2017

A Study of Central Florida College Students' Acceptance of the Theory of Evolution, Microevolution, Macroevolution, and Human Evolution

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A STUDY OF CENTRAL FLORIDA COLLEGE STUDENTS' ACCEPTANCE OF THE THEORY OF EVOLUTION, MICROEVOLUTION, MACROEVOLUTION, AND HUMAN EVOLUTION

by

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A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Education
in the School of Teaching, Learning, and Leadership
in the College of Education and Human Performance
at the University of Central Florida
Orlando, Florida

Summer Term
2017

Major Professor: Kenneth T. Murray

ABSTRACT

In order to study the teaching and learning of the theory of evolution and determine levels of acceptance of the theory of evolution among college students studying biology in Central Florida, the Inventory of Student Evolution Acceptance, I-SEA, was administered to over 500 university students enrolled in a biology course during the Fall 2016 term. An analysis of 489 completed surveys demonstrated strong overall acceptance of the theory of evolution (average score = 103 out of 120 total possible). Of all students, 78% fell into the category of very high acceptance of the theory of evolution. Students who reported attending worship services weekly or more scored statistically significantly lower on the I-SEA than students who reported attending worship services less than weekly. The level of previous high school coursework in biology—whether honors, or advanced biology courses were taken-- did not translate into statistically significant differences in acceptance of evolution as measured by the I-SEA. Three subscales contained within the Inventory of Student Evolution Acceptance are designed to measure student acceptance of microevolution, macroevolution, and human evolution. Students demonstrate higher levels of acceptance of microevolution than macroevolution or human evolution. These findings serve to inform educational leaders and science educators regarding students' worldview and how worldview may inform what students accept as true and valid. The I-SEA serves as a useful educational tool to inform instructional decisions in the biology classroom.

I dedicate this work to you, the reader.

ACKNOWLEDGMENTS

I would like to thank the biology instructors who were instrumental in helping to collect the data necessary for this study. Namely, thank you to Dr. Chris Parkinson, Dr. Cynthia Bayer, Mr. Frank Logiudice, Dr. Patrick Bohlen, Dr. Ken Fedorka, Dr. Joshua King, Dr. Eric Hoffman and Dr. Gregg Klowden, as well as their research and teaching assistants from the Department of Biological Sciences at the University of Central Florida. Thank you to all the students who completed surveys and volunteered to participate in this research. Thank you to Dr. Robert Borgon and Dr. Griff Parks of the Burnett School of Biomedical Sciences at the University of Central Florida and the lab assistants who helped to collect data. Thank you to Dr. Tata and Dr. Saviuk of Daytona State College Biology Department, I appreciate your interest in the research.

Thank you to Dr. Sophia Dziegielewski, the IRB Chair at the University of Central Florida for approving the research. Thank you Dr. Mark Quathamer and Dr. Ron Morrison, the IRB Chairs from Eastern Florida State College and Daytona State College, respectively.

Thank you Dr. Louis Nadelson and Dr. Sherry Southerland for creating, refining, validating and making available a fine instrument, the Inventory of Student Evolution Acceptance, which provided the necessary data to answer the research questions.

Thank you Dr. Lawrence Scharmann for your work in the field of evolution education and for your words of wisdom early on in my journey.

Thank you Dr. Barbara Murray for sharing your knowledge, Dr. Rosemarye Taylor for the example of scholarship you set, Dr. Walter Doherty for your kind words and insightful comments as both a professor and a committee member, Dr. Lee Baldwin for your instruction and guidance throughout the adventure, Dr. Robert “Biology Bob” Everett for your helpful

comments and for dedicating your time to the research. Dr. Jesus Jara, thank you for your inspiring words and example. Dr. Larry Jaffe, thanks for the timely Qualtrics technical support!

Dr. Ken Murray, my dissertation chair, thank you for your direction, helpful comments, instruction, and guidance throughout the endeavor of earning an educational doctorate.

Thank you Jacqueline Feagin and Jeremy Salmon, two principals who hired me as a teacher and have therefore been instrumental in my life's work. Thank you for allowing me the honor to achieve my mission.

Thank you Zach Osbrach, the first principal to hire me and provide the leadership for me to grow professionally during those early formative years as a young teacher. Zach, your friendship is treasured. Our discussions have shaped my educational philosophy.

Thank you Dr. Mary Romjue, a long-time friend of the family and fossil mentor to my son, Isaiah, the paleontologist in training! Mary, your suggestions early on and familiarity with the topic have been extremely helpful in the research. Your willingness to always help is appreciated.

Thanks Mom and Dad! And Grandpa and Grandma and Grandpa and Grandma.

Thank you to my sons Isaiah and Isaac and my daughter Riley who are the reason for it all.

Thank you to my soul-mate Chelsea Nikol Stanton Schleith. You are my hero! I've only been able to dedicate time to my work because of you, including completing this degree and this research. It is thanks to your encouragement I achieve this goal. I love you.

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CHAPTER ONE: INTRODUCTION

Statement of the Problem

72% of high school biology teachers do not strongly advocate for the central theory of their discipline—the theory of evolution, (Berkman & Plutzer, 2011). Concerted efforts to weaken and undermine science education and therefore damage scientific literacy are launched continually from organizations such as the Discovery Institute.

Scientific literacy is important for the continued and future success of human civilization, especially when looking far to the future. The importance of educating students about science as a way of knowing and a body of knowledge is paramount. The promise of fields like biotechnology and stem cell research, and potential benefits and dangers of nanotechnology and artificial intelligence require both a highly educated and specialized professional class of scientists to advance these and other fields, but also require an educated, scientifically literate general populous to understand and deal with the societal implications and ethical considerations of the burgeoning technologies these sciences afford humanity. Every student deserves the right to a free and appropriate public education in America, and the best possible education includes the best possible science education. Threats to science education are repeatedly launched by organizations whose work contributes in a very direct way to scientific illiteracy.

The 2007 National Survey of High School Biology Teachers showed only 28% of U.S. high school biology teachers strongly advocate for the theory of evolution, (Berkman & Plutzer, 2011). Evolution is "a theory that has become the core of the science of biology," (Raven & Johnson, 1999, p. 3). Theories are the most powerful explanations scientists have to offer and the theory of evolution is the best explanation offered in the study of life. "As evolutionary theory is the central and most powerful theory in the discipline of biology, biology teachers must be aware

of its scientific validity, explanatory power, and ability to act as a natural organizational theme for instruction in the biological sciences," (Rutledge & Warden, 2000, p. 30). Scharmann, Butler, and Varol (2013) demonstrated the use of the theory of evolution as an advance organizer in a college-level introduction to biology course for non-science majors to be effective in helping students reconcile previously held naïve beliefs regarding the nature of science as well as reinforce understanding of the science of evolution. This study seeks to utilize the Inventory of Student Evolution Acceptance, or I-SEA, to explore student acceptance of the theory of evolution.

Historically and continually, large segments of the American population do not accept the theory of evolution, (Miller, et al., 2006). A Pew Research poll conducted in 2014 to measure acceptance of evolution showed a wide disparity between Americans who attend weekly worship services and those who attend less than weekly. For Americans who attend worship services weekly or more, 46% of people said that humans evolved over time. For those who attend worship services less than weekly, 74% of people agreed that humans evolved over time. Of those who attend worship services at least weekly, 49% believe that humans existed in their present form since the beginning of time compared to just 22 % who agree that humans have existed in their present form since the beginning of time from respondents who attend worship services less than weekly, (Funk & Alper, 2015). Religious views often times dominate a student's acceptance of evolution, more so than prior education, (Rissler, 2014). Low levels of acceptance of the theory of evolution and low levels of scientific literacy are certainly connected as the theory of evolution is the organizing framework of modern biology. Because the theory of evolution helps to explain humanity's origins, it touches on the same subject matter as religious ideas about creation, "the magnitude of the impact of religious factors on scientific literacy is

substantial. Religion plays more of a role in structuring scientific literacy than does gender, ethnicity, or income," (Sherkat, 2011, p. 1146).

Failure to strongly advocate for the theory of evolution by a majority of high school biology teachers contributes to a "cycle of ignorance" (Berkman & Plutzer, 2011). To date, few studies have been conducted to examine levels of student acceptance of the theory of evolution using the Inventory of Student Evolution Acceptance, or I-SEA. The Inventory of Student Evolution Acceptance was developed to contain three subscales—microevolution, macroevolution, and human evolution. By measuring student levels of acceptance of evolution within each subscale, results can shed light on specific areas where future instruction may focus and curricular attention be paid. One previous study that has utilized the I-SEA is a study of evolution acceptance among Christian University students and the relationship to Biblical literalism. The current study seeks to build upon the body of evolution education research and contribute to research that utilizes the I-SEA to compare evolution acceptance levels in students representing different demographics and exposed to different instructional practices.

The strong correlation between acceptance of evolution and student science achievement has been demonstrated at the state level, (Belin & Kisida, 2015). By examining contributors to acceptance or rejection of different components of the theory of evolution, educators and educational leaders can focus on solutions to the problem spelled out by the researchers who developed the Inventory of Student Evolution Acceptance: "students continue to enter university biology courses demonstrating fundamental misunderstandings of evolutionary theory," (Nadelson & Southerland, 2012, p. 1638).

Purpose of the Study

The purpose of this study was to explore student acceptance of evolution in a novel student population-- college students studying biology in the Central Florida area.

A further purpose of the study is to offer research-based suggestions for educational leaders and science educators regarding the teaching and learning of the theory of evolution. The first aim of the research is to utilize a novel instrument, the Inventory of Student Evolution Acceptance, to explore the levels of acceptance of evolution in college students and determine what contributes to overall acceptance of the theory of evolution, and acceptance of three constructs within evolutionary theory—microevolution, macroevolution, and human evolution. The researchers who developed the Inventory of Student Evolution Acceptance did not establish any specific levels of acceptance or rejection of evolution within their scale which ranges from 24 to 120 based on responses to 24 Likert-style items scored on a 5 point scale where a high score indicates agreeing with the pro-evolution stance on items. Some items are worded with an anti-evolution stance and these items receive reverse scoring. The current research which utilizes the I-SEA adds to a growing body of research studying evolution education and one goal of this study is to contribute to this research by examining a unique demographic of students attending college in the Central Florida area.

A further aim of the current research is to demonstrate how the data collected from the I-SEA may inform classroom instruction by providing instructors "fine-grained" measures of their students' levels of acceptance of evolution as a whole and specific constructs within evolution which the I-SEA was designed to measure including microevolution, macroevolution, and human evolution. By demonstrating how the I-SEA provides such useful data, biology

instructors may be encouraged to utilize the I-SEA as a means to drive their instruction with data about their unique student body.

