendix A
Survey Instrument

Name _____

Email _____

What is your gender?

Male _____

Female _____

What is your age? _____

What is your student level (junior, senior, graduate)? _____

What is your content major? _____ Biology _____ General Science _____ Physics _____ Chemistry

Please check the box beside each science course you have passed:

_____ BIO 101/103 _____ BIO 102/104 _____ BIO 323(Genetics) _____ BIO 332 (Ecology)

_____ BIO 373 (Cell) _____ CHEM 105/107 _____ CHEM 106/108 _____ PHS 201/203

_____ PHS 202/204 _____ GY 210/220 _____ Other Biology courses above 300 level:

For each of the following statements, mark your answer document with one of the following:

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

1. Organisms existing today are the result of evolutionary processes that have occurred over millions of years.
2. The theory of evolution is incapable of being scientifically tested.
3. Modern humans are the product of evolutionary processes that have occurred over millions of years.
4. The theory of evolution is based on speculation and not valid scientific observation and testing.
5. Most scientists accept evolutionary theory to be a scientifically valid theory.
6. The available data are ambiguous (unclear) as to whether evolution actually occurs.
7. The age of the earth is less than 20,000 years.
8. There is a significant body of data that supports evolutionary theory.
9. Organisms exist today in essentially the same form in which they always have.
10. Evolution is not a scientifically valid theory.
11. The age of the earth is at least 4 billion years.
12. Current evolutionary theory is the result of sound scientific research and methodology.
13. Evolutionary theory generates testable predictions with respect to the characteristics of life.

14. The theory of evolution cannot be correct since it disagrees with religious accounts of creation.
15. Humans exist today in essentially the same form in which they always have.
16. Evolutionary theory is supported by factual historical and laboratory data.
17. Much of the scientific community doubts if evolution occurs.
18. The theory of evolution brings meaning to the diverse characteristics and behaviors observed in living forms.
19. With few exceptions, organisms on earth came into existence at about the same time.
20. Evolution is a scientifically valid theory.

Appendix B

Survey Scoring

Scoring Instructions for the MATE.

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.

4. Step 1. Scoring of items 1, 3, 5, 8, 11, 12, 13, 16, 18 and 20 is as follows:
 1. Strongly Agree = 5
 2. Agree = 4
 3. Undecided = 3
 4. Disagree = 2
 5. Strongly Disagree = 1
5. Step 2. Scoring of items 2, 4, 6, 7, 9, 10, 14, 15, 17, and 19 is as follows:
 1. Strongly Agree = 1
 2. Agree = 2
 3. Undecided = 3
 4. Disagree = 4
 5. Strongly Disagree = 5
6. Step 3. An individual's score on the MATE is equal to the sum of the scaled responses to all 20 items.

Appendix C

Interview Protocol

1. When you think back on your history, what experiences have shaped the person you are now?
 - a. probe for clarification relative to family, special persons of influence, peers, community, religion, setting.
2. What influences do you feel are most important now that you are an adult?
 - a. probe strong influences, nature of relationships, religious background, strength of beliefs, interpretation of religious doctrine.
3. Do you consider yourself religious?
 - a. probe their definition of religion, spirituality, and where they see themselves in their beliefs.
4. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)? (Lederman et al., VNOS-C)
5. What kind of experiences did you have with science in high school?
 - a. probe school setting, teaching of evolution, experiences.
6. How do you perceive or think about scientific theory and scientific law? Do these things change? Why do we bother to teach theories? (Lederman, Abd-el-Khalik, Bell, & Schwartz, 2002; VNOS-B, ques. 1, VNOS-C, ques. 5)
 - a. probe for explanations, whether they change, the rationale behind their choice, evidence or support of their position.
7. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in

which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced. What are your thoughts on this?

(Lederman et al., 2002; VNOS-C, ques. 9)

a. probe for explanation of position and examples.

8. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, what are your thoughts about whether scientists use their creativity and imagination during and after data collection? (Lederman et al., 2002; VNOS-B, ques. 5)

9. Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. What are your thoughts about how are these different conclusions possible if all of these scientists are looking at the same experiments and data? (Lederman et al., 2002; VNOS-B, ques. 7)

10. Tell me your thoughts on whether the development of scientific knowledge requires experiments? (Lederman et al., 2002; VNOS-C, ques. 3)

11. Where did you first hear about the idea of evolution?

12. Please explain evolution in your own words.

a. probe for meanings, positions, rationale for ideas, source of ideas.

13. Where did you get your ideas and information about evolution? Where do you go when you have questions?

a. probe for specific persons, places, things the student sees as valued resources.

14. What are your feelings about evolution and religion? What tensions have you experienced?

What do you think causes the tensions?

15. What roles do you see yourself having as a soon-to-be science teacher? What things will be easy for you teach? What will be more difficult? What are you looking forward to teaching?

How do you see yourself in the science classroom?

16. What are your views about teaching evolution?

- a. probe whether they will teach it, what they will teach, how much time, will they teach other views.

CONCLUSION:

EVOLUTION AND PRE-SERVICE SCIENCE TEACHERS

Summary

In an effort to contribute to body of knowledge pertaining to evolution education, this study took a three-pronged approach to understanding the process of acceptance and rejection of evolution among pre-service secondary science teachers studying at a teaching college in the rural Southeastern United States. The first approach was to critically analyze the research literature to identify dimensions surrounding evolution that have been explored and where gaps in the research appear. In this study, it was found that pre-service teachers represent a gap in the literature studying evolution teaching and that conflicting findings regarding the factors that influence acceptance and rejection of evolution as well as the lived experiences relative to those factors leave additional questions in our understanding.

The second study was a quantitative analysis to determine which conflicting factors identified in other studies statistically influence acceptance and rejection of evolution among pre-service secondary science teachers attending a teaching college in the South. The results of the quantitative study explained 45% of variance in acceptance of evolution in the sample group. The results further showed how highly students regard their religious beliefs. Religious beliefs were the most influential factor influencing evolution acceptance with the full prediction model also including STEM influences, the number of individuals in the STEM fields that a person is close to; nature of science understanding; and evolution content knowledge.

The final study built upon the quantitative study by exploring the lived experiences and worldviews of the participants. These experiences were analyzed and coded to create a storyline that led to a theoretical model of the process by which the participants moved toward various levels of acceptance or rejection of evolution. The results of that study described the following: a) the power of religious beliefs and practices in their lives, b) the decision making processes of the participants and, c) how their beliefs about evolution influence their ideas about science and how they will teach their future students. The three studies together present a view of acceptance and rejection of evolution among pre-service secondary science teachers attending a college in a rural area entrenched in the Christian Fundamentalist culture prevalent in the Southeastern United States.

Conclusion

The question has been asked whether acceptance or knowledge should be the goal of science education. When it comes to evolution, we must push students to review the evidence and look toward acceptance over simple understanding because knowledge of evolution simply isn't enough, in light of the cognitive dissonance between beliefs and science, to ensure the retention and transfer necessary for scientific literacy (Ingram & Nelson, 2006; Sinatra et al., 2003). It is evidenced in the three preceding articles, that the controversy surrounding the theory of evolution and its component parts are deeply rooted in conflict with aspects of individuals' worldviews. Although the conflict surrounding evolution appears, superficially, to be as simple as a question of belief for or against it, the processes and underlying influences are quite complex and can be as much extra-rational as rational, intrinsic as extrinsic (Deniz, Cetin, & Yilmaz, 2011; Sinatra et al., 2003). Although it would be unethical to forcibly deconstruct personally held student beliefs in the classroom we can provide richer learning experiences that

put the student, or pre-service teacher, in the role of scientist by getting to the heart of the nature of science through critical thinking, inquiry, and discovery in the classroom allowing them to better understand the processes by which scientific knowledge is generated and how theories come to be accepted (Farber, 2003; Passmore & Stewart, 2002; Pramling, 2008; Rankey, 2003; Robbins & Ray, 2007).