Another goal of the study is to examine the available literature on best practices of teaching evolution and couple this examination with the previously mentioned goal of utilizing the I-SEA itself during biology instruction. Science educators may then learn about the levels of acceptance of evolution and its constructs among their students and deliver instruction in such a way as to achieve the greatest impact among students in developing and enhancing scientific literacy and acceptance and understanding of the theory of evolution, even in students that may traditionally reject the theory of evolution.

"Seen in the light of evolution, biology is, perhaps, intellectually the most satisfying and inspiring science. Without that light it becomes a pile of sundry facts-some of them interesting or curious but making no meaningful picture as a whole," (Dobzhansky, 1973). In his often cited paper (848 times cited in *Web of Science* as of April 22, 2017), *Nothing in biology makes sense except in the light of evolution,* famous geneticist Theodosius Dobzhansky makes an important argument for the need for science educators to present the study of biology with the theory of evolution as the central focus. Evolution offers a unifying explanation for myriad phenomenon studied within the life sciences. Evolution explains the diversity of life and its processes. Evolution explains the interdependence of organisms, and their connection to a changing environment, (Dobzhansky, 1973).

Over the past four decades, the problem of the low levels of acceptance of the theory of evolution among Americans persists even as general education levels rise, (Miller et al., 2006). Among scientists, the acceptance of the theory of evolution is overwhelming and near 100%, (Wiles, 2010; Funk & Rainie, 2015). The instrument utilized in this study is designed to

distinguish between the two often conflated concepts of understanding and acceptance, (Nadelson & Southerland, 2012).

Data collected from this instrument to measure student acceptance of evolution and conclusions drawn from this study will inform educators and educational leaders about what contributes to differences in levels of acceptance of evolution among students.

The implications derived from this study serve to offer educators and educational leaders concerned with student science achievement insight into addressing the problem of low levels of acceptance of evolution in some student populations. This study also explores the means in which humans come to develop and maintain a worldview and the impact of worldview on education. Why do we come to accept what we do as true? In addition to these psychological factors, educational leaders should understand the Federal and State mandates which are designed to ensure that students attending public school receive the best possible education including the best possible science education. The centrality of the theory of evolution to biological science and the controversy surrounding the theory in popular culture indicates it worthwhile to dedicate resources to studying the best way to help students learn science and think scientifically. Students who fail to receive adequate instruction in high school biology may leave high school entering college ill-prepared to learn college level biology.

Significance of the Study

This study will contribute to the body of knowledge that focuses on the teaching and learning of evolution. This study will attempt to determine the prevalence of different levels of acceptance of the theory of evolution among different groups of college and university students studying biology. By analyzing the concepts addressed within the instrument, further conclusions about what factors contribute to student acceptance of evolution can be drawn. These findings

will serve to inform educators, educational leaders, and educational policymakers regarding the importance of teaching and learning about evolution. For example, the finding of the link between student understanding and acceptance of the scientific theory of evolution and success in college; Carter et al., (2015) write:

> We found highly significant, positive relationships between student knowledge of evolution and attitudes toward evolution, as well as between introductory biology course achievement and both precourse acceptance of evolution and precourse knowledge of evolution.

This claim indicates the importance of high school science coursework in developing understanding and acceptance of the theory of evolution in students as it relates to their college readiness. This study will provide insight for educators and educational leaders about areas where instruction may be focused based on contributors to student acceptance of evolution. This acceptance better prepares students for their academic and professional career beyond high school.

The Measure of Acceptance of the Theory of Evolution has been utilized as a primary research instrument for more than a decade, (Rutledge & Warden, 1999; Wagler & Wagler, 2013). The more recently developed Inventory of Student Evolution Acceptance also serves as a useful tool for research in the teaching and learning of the theory of evolution. The current study builds upon the previous research studying evolution education through the use of the novel I-SEA instrument and offers educators and educational leaders more detailed insight into addressing the theory of evolution, and specific constructs therein—microevolution, macroevolution, and human evolution, (Nadelson & Southerland, 2012).

The current study is also significant in its novelty of examining the unique demographics of students represented in the sample of students attending college in the Central Florida area.

The majority of the population of college students studying biology surveyed in this study attended high school in Florida after the adoption of the Next Generation Sunshine State Standards which included a stronger emphasis on the theory of evolution in the science standards, as well as standards related to the nature of science.

Definition of Terms

1. Theory- "A theory, like evolution, is a well-substantiated explanation of some aspect of the natural world," (Trani, 2004). A theory is the most powerful explanation that scientists have to offer, (Next Generation Sunshine State Standard SC.912.N.3.1).

2. Evolution- "Evolution is a broad, well-tested description of how Earth's present-day life forms arose from common ancestors reaching back to the simplest one-celled organisms almost 4 billion years ago. It helps explain both the similarities and the differences in the enormous number of living organisms we see around us," (AAAS, 2006).

3. Creationism- Creationism will be defined broadly as any set of beliefs that account for the existence of life's diversity through the action of a supernatural being or deity—typically God in the Judeo-Christian tradition. There are many Creationist beliefs which may be placed under an umbrella of Creationism, or even on a spectrum, (Scott, 2004). This will be explored more fully in the review of literature.

4. Microevolution- The results of evolution over the short term that lead to changes within a population. Short term is defined here as evolution occurring over several generations, and depending on the lifespan of the organism this may mean years, or hundreds of years to thousands of years.

5. Macroevolution- The results of evolution over the long term; the consequences of microevolution; the development of new species. Long term is defined as millions to hundreds of millions and even billions of years.

6. Human evolution- A selfish branch of evolutionary biology; Evolution in hominid species including modern humans, *Homo sapiens*. Most of the hominid evolution that led to modern humans probably occurred within the past six million years.

7. Advanced Biology Course- An advanced biology course will be defined as Advanced Placement (AP) Biology, International Baccalaureate (IB) Biology, Advanced International Certificate of Education (AICE) Biology, or equivalent college-level courses students may have taken as dual enrolled students while still in high school.

8. Biology I Honors: Biology I Honors is a course approved by the State of Florida. The course code for Biology I Honors is 2000320. Biology I Honors contains 11 specific evolution standards out of 107 total course standards.

9. Biology I- Biology I is a course approved by the State of Florida. The course code for Biology I is 2000310. Biology I contains 9 specific evolution standards out of 85 total course standards.

10. Worship services- Worship services are generally defined as an organized gathering of people for religious purposes. Examples include attending services at a Mosque, Synagogue, Church, Temple, or other place of worship. Because students are self-reporting their frequency of attending worship services, worship services will be broadly and crudely defined as whatever the student considers to be worship services as they answer the question.

Conceptual Framework

Worldview Theory

The overarching theory that frames the research questions to follow is worldview theory. "Worldview provides a nonrational 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," (Cobern, 1996, p. 584). A student's worldview is shaped throughout development and highly dependent on social environment, (Evans, 2001). Differences in worldview that exist in students may account for rejection or acceptance of certain concepts such as evolution, but may also influence a students' resistance to learning new ideas.

One of the important features of worldview theory is the inclusion of metaphysical thought processes, or ways of knowing, and epistemological processes, or ways of thinking. As humans learn, their ways of thinking are influenced by their existing worldview and what students come to accept as true and how they value certain kinds of knowledge are both shaped by and help reshape worldview, (Cobern, 1996). Cobern describes the distinction between comprehension and apprehension; comprehension being a thinking process-- the ability to understand a concept, and apprehension being a metaphysical process of knowing and accepting as true and valid. The current study seeks to explore the acceptance of the theory of evolution in college students studying biology at different stages in their undergraduate career. Worldview theory, and its examination of the metaphysical thought processes that explain what humans come to accept as true and valid informs the research by offering explanations of why students may reject different components of the theory of evolution.

The formation and changes in worldview that occur throughout development and last into adulthood can be understood through Piaget's theory of cognitive development and Vygotsky's

sometimes juxtaposed, yet complementary theory of social constructivism. The theory of motivated reasoning, (Kunda, 1990), helps explain how people alleviate uncomfortable cognitive dissonance that is created as an artifact of receiving perceived conflicting information such as information obtained in public school versus Sunday school. When presented with information that challenges a core belief, foundational to a student's worldview, the student's belief is often reinforced or strengthened, (Batson, 1975), and this is known as worldview backfire effect. A student may rely upon motivated reasoning to seek out information compatible with existing belief structure and worldview, rather than reshaping worldview or rejecting core beliefs.

Cognitive Development: Piagetian Constructivism

Piaget described how humans begin to learn from birth by developing schemes in the mind that help to guide behavior, (Piaget, 1937/1952). Learning, according to Piaget, involves two processes collectively known as adaptation. Learners will either assimilate new information in terms of existing schemes or they may modify existing schemes to accommodate the new information that may challenge existing schemes, (Piaget, 1937/1952). A central tenet of Piaget's theory involves the process of equilibration where the balance between assimilation and accommodation is struck as children develop more sophisticated schemes to account for the range of phenomenon encountered throughout development. "When anyone, scientists or non-scientist, approaches matters of science, their approach is in the context of pre-existing mental constructs, i.e. an individual's philosophical background and assumptions," (Kantor, cited in Blackwell, 2003, p. 63).The belief in theistic evolution, or God-guided evolution may exist due to a process of accommodation for students reconciling belief in the Bible and God and belief in the evidence for evolution, (Winslow, 2008). Many Young-Earth Creationists believe in a literal interpretation of the Bible and tend to reject theistic evolution (Mitchell, 2012). The application

of worldview theory helps one understand how a worldview informed by Biblical literalism would lead a student to entertain unscientific explanations for observed phenomenon and reject a wide range of scientific evidence from many fields including important conclusions about the nature of the world and universe from astronomy, geology, and biology. Answers in Genesis, an organization that supports Young-Earth Creationism, offers their own sequence of courses on the previously mentioned disciplines and their curricula is founded upon unscientific principles such as supernatural causation and therefore students who learn from such a perspective are not really learning science. Certainly, not everyone is exposed to such a biased curriculum, but such a curriculum does exist, (answersingenesis.org/education/online-courses/, accessed June 24, 2016). Individuals who are raised in a social environment where Creationism is the accepted belief structure will likely develop a similar set of beliefs which may include negative feelings toward the theory of evolution. Whether or not students maintain worldviews adopted early on in life and the extent to which worldviews are modified are dependent on both cognitive and social factors, (Evans, 2001). Thus, an important consideration and complement to Piaget is Vygotsky's theory of social constructivism. "Jean Piaget's so-called biological perspective is often paired with the viewpoint of Lev Vygotsky when we speak of learning in humans," (Alves, 2014, p. 24).

Vygotsky's Social Constructivism

How does the social environment of childhood construct and shape persistent worldviews regarding religion, and other ways of knowing including science?

Learners construct knowledge by building upon existing schemes and scaffolding up toward more complex concepts, (Slavin, 2006). This theory includes ideas like the zone of proximal development and the more knowledgeable other, (Vygotsky, 1935/2011). For infants,

this more knowledgeable other is likely the parent or caregiver, but could potentially be anyone. The zone of proximal development is defined by Vygotsky (1935):

> The distance between the level of his actual development, determined with the help of independently solved tasks, and the level of possible development, defined with the help of tasks solved by the child under the guidance of adults or in cooperation with more intelligent peers.

Within this definition the role of the more knowledgeable other is embedded. The more knowledgeable other is the adult or "more intelligent peer" who is guiding the learner to solve tasks. The social context of the interaction between learner and more knowledgeable other is important, especially early, when mental schemes are first formed. Families who believe in a worldview associated with Biblical literalism and Creationism help young children construct a similar worldview, (Wamsley, 2015). For example, imagine the different social context of a public school teacher and a Sunday school teacher working with young students. The expectations and mandates are different for these unique settings.

A student who has developed a mental scheme of Biblical Creation as an explanation of life's diversity will not easily be able to assimilate the information that may be learned in a biology class covering evolution. The student will likely reject the theory of evolution. Another possibility is modification of the creation scheme and accommodating the evidence for evolution in a scheme of theistic evolution where the mechanisms of evolution are accepted and the belief in God as directing evolution is maintained. The diversity of beliefs along a creation-evolution continuum is explored in greater depth in the review of literature. The process of equilibration, where new information is received and reconciled into a coherent framework, that is central to Piaget's theory may indeed take years, if at all, and the social environment of the learner outside of biology class has considerable impact on how evolution will be received, (Brem et al., 2003;

Long, 2012, Winslow et al., 2012). Biology instructors who recognize this possible impediment to learning may focus on the nature of science, which is shown to improve students' acceptance of evolution, (Scharmann et al., 2005; Southerland & Scharmann, 2013). To focus on the nature of science as a way of knowing while simultaneously respecting other ways of knowing, the nature of science honors students' worldview and demonstrates the compatibility of ideas that may have previously been thought irreconcilable. Wise, (1998) writes:

> As scientists, we must emphasize repeatedly that the argument against creationism is not against religion as such but rather against a fringe group's attempt to force the Bible into the public schools in the guise of a science textbook.

Theistic evolution is different than natural evolution, or non-theistic evolution which relies on entirely natural processes. Those who believe in natural evolution are in a minority as only 9-16% of Americans believe in purely natural evolution, (Gwon, 2012). For Americans who attend church at least weekly, the opinion is roughly split between those who believe in evolution and those who do not. This equal divide disappears into a majority for those who believe in evolution when looking at the group of Americans who attend worship services less than weekly, (Funk & Alper, 2015). This indicates an important fraction of people who have complex and mature views on the theory of evolution and belief in God, (Miller, 1999; Winslow, 2012; Gwon, 2012).

The theory of motivated reasoning explains such a stance in terms of the balance between accuracy goals and directional goals. Constructivist theories help to explain how the social context of learning influences what sort of directional goals may be sought. The first principle of science learning is that "concepts are acquired early in life," (Novak, 2006).

Early Childhood Evolution Education

In the State of Florida, the first specific evolution standards are introduced in third grade science with the following two standards:

> SC.3.L.15.1 Classify animals into major groups (mammals, birds, reptiles, amphibians, fish, arthropods, vertebrates and invertebrates, those having live births and those which lay eggs) according to their physical characteristics and behaviors.
>
> SC.3.L.15.2 Classify flowering and nonflowering plants into major groups such as those that produce seeds, or those like ferns and mosses that produce spores, according to their physical characteristics, (cpalms.org).

The single fifth grade Next Generation Sunshine State science standard that addresses evolution:

> SC.5.L.15.1: Describe how, when the environment changes, differences between individuals allow some plants and animals to survive and reproduce while others die or move to new locations, (cpalms.org).

Evolution is not covered in fourth grade science, and is not mentioned by name until seventh grade science standards in the state of Florida. There are nine specific evolution standards belonging to the high school Biology I course out of 85 total course standards.

Some argue for the introduction of evolutionary concepts much earlier in the curriculum than is traditional, (Nadelson et al., 2009). Kelemen et al., (2014) argue for the use of interventions with elementary school students to address natural selection to avoid misconception:

> Misconceptions are rooted in cognitive biases found in preschoolers, yet concerns about complexity mean that adaptation by natural selection is generally not comprehensively taught until adolescence. This is long after untutored theoretical misunderstandings are likely to have become entrenched.

Kelemen's argument favors the Vygotsky view that learning can inspire cognitive growth, whereas the predominant Piagetian view is that development precedes learning. Certainly this line of reasoning informs sequencing of curricula, but studies like that of Kelemen et al. suggest the introduction of complex ideas like evolution may be appropriate far earlier through novel interventions like storybooks with pictures. Using storybooks to teach kindergartners evolution is criticized by those in the Intelligent Design-Creationist camp as indoctrination, (Chaffee, 2016).

Indoctrination

Indoctrination has many definitions and by some of these definitions any form of schooling could be considered indoctrination, (Young, 1984). Indoctrination as the teaching of doctrines as infallible that shouldn't be questioned is not in line with the nature of scientific thinking which calls for scientists to "question everything," (Tyson, 2014). The idea that proper education defuses the power of indoctrination is apt. By teaching students genuine problem solving and critical thinking skills, students are better equipped to resist indoctrination, (Cuypers & Haji, 2006).

Before even entering formal schooling, children learn in the social context of their family and the social networks connected to the family or home environment. For students that are raised to believe certain theology or ideology, the roots of these schemes go deep. "Social influences, e.g. belonging to a religion, are more a function of your family's beliefs than original belief of your own," (Mazure, as cited in Williams, 2009, p. 1256). For example, if a student believes in a Young Earth Creationist view, then the belief in a young age of the Earth is in direct conflict with modern conclusions of geology, (Winslow, 2008). This Young Earth Creationist view is grounded in Biblical literalism where the generations from Jesus to Adam can be counted and therefore the age of the Earth can be approximated at perhaps 10,000 years old, (Scott,

2004). Two of the items on the Measure of Acceptance of the Theory of Evolution, a common instrument utilized in evolution education research, address this belief with the items: "The age of the earth is less than 20,000 years," and "The age of the earth is at least 4 billion years," (Rutledge & Warden, 1999). A student who has developed a mental scheme for a literal interpretation of Genesis, which many Young Earth Creationists hold, will not be easily persuaded to accept evolution even after instruction on the theory of evolution, (Long, 2012). Students can rely on more affective goals to motivate their reasoning, to avoid the uncomfortable cognitive dissonance which would arise by reliance on a motivation for accuracy goals alone, (Kunda, 1990). Powerful directional goals like the need to be accepted by family and peer groups, (Brem et al., 2003; Long, 2012; Hill, 2014), and the desire to not burn in hell are powerful motivators for students who hold such beliefs to reject the theory of evolution. Students who hold certain Creationist beliefs may feel that accepting evolution will condemn the student to eternal damnation and students therefore reject the theory, often times before instruction even begins, (Wamsley, 2015). The logical appeal of the theory of evolution as a motivation to be accurate is insufficient to compete with such strong directional motivations certain students possess. Appealing to the cognitive domain alone is inadequate to get students to accept the theory of evolution if students already possess an entrenched belief regarding Biblical creation, (Cobern, 1996). In fact, such an approach may cause a so-called worldview backfire effect, where the student believes even more strongly in information that has been challenged, (Batson, 1975).

Rather, the nature/philosophy of science serves as an additional scheme to provide students a "place to stand" (Scharmann et al., 2005; Scharmann, 1990), so they may learn about evolution and perhaps eventually accept evolution without rejecting their religious worldview,

but perhaps accommodating evolution through a position of "theistic evolution" (Winslow, 2008).

Motivated Reasoning

The theory of motivated reasoning helps to explain why individuals accept or reject different ideas, "it is now clear that directional goals do affect reasoning. People are more likely to arrive at those conclusions that they want to arrive at," (Kunda, 1990, p. 491). Directional goals are those that direct or motivate someone in a predetermined direction towards a biased conclusion, "People rely on cognitive processes and representations to arrive at their desired conclusions, but motivation plays a role in determining which of these will be used on a given occasion," (Kunda, 1990, p. 481). The theory of motivated reasoning explains why individuals may reject an idea like the theory of evolution even after instruction, especially if the learner feels that the theory of evolution contradicts an established belief like Creationism, "Biology teachers regularly encounter students who understand evolutionary theory but do not believe that it is true," (Smith & Siegel, 2004, p. 566):

> When dealing with students who have fundamentalist religious views or who come from cultures (e.g., parts of the southern U.S.) where such views are prominent, the mere use of the word *believe* in the same sentence with the word *evolution* is likely to raise a red flag in the minds of many. Such students have been taught that one cannot "believe in God and evolution" and that evolutionist biology teachers will try to turn them into atheists.

Learners may actively, or perhaps subconsciously, seek out information that supports a position to which a predisposition exists. Organizations such as Answers in Genesis, the Institute for Creation Research, the Discovery Institute, and the Biologic Institute serve as examples of the misinformation machinery that perpetuate rejection of the central theory of biology, despite overwhelming consensus among scientists who support evolution, (Forrest, 2007, 2005; Wiles,

2010). Ease of access to information makes it easier than ever for those with a preconceived disposition informed by a religious worldview to seek out information that presents itself as scientific, but does not come close to the strict standards of science. Rather, a religious philosophy may disguise itself as scientific. This is the hallmark of the pseudoscientific endeavor of intelligent design creationism. The following quote is found on the Answers in Genesis website, (Mitchell, 2012):

> We share not a common ancestor but a common Designer. God used similar genetic building blocks to produce features needed in similar sorts of organisms. God created each kind of organism and equipped each with the DNA information to reproduce after its kind.

The above quote invokes supernatural causation and so does not meet criteria for a scientific explanation; furthermore, it is not testable, (Scott, 2004). The statement would offer a learner with a Creationist belief system an opportunity to assimilate scientific evidence into the Creationist scheme, and therefore such a learner may accept lines of scientific evidence, while perhaps still rejecting the theory of evolution. "One of [intelligent design]'s most attractive elements is the way in which its proponents have couched it in the language of modern science," (Miller, 2008, p. 74). Researchers have explored the differences between understanding and belief, (Cobern, 1996; Hermann, 2012; Probiner, 2016), the Inventory of Student Evolution Acceptance highlights the utility of gauging students' acceptance of evolution as a line of evidence to examine prior instruction and inform future instruction. Certain items on the I-SEA specifically measure students' attitudes of evidence for a construct within the theory of evolution. Unscientific explanations are offered by organizations like Answers in Genesis and the Discovery Institute and the desire to create such elaborate unscientific propaganda, (Forrest,

2007, 2005), can be understood through the framework of motivated reasoning; Kunda, (1990, p. 13).writes:

> Indeed, it seems possible that accuracy goals, when paired with directional goals, will often enhance rather than reduce bias. This is because the more extensive processing caused by accuracy goals may facilitate the construction of justifications for desired conclusions. Thus people expecting to incur heavier costs if their desired beliefs turn out to be wrong may expend greater effort to justify these desired beliefs.