Thus far, studies have indicated that teachers in the United States have only a moderate level of acceptance of the theory of evolution (Akyol, Tekkaya, & Sungur, 2010; Rutledge & Warden, 2000). This level of acceptance is persistent despite years of reform in science education and the implementation of standards to more closely align the teaching of science across the nation (National Research Council, 2011). It is important that we not overlook the power of beliefs and perceptions in regards to teaching and learning in our schools (Demastes, Good, & Peebles, 2009; Winslow et al., 2011; Woods & Scharmann, 2001). Teacher beliefs and perceptions color what students are exposed to in the classroom as well as the attitudes they attribute to these concepts when they are recalled later in life (BouJaoude et al., 2011; Nadelson & Nadelson, 2010; Rutledge & Mitchell, 2002; Schrein et al., 2009). Teachers have ultimate autonomy in the classroom, which despite standards that specifically include evolution may not occur (Goldston & Kyzer, 2009) if they perceive the topic as conflicting with their own beliefs or they feel will cause issues in their classrooms, schools, and communities (Dagher & BouJaoude, 2005; Hokayem & BouJaoude, 2008). It is for this reason that we must find ways to increase knowledge and acceptance of evolution in teachers (Alters & Alters, 2001; Bowman, 2008; Catley, 2006; Deniz & Donnelly, 2011; Veal & Kubasko, 2003).

In addition to increasing knowledge and acceptance of evolution in our teachers, there is a need to provide them with support to teach with confidence and purpose (Chuang, 2003). This

is especially true in areas of high conflict, such as the Southeastern United States, where, despite standards including evolution, there are often conflicting pressures coming from clergy, politicians, administrators, and the community (Brem, Ranney, & Schindel, 2003; Fowler & Meisels, 2010; Goldston & Kyzer, 2009; Nehm, Kim, & Sheppard, 2011; Rutledge & Warden, 2000). One way to do this is to teach coping strategies to students and future teachers so that they are more able to explore their beliefs (Griffith & Brem, 2004). When coping strategies are absent or one-dimensional, conflict leads to rejection of that which does not align with closely held beliefs (Hansson & Lindahl, 2010; Sfard & Prusak, 2005). Teachers and students alike need to be aware that the process of acceptance of evolution is not simple and that acceptance does not mean absence of conflicting beliefs or lack of religious beliefs and that there are many ways of coping with the conflicts that arise between evolution and their own beliefs (Dotger, Dotger, & Tillotson, 2009; Griffith & Brem, 2004; Meadows, Doster, & Jackson, 2000; Sanders & Ngxola, 2009; Shipman et al., 2002; Trani, 2004).

Before evolution acceptance increases in any population, there must be changes made in the way we train teachers and approach the teaching of evolution across levels of education (Goldston & Kyzer, 2009; Moore, 2008; Moore & Kraemer, 2005). The depth of exposure to evolutionary theory is often minimal across grade levels, meaning that teacher training thus far has not had the widespread desired effect on student or teacher acceptance (Athanasiou & Papadopoulou, 2011; Nadelson & Nadelson, 2010, Schrein et al., 2009). Evolution is still widely regarded by some as unnecessary information or even as propaganda of a belief-barren scientific community (Aguillard, 1998) and many still lack a basic understanding of the processes or evidence supporting evolution (Bishop & Anderson, 1990; Jorstad, 2002; Nadelson 2007; Wiles, 2008; Woods & Scharmann, 2001). Even when individuals do participate in strong content

experiences, their exposure is often too short in duration and lacking in consistency to cause lasting change (Nehm & Schonfeld, 2007). To cause lasting conceptual change, programs and methods are needed that engage students by continually probing their underlying beliefs and expectations with the same intensity as those beliefs (Nehm, Kim, & Sheppard, 2009; Schilders et al., 2009).