The Intelligent Design movement and the predecessor Creation Science are examples of great effort spent to justify desired beliefs and in so doing damaging the practice of science and weakening the power of scientific knowledge. This issue has been framed previously as a fight for "America's scientific soul", (Miller, 2008). Religious beliefs and the scientific understanding of biology need not be in conflict (Miller, 1999; Winslow et al., 2012), but only through an exploration of the nature of science and educating students about epistemology and ontology can students develop mature views on scientific ways of understanding and other equally valuable and valid ways. When viewed through a lens of motivated reasoning, the long history of Creation Science and Intelligent Design is understood more clearly. Individuals who identify strongly with certain religious groups, and those possessing mental schemes of Creationism and Biblical literalism can be highly cognitively reflective, but only focusing on evidence that supports a preexisting worldview. Kahan, 2013, p. 407 writes:

> Subjects who scored highest in cognitive reflection were the *most* likely to display ideologically motivated cognition. These findings corroborated an alternative hypothesis, which identifies ideologically motivated cognition as a form of information processing that promotes individuals' interests in forming and maintaining beliefs that signify their loyalty to important affinity groups.

Church groups and their associated extended social networks significantly impact the worldview and belief structure of members of the group, (Evans, 2001; Long, 2012; Hill, 2014). Some members perhaps even grow up to become high school biology teachers. The results of the 2007 National Survey of High School Biology Teachers showed 13% of high school biology teachers nationally teach creationism or intelligent design, contrary to law, (Berkman & Plutzer, 2011, Kitzmiller v. Dover, 2005).

Despite overall graduation rates in the United States consistently topping well above 70 percent (National Center for Educational Statistics, nces.ed.gov, n.d.), the public acceptance of the theory of evolution among Americans is usually less than 50 percent, (Miller et al., 2006). The theory of motivated reasoning helps to explain why even after instruction in biological science students may reject the theory of evolution (Hill, 2014). A noteworthy contributor of this problem is that only 28% of high school biology teachers strongly advocate for the theory of evolution, (Berkman & Plutzer, 2011). The science of biology is required instruction for every high school graduate in the state of Florida. The Florida standards belonging to high school biology courses address the theory of evolution adequately, (Lerner, quoted in Almandsmith, 2007).

"Public opinion about human origins is filled with nuance, complexity, and uncertainty," (Gwon, 2012). "The statistically significant contributors to this model [Creationism model] are evolutionary science knowledge, the Right-wing-authoritarianism scale, being male, religious tradition, frequency of church attendance, belief in God's existence, views of the Bible," (Gwon, 2012, p.114). Knowledge of evolutionary science shows up as just one contributor to predicting whether or not one may accept or reject evolution for this particular model. This finding supports

the theory of motivated reasoning, as many factors contribute to the likelihood of acceptance or rejection of the theory of evolution beyond just knowledge of evolutionary science.

The I-SEA is an instrument that is designed to shed light on the issue of student acceptance of evolutionary theory at a level where practical questions regarding curriculum design and lesson planning based on components of the theory of evolution may be answered. This study adds to the body of research on evolution education by utilizing the Inventory of Student Evolution Acceptance to study a unique population of college students studying biology.

Research Questions

(1) What are the levels of acceptance of the theory of evolution among Central Florida college students studying biology?

This research question was chosen to expand upon the data collected by Nadelson and Southerland (2012) in developing the instrument to be utilized in this study—the Inventory of Student Evolution Acceptance. Previous studies of student acceptance of evolution for students in the "Deep South" (Rissler et al., 2014), haven't focused on the geographic region of Central Florida and the unique demographics represented therein.

(2) What is the difference in acceptance of three components of the theory of evolution: microevolution, macroevolution, and human evolution, among college students?

This research question was chosen to utilize the power of the I-SEA instrument as it was developed to examine student levels of acceptance of evolution within each of the three subscales: microevolution, macroevolution, and human evolution. By examining student levels of acceptance of evolution at a more fine-grained scale, instructors and instructional leaders can develop and refine instruction in biology to maximize student acceptance of the theory of evolution.

(3) What is the difference in acceptance of evolution for students who took an advanced biology course, students who took Biology I Honors, and students who took Biology I in high school?

This research question was chosen to examine the possible strength of the correlation to previous high school coursework and student acceptance of evolution. This information may prove useful for curriculum development and course offerings for high school students leading to college readiness.

(4) What is the difference in acceptance of evolution for students who attend worship services weekly or more and those who attend worship services less than weekly?

This research question was selected to explore the previously discovered strong correlation between religiosity and rejection of the theory of evolution, (Blackwell et al., 2003; Brem et al., 2003; Southerland & Scharmann, 2013; Hill, 2014; Rissler et al., 2014). Utilization of the Inventory of Student Evolution Acceptance to explore this research question may shed light on particular aspects of the theory of evolution that are commonly accepted or rejected by students as a function of their frequency of attending worship services.

Delimitations

(1) The study is delimited to request data from students attending Eastern Florida State College, Valencia College, Seminole State College, Daytona State College and the University of Central Florida. While Institutional Review Board applications were sent to each of the institutions listed above, only the University of Central Florida and Daytona State College approved the application to conduct research, and only biology instructors from the University of Central Florida agreed to assist in the data collection.

(2) The study is delimited to examine only data from students taking a college level biology course.

Limitations

(1) A limitation of this study is that a convenience sample of students enrolled at the University of Central Florida will be utilized. The representativeness of this sample to a broader population will be examined from demographic information obtained in the survey instrument.

(2) Another limitation of this study is the self-reported nature of the data collected from the survey instrument. The extent to which students accurately answer questions is unknown and is thus recognized as a limitation.

(3) A limitation associated with research question three is the time gap between high school biology coursework and the time university students may take the I-SEA. For junior and senior undergraduates, high school biology would have taken place perhaps two or three years prior with college-level biology instruction occurring in between. This fact certainly may diminish the impact of high school biology class(es) on current acceptance of evolution in junior and senior level students and to some degree sophomores as well. Recognition of this limitation led naturally to the question of how do levels of acceptance of evolution vary with grade level in college students—from freshmen year to senior year? The analysis of this question is included in the additional findings.

(4) A limitation that must be recognized is the strength of the assumption that the behavior of attending worship services weekly or more translates into the person exhibiting such behavior as also possessing a religiously oriented worldview and the conclusions drawn in this study connect such a worldview with low level of acceptance of evolution, rather than connecting low level of acceptance of evolution with the behavior itself. In other words, one may argue that those who attend worship service weekly or more aren't able to spend enough time studying evolutionary biology and this lack of time is why their acceptance is lower, but this

laughable (yet possible) conclusion is not the assumption made in this study where the behavior of attending worship services is assumed to be connected to the possession of a religiously oriented worldview.

Organization of the Study

This study is organized into five chapters:

Chapter one is an introduction where the problem of practice is stated. The purpose of the study is described. The definitions of key terms are contained in chapter one. The significance of the study is explained, and the conceptual framework that underpins the study is laid out. The research is focused into four research questions which are included in chapter one along with the delimitations and limitations of the study.

Chapter two provides a review of the relevant literature. The literature review is subdivided into sections covering the relevant law regarding biology education in Florida, the broader context of the history of teaching evolution and Creationism in public schools in America, the continuum of Creationist worldviews and the organizations that support and help perpetuate these beliefs, how learners form belief systems in general and student acceptance of evolution specifically. The teaching methods found to be effective in increasing student understanding and acceptance of evolution will also be covered in the literature review.

Chapter three describes the research methodology employed to answer the research questions. A description of the population and sample, data collection methods and procedures will be included in chapter three. A detailed description of the statistical tests that will be conducted with the collected data will be explained in chapter three and connected to how these tests may answer the research questions.

Chapter four presents the analysis of the data. The analysis will focus on the specific research questions posed, but will not be limited to these analyses.

Chapter five includes the conclusions drawn, and discusses implications of the research for the practice of science teaching. Recommendations for practice and recommendations for future research are included in chapter five as well as additional findings.

CHAPTER TWO: LITERATURE REVIEW

Evolution Education in Twenty-First Century Sciences

In the first few decades of the twenty-first century, humanity has witnessed advances in many scientific fields and the pace of discovery is accelerating. For biology, advances such as the discovery of clustered regularly interspaced short palindromic repeats, or CRISPR in DNA along with their associated proteins, Cas, and their utility and ease of use in gene editing systems has changed the way biology research is conducted including in fields of evolutionary biology, (Callaway, 2016).

In astronomy, the discovery of thousands of exoplanets—planets outside of the solar system that orbit a star other than the Sun-- confirms with near certainty the existence of countless other exoplanets. A potential Earth-like planet has been discovered in the nearest star system, Proxima Centauri, (Anglada-Escudé, et al., 2016), and this is just one among many other exoplanets that seem Earth-like. Seven earth-like planets were discovered in a system, TRAPPIST-1, which is about forty light-years away—practically right down the road from a cosmological perspective. "Using a one-dimensional cloud-free climate model that accounts for the low-temperature spectrum of the host star, we deduce that planets e, f and g could harbour water oceans on their surfaces, assuming Earth-like atmospheres," (Gillon et al., 2017, p. 458). This study is further evidence of potential Earth-like habitats because the star TRAPPIST-1 is a red dwarf star, and these stars are the most abundant in the Universe. An atmosphere was recently discovered in an Earth-sized exoplanet, GJ1332b, (Southworth et al., 2017). These discoveries have opened up the possibility of exobiology as a field of study. Exobiology is the study of life outside of Earth, (Chela Flores, 1998) and relates to the field of astrobiology, (Lineweaver, 2008). Andrew Knoll of Harvard University has discussed models of coevolution

where the organisms that evolve on a planet also help to shape and change the environment over very long time scales, (Knoll, 2009). An example of this concept is the oxygenation of Earth's atmosphere thanks to photosynthetic organisms. Human evolution and the coevolution of humankind with Earth has already been characterized in the modern era as the Anthropocene or "age of the humans". Human activity dominates changes on Earth at present, "…astronomical and geophysical forcings in the Holocene, and perhaps even through the entire Quaternary, approximate to zero compared with the impact of current human pressures on the rate of change of the Earth System," (Gaffney & Steffen, 2017, p. 3). These scientific theories beg incredibly important questions for twenty-first century scientists to pursue including: How abundant is life in the cosmos and how often does life succeed in developing measures of intelligence? And, how can humans coexist sustainably on Earth with other life symbiotically?

The theory of evolution serves as the centerpiece of an impressive explanation of life's diversity on Earth and life's interrelationship with the Earth itself. Scientific organizations like the American Association for the Advancement of Science (AAAS), the National Research Council (NRC), and the National Science Teachers Association (NSTA) have all published statements and even entire books advocating for the centrality of evolutionary theory to biology curricula. (NSTA, 2013; National Academy of Sciences, 2008; AAAS, 2006). To prepare the scientists of the twenty-first century, students must understand the most powerful explanation that science has to offer for understanding life—the theory of evolution.

Educational leaders are tasked with the challenge of providing the best possible education to students in a culture that respects diverse worldviews. Educational leaders must be aware of and abide by the mandates put in place from the State and Federal levels, but sometimes must navigate these mandates respecting the segments within in a local culture that may be averse to

the teaching of evolution. Educational leaders should understand the broad context in which evolution education has itself evolved in American education since the time Darwin published *On the Origin of Species* in 1859 to the Scopes Trial in 1925 to the lesson of a Maine school teacher, Lou Sullivan in 2015. Sullivan, an elementary school teacher, taught a lesson which included a discussion of intelligent design and ultimately caused a letter from the American Civil Liberties Union to be sent to the superintendent of schools in New Brunswick to protest the lesson. By educating educators about the unconstitutionality of teaching Intelligent Design-Creationism, educational leaders may impact the scientific literacy of the students and teachers following their leadership.

Case law of particular concern to educational leaders considering science education specifically includes several Supreme Court rulings, perhaps most notably Edwards v. Aguillard in 1987, which banned the teaching of Creationism in public school on establishment clause grounds; the teaching of Creationism establishes religion which violates the First Amendment of the United States Constitution, (Edwards v. Aguillard, 1987). A Federal court ruling of concern to educational leaders is the Kitzmiller v. Dover Area School Board case of 2005 which conclusively demonstrated the manner in which Creationism was repackaged as intelligent design following the Edwards v. Aguillard decision, (Kitzmiller v. Dover Area School Board, 2005), and so demonstrated the unconstitutionality of teaching intelligent design in public schools. Understanding the case law related to the teaching of the theory of evolution provides context for the issues surrounding evolution education. In Florida, the law today is clear regarding the importance of biology education and the focus on the theory of evolution within the teaching of biological science, and still challenges to the teaching of evolution have been

launched in Florida since the adoption of stronger science standards, the Next Generation Sunshine State Standards, in 2007.

The following review of literature explores the relevant Florida statutes and educational standards related to biology education and the theory of evolution. This review provides the context for state mandates which educational leaders in Florida must follow related to evolution education. The specific challenges that have been launched against the theory of evolution in Florida and their origin in the Discovery Institute's "Model Bill" (Matzke, 2015), will be explored and set against the national context of case law related to the teaching of the theory of evolution going back to the trial of John Scopes in 1925, who served as advocate for the teaching of the theory of evolution to challenge a Tennessee law—the Butler Act-- which prohibited the teaching of evolution, (Scopes v. Tennessee, 1925). The mandates put in place from the Federal level which have evolved from the time of Scopes over the past nine decades are relevant to educational leaders and are spelled out in the case law reviewed.

The final section of the review of literature will explore worldview theory—the theory that provides the overarching conceptual framework for the current study. Literature related to the nature of science and the affective domain as powerful and important learning tools to increase knowledge, understanding, and acceptance of the theory of evolution in students will also be reviewed.

State Mandates: Florida Statutes Related to Required Biology Instruction

Florida statute 1003.42, a portion of which is included below, spells out the requirement for Florida students to take a course in Biology. In order to receive a standard high school diploma, Florida high school students must also take a statewide standardized Biology end of course exam.

> F.S. 1003.4282 Requirements for a standard high school diploma.— (c) Three credits in science.—Two of the three required credits must have a laboratory component. **A student must earn one credit in Biology I** and two credits in equally rigorous courses. The statewide, standardized **Biology I EOC assessment** constitutes 30 percent of the student's final course grade. A student who earns an industry certification for which there is a statewide college credit articulation agreement approved by the State Board of Education may substitute the certification for one science credit, **except for Biology I**.
>
> F.S. 1008.22 Student assessment program for public schools.— (b) End-of-course (EOC) assessments.—EOC assessments must be statewide, standardized, and developed or approved by the Department of Education as follows:
>
> 1. EOC assessments for Algebra I, Geometry, Algebra II, **Biology I**, United States History, and Civics shall be administered to students enrolled in such courses as specified in the course code directory.

From this language included in the Florida State Statutes it is apparent that all students take Biology I as part of their high school coursework and all students must take an End of Course examination for Biology. The importance of biology education is underscored in these statutes by the fact that industry certification may substitute one of the three required science credits, except for Biology I, meaning that Biology is not a science course that can be avoided. Biology I is the only science course for which a statewide end of course examination exists, further evidence of Florida's emphasis on the importance of Biology education. Writing about Darwin's theory of evolution, editor of the American Biology Teacher, the journal of the National Association of Biology Teachers, stated, "Clearly, this extraordinary concept must inform biology instruction at every level…just as nothing makes sense in the biological sciences without evolution, we cannot consider ourselves biology teachers without it either. Biology education is evolution education," (McComas, 2016).

State Mandates: Next Generation Sunshine State Standards

Belonging to the course description of Biology I are the following standards specifically related to the teaching of scientific theories in general and the theory of evolution specifically:

> SC.912.N.2.1: Identify what is science, what clearly is not science, and what superficially resembles science (but fails to meet the criteria for science). Remarks/Examples: Science is the systematic and organized inquiry that is derived from observations and experimentation that can be verified or tested by further investigation to explain natural phenomena (e.g. Science is testable, pseudo-science is not; science seeks falsifications, pseudo-science seeks confirmations.)

This standard directly emphasizes the importance of having students learn how to evaluate endeavors as scientific or not. This standard is important to educate students about pseudo-scientific ideas like intelligent design-creationism, and through this nature of science standard teachers may address questions about intelligent design that students may pose, recognizing first that intelligent design is not a competing theory with evolution as intelligent design is not a scientific theory, (Kitzmiller v. Dover Area School Board, 2005).

> SC.912.N.2.2: Identify which questions can be answered through science and which questions are outside the boundaries of scientific investigation, such as questions addressed by other ways of knowing, such as art, philosophy, and religion.

This standard, which encapsulates the idea of the bounded nature of science, has been shown to be an effective path to educating students about science as a way of knowing that is different from other ways of knowing, (Southerland & Scharmann, 2013). By focusing on the criteria for science included in the previously listed standard, teachers may educate students about the epistemology of science and its boundaries. An extraordinary example from the history of science regarding the bounded nature of science can be found in an essay written by the great

Scottish physicist James Clerk Maxwell who famously expressed the laws of electromagnetism in his famous equations known as Maxwell's equations and also calculated the speed of electric waves as the known speed of light and so too was the first to realize that light was also an electromagnetic phenomenon which lead to the discovery of radio waves and revolutionized human society. In an essay entitled *Molecules* (1873), Maxwell captures the bounded nature of science elegantly:

> Thus we have been led, along a strictly scientific path, very near to the point at which Science must stop. Not that Science is debarred from studying the internal mechanism of a molecule which she cannot take to pieces, any more than from investigating an organism which she cannot put together. But in tracing back the history of matter Science is arrested when she assures herself, on the one hand, that the molecule has been made, and on the other that it has not been made by any of the processes we call natural.
>
> Science is incompetent to reason upon the creation of matter itself out of nothing. We have reached the utmost limit of our thinking faculties when we have admitted that because matter cannot be eternal and self-existent it must have been created.

Focusing on the bounded nature of science is a powerful educational tool to expose students to the science of epistemology and to recognize that different ways of knowing follow different norms and have different standards of practice and evidence. Another relevant nature of science standard included in the Florida Department of Education approved course Biology I follows:

> SC.912.N.3.1: Explain that a scientific theory is the culmination of many scientific investigations drawing together all the current evidence concerning a substantial range of phenomena; thus, a scientific theory represents the most powerful explanation scientists have to offer.

(From Biology I Course Description retrieved from www.cpalms.org/Public/PreviewCourse/Preview/13083).

This nature of science standard is important to educate students about the role and meaning of the often confused or conflated concepts of hypotheses, laws, theories, and models. To call evolution a theory is not to take away from its power, on the contrary, a theory is the most powerful explanation scientists have to offer.

The three standards so far listed fall under the strand of nature of science standards and were included in the literature review because of their importance and relevance to studies conducted demonstrating the link between emphasis on the nature of science and improved student outcomes in understanding concepts of biological evolution, (Scharmann, Smith & James, 2005; Butler, 2010; Southerland &Scharmann, 2013). The other set of standards included in the literature review serves to showcase the emphasis on evolution on biological science education. These standards not only serve as an important set of State level mandates of which educational leaders should be aware, but also serve as a great launch pad to excellent science instruction. Educational leaders who embrace the ideas contained in the evolution standards will more readily cultivate a climate of genuine scientific inquiry which leads to increased scientific literacy for students and teacher-researchers alike.

> Standard 15: Diversity and Evolution of Living Organisms
> A. The scientific theory of evolution is the fundamental concept underlying all of biology.
> B. The scientific theory of evolution is supported by multiple forms of scientific evidence.
> C. Organisms are classified based on their evolutionary history.
> D. Natural selection is a primary mechanism leading to evolutionary change.
> SC.912.L.15.1: Explain how the scientific theory of evolution is supported by the fossil record, comparative anatomy, comparative embryology, biogeography, molecular biology, and observed evolutionary change.

SC.912.L.15.4: Describe how and why organisms are hierarchically classified and based on evolutionary relationships.

SC.912.L.15.5: Explain the reasons for changes in how organisms are classified.

SC.912.L.15.6: Discuss distinguishing characteristics of the domains and kingdoms of living organisms.

SC.912.L.15.8: Describe the scientific explanations of the origin of life on Earth.

SC.912.L.15.10: Identify basic trends in hominid evolution from early ancestors six million years ago to modern humans, including brain size, jaw size, language, and manufacture of tools.

SC.912.L.15.13: Describe the conditions required for natural selection, including: overproduction of offspring, inherited variation, and the struggle to survive, which result in differential reproductive success.

SC.912.L.15.14: Discuss mechanisms of evolutionary change other than natural selection such as genetic drift and gene flow.

SC.912.L.15.15: Describe how mutation and genetic recombination increase genetic variation.

(Retrieved from www.cpalms.org/Public/PreviewCourse/Preview/13083).

These standards are accessible through the website cpalms.org, an online repository of sample lessons teachers upload related to the Florida standards. For example, it is worth repeating that under the category of life science, the high school standard entitled *Diversity and evolution of living organisms* has the first sentence reading: "A. The scientific theory of evolution is the fundamental concept underlying all of biology," (Retrieved from http://www.cpalms.org/Public/PreviewIdea/Preview/586). The state of Florida has recognized in their standards the importance of evolution in the study of biological science. As of March 26, 2017, there are 147 resources belonging to this standard on the cpalms.org website. These resources are uploaded by the teachers who craft lessons to address the standards and offer them

in good will to help other teachers who may be looking for resources to address the same standards in their own classes.