Thus far, research in evolution has yielded few results that are generalizable to the whole student, teacher, or pre-service teacher population in the United States (Cavallo & McCall, 2008; Nadelson & Sinatra, 2010; Rutledge & Mitchell, 2002). This is due to the wide variety of cultures and beliefs that are held across social groups and regions of the nation. The culture of many students in the rural Southeastern United States is in direct conflict with the prevailing cultures of scientific practice. So long as we continue to approach the teaching of evolution in absolutes, or approach students as existing in a vacuum devoid of social contexts, we face failure. The world in which we live and the cultures in which we are reared form the basis for interpreting all experiences we encounter. The current climate surrounding evolution, especially in Christian fundamentalist regions such as the Southeastern United States, takes on a presence of "us versus them," with religious culture on one side and the science community on the other (Kim & Nehm, 2011; Moore, Brooks, & Cotner, 2009). This barrier must be broken down to shift the teaching of evolution away from current dichotomy between evolution and Creationism. Although there are some pre-service science teachers who have been able to straddle the center line, they tend to find themselves in a place of non-inclusion among one or both cultures when it comes to evolution, with neither group fully accepting them. For many, to accept evolution is to reject long-held beliefs that are closely guarded whereas to reject evolution is to be regarded as

existing on the fringe of scientific practice (Asghar, Wiles, & Alters, 2010; Coburn & Henriquez, 2006; Murphy, Hickey, & Beggs, 2010).

Currently, pre-service teacher knowledge is, quite often, slight in scope, disconnected, and incomplete (Banet & Ayuso, 2003; Catley, 2006; Catley & Novick, 2008). To combat these obstacles there needs to be more focus on the nature and practice of science, self-assessment of beliefs, and more content time spent discussing evolution, especially misconceptions and evidence (Cavallo & McCall, 2008; Crawford et al., 2005; Nadelson & Sinatra, 2010; Nehm, Kim, & Sheppard, 2009; Wiles & Alters, 2011). These measures should also be not only required for teacher education candidates, but an relevant aspect of the appropriate content courses to sustain any effects (McKeachie, Lin, & Strayer, 2002, Wiles & Alters, 2011). Last though not least, pre-service teachers should also be well versed on the legal precedent regarding the teaching of evolution and alternatives in public education, which many do not clearly understand (Bowman, 2008; Moore, 2004, 2008).

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IRB Certification

Office for Research
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Protection of Human Subjects

THE UNIVERSITY OF
ALABAMA
R E S E A R C H

January 7, 2013

Amanda Glaze
Department of Curriculum & Instruction
College of Education
Box 870232

Re: IRB#: 12-OR-015-R1 "Investigating Acceptance and Rejection of
Evolutionary Theory among Pre-Service Secondary Science Educators"

Dear Ms. Glaze:

The University of Alabama Institutional Review Board has granted approval for
your renewal application.

Your protocol has been given expedited approval according to 45 CFR part 46.
Approval has been given under expedited review category 7 as outlined below:

*(7) Research on individual or group characteristics or behavior (including, but
not limited to, research on perception, cognition, motivation, identity, language,
communication, cultural beliefs or practices, and social behavior) or research
employing surveys, interview, oral history, focus group, program evaluation,
human factors evaluation, or quality assurance methodologies.*

Your application will expire on January 6, 2014. If your research will continue
beyond this date, complete the relevant portions of the IRB Renewal Application.
If you wish to modify the application, complete the Modification of an Approved
Protocol Form. Changes in this study cannot be initiated without IRB approval,
except when necessary to eliminate apparent immediate hazards to participants.
When the study closes, complete the appropriate portions of the IRB Request for
Study Closure Form.

Should you need to submit any further correspondence regarding this proposal,
please include the above application number.

Good luck with your research.

Sincerely,


Carpano F. Myles, MSM, CIM
Director & Research Compliance Officer
Office of Research Compliance
The University of Alabama



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