The language of these standards clearly spells out the importance of the theory of evolution as it relates to understanding and explaining life. High school biology teachers honor the discipline of biology when the central and core idea of the field is also the core focus of the classroom, (National Academy of Sciences, 1998). Many organizations and evolution education researchers have called for the focus of biology classrooms to center on evolution particularly because it is a good example to teach students the nature of science. "Teaching about evolution has another important function. Because some people see evolution as conflicting with widely held beliefs, the teaching of evolution offers educators a superb opportunity to illuminate the nature of science and to differentiate science from other forms of human endeavor and understanding," (National Academies Press, 1998). A similar view is held by Pennock (2005, as quoted in Scharmann & Butler, 2015):

> Evolution, as one such fundamental scientific discovery, should be included as a pervasive explanatory framework in all biology courses. But teaching it as a list of facts to be learned is not enough. It ought to be held up as a model of how good science is done. Teachers need to make clear that evolution is science done right, and it is one of the best examples to illustrate the nature of science."

The theory of evolution has stood the test of time and the progress made in human understanding of life has advanced by leaps and bounds thanks to the explanation of evolution. The theory of evolution organizes research and helps formulate questions. In early February 2017, *Nature* published an article reporting the discovery of an ancient microfossil, the preserved remains of a microscopic organism that likely lived over 500 million years ago. Such a discovery is relevant because it helps biologists fill in the 'roots' of our evolutionary tree. The organism represented not just a newly discovered species or genus, but rather an entire new family Saccorhytidae and

stem group of organism Saccorhytida, (Han, et al., 2017). Discoveries such as this speak to the ongoing benefit of evolutionary theory as an organizing framework, "…collectively these findings suggest that a key step in deuterostome evolution was the development of lateral opening that subsequently were co-opted as pharyngeal gills," (Han, et al., 2017, p. 228). The quote from the author deserves further explanation. Deuterostomes are the group of organism to which humans and anything else with a backbone belong, but so do some other types of organism which don't have backbones. Thus, deuterostomes go far back on the evolutionary tree, and so the discovery of this organism helps biologists better understand a part of human evolution in a way, just much further back in time than the typical primate-like mammals one may associate with early human evolution. While the species wasn't some kind of ancient ancestor to humans, the discovery does help elucidate biologist's understanding of fundamental questions like how did our organ systems evolve? Because research like the discovery of this microfossil helps to piece together the puzzle of human origins, it ultimately touches on the same subject matter as many religious beliefs which also explain human origins. Failure to observe coherence or compatibility between beliefs may lead to the rejection of one or the other opposing beliefs. Science educators must be aware of the bounded nature of science and help students 'identify what questions are outside the boundaries of science' as the previously referenced Florida nature of science standard states. That particular nature of science standard specifically mentions religion as another way of knowing and so through the bounded nature of science, students may come to accept evolution without rejecting their religious worldview, if one is held. The bounded nature of science has been proven an effective educational strategy in teaching students the theory of evolution, (Southerland & Scharmann, 2013). The wealth of research that suggests instruction in the nature of science leads to increased understanding and acceptance of

the theory of evolution is evidence of a positive feedback cycle where the theory of evolution is good content to teach scientific methods and epistemology and knowledge of such philosophy of science leads to increased acceptance and understanding of the theory of evolution.

Despite clear best practices and a wealth of resources available to high school biology teachers on teaching the theory of evolution, (Carter et al., 2015), Berkman and Plutzer found that only 28% of high school biology teachers in the United States strongly advocate for the theory of evolution, (Berkman & Plutzer, 2011). The evolution and nature of science standards were adopted in Florida in 2007, but the history of the teaching and learning of evolution goes back much further and the consequences of the evolution polemic are felt in biology classrooms.

Most high school biology teachers do not adequately address the most central theory of their discipline, (Berkman & Plutzer, 2011). "The contemporary theory of biological evolution is one of the most robust products of scientific inquiry. It is the foundation for research in many areas of biology as well as an essential element of science education," (AAAS Resolution, 2013). Based on data collected in the 2007 National Survey of High School Biology Teachers, 60% of high school biology teachers fall into a middle group of teachers who "cautiously" avoid the subject of evolution in their biology classroom in favor of focusing on other aspects of the curriculum, (Berkman & Plutzer, 2011). A flagrant minority of high school biology teachers teach Creationism or intelligent design, (Berkman & Plutzer, 2011), in clear violation of the Establishment Clause of the First Amendment of the United States Constitution which begins, "Congress shall make no law respecting an establishment of religion, or prohibiting the free exercise thereof," (US Const. amend I). The most recent three decades of a near century long legal war between evolution and creationism have consistently shown creationism to be an

establishment of religion, (Epperson v. Arkansas, 1968, McLean v. Arkansas, 1982, Edwards v. Aguillard, 1987, Kitzmiller v. Dover Area School Board, 2005).

The importance of understanding the legal context of the teaching of evolution is essential. Not only is the case law clear regarding the rejection of establishing religious ideas in public classrooms, but the State adopted standards in Florida require high school biology teachers to rigorously teach the theory of evolution, and to teach what it means to be a scientific theory. Adherence to the precedent set in the courtroom and the legally adopted state approved standards and district approved curriculum is not strictly followed by a majority of high school biology teachers (Berkman & Plutzer, 2011, 2010). This fact is inflamed by the introduction of legislation like Florida Senate Bill 2692 in 2008, Florida Senate Bill 2396 in 2009 and Florida Senate Bill 1854 in 2011, all of which included language that would undermine the teaching the evolution and threatened to weaken science education in the state of Florida.

Challenges to Evolution in Florida since the adoption of the Next Generation Sunshine State Standards

In 2008, Florida Senate Bill 2692 was introduced by Senator Ronda Storms and this "Academic Freedom Act" included language to address an apparent gap in Florida law: "The Legislature finds that current law does not expressly protect the right of teachers to objectively present scientific information relevant to the full range of scientific views regarding chemical and biological evolution," (SB 2692, 2008). The language of this bill originates with the Discovery Institute's "Model Bill" that has been modified and included in at least 71 bills introduced in 16 states, (Matzke, 2015). The existence of such a law is redundant as teachers already possess academic freedom. The same First Amendment that correctly protects the citizenry from the government's establishment of religion protects the freedom of speech of those citizens, (US const. amend. I). While teachers possess a great deal of freedom in terms of

how they present information and how they run their individual classroom, it is often true that teachers must align their instruction to district level curricular decisions and state adopted standards. This fact was upheld in LeVake v. Independent School District 656; American high school public school teachers do not possess a great deal of academic freedom to stray from the adopted curriculum of the local school board. In LeVake v. Independent School District 656, the court found that a high school biology teacher did not have the right under free speech claims to deviate from the school district's approved biology curriculum, (LeVake v. Independent School District 656, 2000). Rodney LeVake is an empirical case of the frightening picture of biology education in America painted by Berkman and Plutzer's research, (2015, 2011). Rodney LeVake basically held a view that life's complexity cannot be explained by the theory of evolution, this misinformed view is a common one held by Creationists and now "Intelligent Design theorists", namely those fellows of the Discovery Institute's Center for Science and Culture, formerly the Center for the Renewal of Science and Culture, (Forrest, 2004). Intelligent design doesn't pass scientific muster and should not be taught in science class, (AAAS position statement, 2006), and isn't even very compelling theologically (Peterson, 2002). The history of acceptance of evolution which exists in the Catholic Church, for example, demonstrates how theologians accept science and find harmony in the belief in God and in evolution.

In 2009, Florida State Senator Stephen R. Wise introduced Senate Bill 2396 which introduced language that would amend Florida Statute 1003.42, which addresses certain areas of required instruction. Specifically, the inclusion of the language for required instruction would be amended to include the phrasing, "A thorough presentation and critical analysis of the scientific theory of evolution," (SB 2396, 2009). Although this bill was ultimately defeated, Senator Wise

introduced Senate Bill 1854 in 2011 which included the same wording regarding critical analysis of the theory of evolution. Senate Bill 1854 was also defeated.

In the AAAS statement, *On the teaching of evolution* in 2006 it reads, "The AAAS Board of Directors is deeply concerned, therefore, about legislation and policies recently introduced in a number of states and localities that would undermine the teaching of evolution…if passed, would weaken science education," (AAAS statement, 2006). The statement goes on to specifically cite the strategies used to undermine the teaching of evolution, "A number of bills require that students be taught to 'critically analyze' evolution or to understand 'the controversy'…the current controversy surrounding the teaching of evolution is not a scientific one," (AAAS statement, 2006).

Over a decade after the American Association for the Advancement of Science, issued the statement above, the then-nominee and current Secretary of Education, Betsy DeVos during her confirmation hearing, fielded a question from Senator Sheldon Whitehouse of Rhode Island who asked her if she would support junk science including intelligent design and her answer included the following: " I support the teaching of great science and especially science that allows students to exercise critical thinking and to really discover and examine in new ways,"(Confirmation hearing transcript from January 17, 2017, retrieved from www.c-span.org/video/?c4651029/sen-sheldon-whitehouse-vs-devos-creationism-junk-science). After reading the 2006 statement from the AAAS, this answer is troubling for science educators. Furthermore, Betsy DeVos' family has contributed tens of thousands of dollars to the Thomas More Law Center which among other acts, provided the legal counsel for the Dover Area school board who tried to refer students to textbooks including intelligent design-creationism which subsequently led to the Federal case Kitzmiller v. Dover Area School Board, the decision which

effectively outlawed the teaching of intelligent design in science class as an alternate to the theory of evolution. Betsy DeVos' family has also donated millions of dollars to groups like Focus on the Family which produces anti-evolution material including a "Christian worldview curriculum" known as The Truth Project which includes intelligent design-creationism, (Waldman, 2017).

The legal mind behind intelligent design is Phillip Johnson, a retired law professor and program advisor for the Discovery Institute who authored *Darwin on Trial* in 1991 and in an interview for a Public Broadcasting Station NOVA special on the Dover Pennsylvania case was quoted as saying:

> I know it can be made to sound like something sinister and conspiratorial. But the wedge strategy, as I have explained it, is quite simple and innocent. When you use a wedge to split a log, you start with the sharp edge of the wedge. My job is to be the sharp edge of the wedge, to use my academic credentials and legal abilities to get some hearing for the proposition that there really is something fundamentally wrong with the Darwinian story. But I can't answer all the questions that arise, so we need other people to form the thick edge of the wedge to take on the questions that do require a scientific expertise.

Phillip Johnson admits in this quote two things: one is that he doesn't have scientific expertise and two that he is using his "academic credentials and legal abilities to get some hearing". This contrived controversy is damaging the field of science education. A preservice biology teacher and participant in a study conducted by Berkman and Plutzer was in a focus group and stated, "No, just the whole evolution…connection to God…I wouldn't touch it…It has too many…it's too controversial, like too many negative connotations attached to it, it's just too much," (Berkman & Plutzer, 2015, p. 263). This quote is testament in part perhaps to the sad success of Johnson's strategy and perhaps also due in part to a friction that has existed between science and

religion catalyzed by Charles Darwin's publication of *On the Origin of Species* in 1859 and played out in American courtrooms and popular culture for a century.

Florida State Standards addressing the nature of science are clear. The standards which belong to Biology I related to the nature and practice of science clearly establish the acceptable boundaries under which evolution is properly taught in the broader context of scientific practice. To introduce language to "critically analyze" evolution by amending Florida Statute 1003.42 which is the statute on required instruction reserved for items like the teaching of Declaration of Independence and the Constitution is beyond ironic; its defeat is poetic justice.

Florida Senate Bill 864 is one bill that did pass and while this bill does not directly challenge the teaching of evolution it does relate to the rules by which school districts adopt instructional materials in a sense making it easier to stray from the State approved course descriptions and standards, (SB 864, 2014). A similar event occurred in Dover, Pennsylvania when the school board decided to get into a battle with local science teachers over the adoption of their preferred science text. The obviously religious text *Of Pandas and People* became a primary source of evidence in the Dover case and through Dr. Barbara Forrest's extensive examination of unpublished editions of that text it could be proven quite clearly that Creationism and Intelligent Design were the same, (Kitzmiller v. Dover Area School District, 2005). Members of the Discovery Institute disagree, (DeWolf, 2007), and this line of argumentation represents a future threat to science education. The Discovery Institute is working to legitimize intelligent design and publishes handbooks for students, educators, and parents as back to school guides to dealing with intelligent design, (see www.evolutionnews.org/backtoschoolguide.pdf, accessed February 19, 2017).

Included in the Test Item Specifications that assist Florida teachers in preparing their students for such important tests as the Biology End of Course exam which constitutes 30% of a students' grade, one of the test item specifications related to the annually assessed standards on evolution reads: "Test Item Specifications- Items will not assess the differences among intelligent design, creationism, and the scientific theory of evolution," (www.cpalms.org/Public/PreviewStandard/Preview/1992). The fact that such a statement exists in the test item specifications speaks to what Kenneth Miller, an evolutionary biologist at Brown University and key witness in the Kitzmiller v. Dover case of 2005, has called "the battle for America's scientific soul," (Miller, 2008). Proponents of intelligent design-creationism seek to change the very definition of science. Science educators and educational leaders possess a tremendous responsibility to educate students about science as a way of knowing about the natural universe. Science educators must teach students the nature and philosophy of science in order to achieve the highest levels of scientific literacy.

In 2014, a complaint against a teacher in Louisiana included allegations that "At least one science teacher treats the Bible as scientific fact, telling students that the Big Bang never happened and that evolution is a 'stupid' theory that 'stupid' people made up because they don't want to believe in God," (Lane v. Sabine Parish School Board, 2014).

Federal Mandates: Impact of Evolution Case Law on Biology Education

In 1925, the Scopes v. Tennessee decision would in part set in motion a series of events that included the pressure for textbook publishers to adopt a position similar to the "cautious 60%" of high school biology teachers today; textbook publishers stopped including Darwinian evolution in their textbooks and so in many ways it fell out of the curriculum, (Scott, 2004). This fact was acknowledged by Judge Overton in his opinion in McLean v. Arkansas, "Generally,

textbooks avoided the topic of evolution and did not mention the name of Darwin. Following the launch of the Sputnik satellite by the Soviet Union in 1957, the National Science Foundation funded several programs designed to modernize the teaching of science in the nation's schools," (McLean v. Arkansas, 1982). Entertaining nonscientific ideas in public school classrooms like creationism have been known as unconstitutional as long ago as the early 1980s. Repackaging those ideas as intelligent design and devising new terminology to continuously challenge the same unconstitutional proposition time and again in both the courtroom and in legislative sessions represents a step backwards in the scientific literacy of the populous of the nation, (Forrest, 2007). Students should be moving forward to the cutting edge of modern science armed with the best possible education of the most current interpretations of the most powerful explanations science has to offer for the natural universe including the theory of evolution, (AAAS Project 2061).

The challenge of keeping non-science out of the science classroom is one recognized by the American Federation of Teachers who state in their resolution, *"*Affirming the role of science in climate science courses" the language:

> Whereas, powerful economic interests have shown willingness to deny the existence of climate changes; and whereas, it is the responsibility of the American Federation of Teachers to preserve the integrity of science in the classroom:…Resolved, that the AFT call upon its members to assist those engaged in overseeing science education policy to understand the nature of science, the content of contemporary climate science and the inappropriateness of including non-science in our science curriculum. (AFT Resolution, 2014).

The call to action by both the AAAS and the AFT to preserve the integrity of science in the science classroom is an important one to heed. While the efforts to undermine specifically

evolutionary theory are well concentrated like a laser refined at the Discovery Institute, other areas of special interest in business or commerce may take issue with the teaching of climate science or in the past the tobacco industry wanting to discredit evidence linking smoking to cancer, "You don't have to necessarily prove an alternate theory, you just have to shed sufficient doubt on the prevailing scientific consensus. This is not an original idea. A variety of people and groups use the strategy of enabling doubt, in terms of doubting evolution, or climate change, or even, in the past, with tobacco research." (Berkman, 2015 as quoted in Swayne, 2015). The importance of educating the public in a functioning democracy cannot be overstated, (Forrest, 2007). Scientific theories as understood through the frame of the nature of science are the most powerful explanations that scientists have to offer. Teachers who strongly advocate for the theory of evolution must be aware that the law is on their side. Science continues to build an ever more impressive theoretical framework for the explanations of natural phenomenon (AAAS Resolution, 2013).

Efforts to undermine the teaching of science may take new form, but the essential thrust is the same. Organizations like the Discovery Institute sow the seeds of doubt and try to redefine science in a most unproductive and sweeping way that would permit lines of research such as astrology as permissible science, (Apsell, 2007).

Florida has experienced threats to the teaching of evolution in Senate Bills 2692, 2396 and 1854 introduced and defeated in 2008, 2009 and 2011 respectively. The AAAS statement, *On the teaching of evolution* explains, "Many of the proposed bills and policies aim explicitly or implicitly at encouraging the teaching of 'Intelligent Design' in science classes as an alternative to evolution. Although advocates of intelligent design usually avoid mentioning a specific

creator, the concept is in fact religious, not scientific," (AAAS Board of Directors statement, 2006).

The Discovery Institute, an organization that strongly promotes intelligent design, drafted a Model Bill similar to the Academic Freedom Act that was introduced in Florida in 2008. In fact, 71 variations of this bill were introduced in 16 states, (Matzke, 2015), showing the influence the Discovery Institute hopes to hold on the legislative process. This bill did become law in Tennessee and Louisiana.

In Edwards v. Aguillard, the Supreme Court struck down the teaching of Creationism in public schools as unconstitutional, (Edwards v. Aguillard, 1987). The court reasoned that Creationism was a religious idea and its inclusion in public school curriculum is prohibited by the establishment clause of the first amendment. Effectively applying what is known as the Lemon test to establishment clause cases related to the first amendment the court seeks evidence that a statute has a clear secular legislative purpose, the primary effect of the law doesn't advance or inhibit religion, and it must not excessively entangle the government with religion, (Alexander & Alexander, 2012), if the three parts of the Lemon test hold than the law could be considered as constitutional in terms of the First Amendment's Establishment clause. In Edwards v. Aguillard, (1987) and Kitzmiller v. Dover Area School District, (2005), the laws failed the Lemon test and were therefore held unconstitutional, (Kitzmiller v. Dover Area School District, 2005).

The facts of the Dover case made it clear that members of the Dover Area school board acted with religious motivation, (Kitzmiller v. Dover Area School District, 2005). Judge Jones III in his opinion in *Kitzmiller* states: "The evidence at trial demonstrates that ID is nothing less than the progeny of creationism. What is likely the strongest evidence supporting the finding of

ID's creationist nature is the history and historical pedigree of the book to which students in Dover's ninth grade biology class are referred, Pandas [Of Pandas and People]." (Kitzmiller v. Dover Area School District, 2005).

Judge Jones III denied a motion for the publishers of that textbook, Of Pandas and People, to intervene in the case before the trial started. "the publisher of Pandas, the Foundation for Thought and Ethics (FTE), sought to intervene as co-defendant. FTE filed a motion to intervene on May 23, 2005, but after hearing the motion, Judge Jones denied it on July 27, 2005," (68 Mont. L. Rev. 7. , 2007).

In the Montana Law Review article quoted above, the authors make the argument that the decision in the Dover case will not stop the Intelligent Design Movement or IDM. The authors of the article are all associated with the Discovery Institute. The title of the article, *Intelligent design will survive Kitzmiller v. Dover*, suggests that the exploitation of our system of jurisprudence to the effect of contriving false controversy to undermine science education will continue. The Florida Senate Bills introduced by State Senator Wise in 2009 and again in 2011 are examples in Florida of this effort to drive science out of the science classroom.

The American Association for the Advancement of Science on July 1, 2013 adopted their *Resolution on Intelligent Design Theory* where they state:

> Over the past several years proponents of so-called 'intelligent design theory' also known as ID, have challenged the accepted scientific theory of biological evolution. As part of this effort they have sought to introduce the teaching of 'intelligent design theory' into the science curricula of the public schools…the lack of scientific warrant for so-called 'intelligent design theory' makes it improper to include as a part of science education…AAAS urges citizens across the nation to oppose the establishment of policies that would permit the teaching

> of 'intelligent design theory' as a part of the science curricula of the public schools…AAAS calls upon its members to assist those engaged in overseeing science education policy to understand the nature of science, the content of contemporary evolutionary theory and the inappropriateness of 'intelligent design theory' as subject matter for science education. (AAAS resolution, 2013).

In *Intelligent design will survive Kitzmiller v. Dover,* authors and Discovery Institute fellows DeWolf, West, and Luskin make it clear that the members of the Dover Area School Board were not representing ID and the refusal by Judge Jones III to let the textbook publisher at the core of the controversy to intervene was a mistake that could be challenged, (DeWolf, et al, 2007). The Thomas More Law Center, who provided legal counsel for the school board of Dover in the case and the counsel for the plaintiffs requested that Judge Jones III rule on the issue of whether or not ID is science. DeWolf and other members of the Discovery Institute who warned the school board members not to adopt their ID policy clearly do not think that Judge Jones' ruling closes the case on intelligent design. Rather, they acknowledge the danger of being so aggressive. However, documents such as the ominous 'wedge' document as described by Johnson highlight the hidden agenda of the Discovery Institute's clear religious motivation, (Forrest, 2007).

A striking piece of evidence presented in trial and acknowledged by Judge Jones himself as being the "strongest evidence supporting the finding of ID's creationist nature" is the history of the textbook *Of Pandas and People*. This textbook was referenced in the ID policy of the Dover School District that required the reading of a sort of educational disclaimer about evolution that referred students to the library to check out *Of Pandas and People* if they wanted, (Kitzmiller v. Dover Area School District, 2005). The plaintiffs in the case supported by the American Civil Liberties Union of Pennsylvania were able to show convincing evidence that as the Supreme Court decided Edwards v. Aguillard in 1987, the revisions in the textbook *Of*

Pandas and People changed only terms like creationism to intelligent design, but the definitions provided for the terms were identical, (Kitzmiller v. Dover Area School Board, 2005).

Judge Jones had a rich history of case law to draw upon which he effectively did in his opinion where he ruled in favor of the plaintiffs that the ID policy adopted by the Dover Area School District was unconstitutional violating the first amendment's establishment clause by failing the aptly applied Lemon test. Judge Jones cites the expert testimony of Dr. Kevin Padian for the plaintiff in his opinion: "Dr. Padian bluntly and effectively stated that in confusing students about science generally and evolution in particular, the disclaimer makes students 'stupid' (Kitzmiller v. Dover Area School District, 2005). In Freiler v. Tangipahoa Parish Board of Education, the reading of a disclaimer about evolution was also struck down as unconstitutional, (Freiler v. Tangipahoa Parish Board of Education, 2000).

Florida has state standards that adequately address the theory of evolution and bills which were introduced in the Florida State legislature in 2009 and 2011 to "critically analyze" the theory of evolution both failed to pass. Yet, the teaching of the theory of evolution is riddled with a history of contrived controversy that can be dated back even to the McLean v. Arkansas case where Judge Overton delivered the opinion, which in part states: "The approach to teaching 'creation science' and 'evolution-science' found in Act 590 is identical to the two-model approach espoused by the Institute for Creation Research…The two model approach of the creationists is simply a contrived dualism, (McLean v. Arkansas, 1982). Judge Overton is prescient in his reasoning. It is difficult to legally fight the first amendment which is the failed legal position of Creationists and more recently, Intelligent Design Creationists. Indeed, rather than accepting this fact, institutions like the Discovery Institute try to establish intelligent design as a legitimate theory by trying to distance it from creationism. Unfortunately for the Discovery

Institute, it is very clear that while ID proponents may profess nonreligious and genuine scientific curiosity about intelligent agents or causes acting in the universe, it has been proven both in Kitzmiller v. Dover and through the research of Dr. Barbara Forrest that intelligent design is just Creationism, (Forrest, 2007).

The Discovery Institute's policy calling for teachers to "teach the controversy" is damaging to science and science education because there is not scientific controversy related to the theory of evolution, (AAAS, 2006). The intelligent design argument follows a line of reasoning where things in nature are too complex to have arisen through natural, physical processes, so a supernatural explanation becomes necessary. Supernatural causation is outside of the realm of science, (Scott, 2004). There are research organizations like SETI, the Search for Extra Terrestrial Intelligence that are legitimately dedicated to finding intelligence in the universe without reliance on supernatural causation. Barbara Forrest asserts intelligent design should be relabeled the intelligent design creationist movement, (Forrest, 2007), and supports such an assertion with mountains of evidence. An excerpt from the Discovery Institute's website's Frequently Asked Questions page sums up their position:

> 7. Is intelligent design theory the same as creationism?
> No. Intelligent design theory is simply an effort to empirically detect whether the "apparent design" in nature acknowledged by virtually all biologists is genuine design (the product of an intelligent cause) or is simply the product of an undirected process such as natural selection acting on random variations. Creationism is focused on defending a literal reading of the Genesis account, usually including the creation of the earth by the Biblical God a few thousand years ago. Unlike creationism, the scientific theory of intelligent design is agnostic regarding the source of design and has no commitment to defending Genesis, the Bible or any other sacred text. Why, then, do some Darwinists keep trying to conflate intelligent design with creationism? It is a rhetorical strategy on

> the part of Darwinists who wish to delegitimize design theory without actually addressing the merits of its case (Discovery Institute, n.d.).

This quote includes language that would favor well for a legal argument that there is a clear secular purpose to including a discussion of intelligent design as an alternate view to evolution in biology class. The Discovery Institute is not so bold as to advocate for the inclusion of intelligent design's equal treatment alongside evolution. The case law regarding equal treatment is clear, there cannot be equal treatment for Creationism and evolution because Creationism has a clear religious foundation, (McLean v. Arkansas, 1982). Rather, the Discovery Institute adopts a position to encourage science teachers to challenge, flout, and even break the clear letter of the law. Intelligent design is not science, (Dover v. Kitzmiller, 2005). An appropriate inclusion of Intelligent Design in science class would be in a discussion of the nature of science; former president of the US National Academy of Sciences Bruce Alberts wrote: "It is through the careful analysis of why intelligent design is not science that students can perhaps best come to appreciate the nature of science itself," (Alberts, 2005 as quoted in Nelson, 2008). Another answer to a Frequently Asked Question on the Discovery Institute's website reads:

> 4. Is teaching about intelligent design unconstitutional?
> Although Discovery Institute does not advocate requiring the teaching of intelligent design in public schools, it does believe there is nothing unconstitutional about discussing the scientific theory of design in the classroom. In addition, the Institute opposes efforts to persecute individual teachers who may wish to discuss the scientific debate over design in a pedagogically appropriate manner, (Discovery Institute, n.d.).

This quote speaks to the problem that is outlined by Berkman and Plutzer regarding the 13% of high school biology teachers who teach either creationism or intelligent design. Perhaps

more troubling than the 13% of high school biology teachers in the United States who violate the US Constitution, is the 60% of high school biology teachers that do not strongly advocate for the theory of evolution, (Berkman & Plutzer, 2011). It is irresponsible as a science educator, as evidenced by the state standards in Florida that rigorously address the teaching of evolution, to ignore such standards, and doing so has been called "educational malpractice" (Moore & Cotner, 2008).

The efforts of organizations like the Discovery Institute to undermine science may yield success as evidenced by the facts pertaining to a letter addressed to the Superintendent of the Brunswick School Department in Maine from the ACLU of Maine dated March 27, 2015 regarding the most well-intentioned but severely misguided treatment of a science lesson by one Lou Sullivan. The ACLU of Maine stated: "Mr. Sullivan must immediately cease teaching about intelligent design, or the Brunswick School Department could be held liable for his blatantly unlawful actions," (Letter to Superintendent Paul Perzanoski, Bruswick School Department from Zachary Heiden Legal Director ACLU of Maine, March 27, 2015). Science teachers like Lou Sullivan exist not just in elementary schools like where Mr. Sullivan taught, but also high school where more than 70% of high school biology teachers do not strongly advocate the theory of evolution in their classroom, (Berkman & Plutzer, 2011).

The challenge for educational leaders is to firmly establish science curriculum consistent with recommendations from organizations with unique expertise including the National Research Council, the American Association for the Advancement of Science, and the National Science Teachers' Association. Training science educators about the appropriate and effective approaches to teaching evolution in a meaningful way to students is achievable within the scope of the educational leaders' impact and influence.

Barbara Forrest was a key witness in the *Kitzmiller v. Dover* case (2005) and her testimony provided solid proof that intelligent design was creationism repackaged. Forrest examined versions of the creationist textbook *Of Pandas and People* that spanned the 1986-87 Supreme Court ruling Edwards v. Aguillard which established the teaching of creationism as a violation of the establishment clause of the First Amendment of the United States Constitution and therefore unconstitutional. Authors of the textbook sloppily changed key words like creationists into design proponents, but in their haste Dr. Forrest discovered 'cdesign proponentists', a relic of the editing evolution from creationism to intelligent design. Some researchers have referred to 'cdesign proponentists' as a "textual transitional fossil", (Scott & Matzke, 2007). Indeed, Forrest highlights early in her position paper entitled *Understanding the intelligent design creationist movement: Its true nature and goals* (2007), the need to remind the public that intelligent design is just a repackaged form of creationism that the court has already addressed as nonscientific, (Kitzmiller v. Dover, 2005), and therefore unworthy of being considered in a serious discussion of biological science that would occur in a high school biology classroom. The Discovery Institute is diligently working to craft an argument that, while may not be able to stand the intense scientific scrutiny of such unscientific endeavors, may be able to pass constitutional muster if they are able to continue to distance intelligent design from Creationism which they work adamantly to accomplish, (Forrest, 2007). The attempt to change the definition of science is not only devastating to the integrity of science, but also to the entire system of public education and the prevention of the government's establishment of religion, "Public education and the separation of church and state are interdependent; the strength of American constitutional democracy depends on the preservation of both," (Forrest, 2007). Forrest exposes the fact that Phillip Johnson's wedge strategy is clearly religiously motivated. In his interview

given for the PBS NOVA special on the Kitzmiller case Johnson is quoted as saying, "The Darwinian story, when it became accepted, had a huge cultural impact, and if that story were discredited, then the cultural impact would be reversed, and there would be cultural changes in the other direction as well," (Phillip Johnson, 2006). Here the author of the ominous Wedge Strategy admits the true reasoning for the scientifically bankrupt proposition of intelligent design, not to follow the researcher's scientific curiosity, but rather set out from the start to disprove the accepted view of evolution because of perceived connections of that theory with cultural changes, (Forrest, 2005).

The Discovery Institute should change the answer to the frequently asked question on their website, Is teaching intelligent design unconstitutional? from no to yes, (Edwards v. Aguillard, 1986, Kitzmiller v. Dover Area School Board, 2005). Judge Overton in the McLean v. Arkansas case of 1982 cited as evidence in his decision that Act 590, which provided for the balanced treatment of creationism and evolution, was clearly religiously motivated because one of the proponents of the Act, one Paul Ellwanger of the Citizens for Fairness in Education warned politicians in favor of the bill not to "present our position and our work in a religious framework," (Ellwanger as cited in McLean v. Arkansas, 1982). Judge Overton writes in his opinion, "Ellwanger's correspondence on the subject shows an awareness that Act 590 is a religious crusade, coupled with a desire to conceal this fact," (McLean v. Arkansas, 1982).

Organizations like the Institute for Creation Research and the Discovery Institute demonstrate the special interests that are linked to Christian fundamentalism who seek to sow the seeds of doubt. One strategy is to use the legal system as the sharp end of a "wedge' to ultimately drive science out of the science classroom, (Forrest, 2007). Not all denominations of Christianity nor do all Christians disavow the theory of evolution which is supported by mountains of

evidence from different lines of research, a fact recognized by one thinker: *"*The convergence in the results of these independent studies—which was neither planned nor sought—constitutes in itself a significant argument in favor of the theory," this was the view given in a message to the Pontifical Academy of Sciences: On Evolution by Pope John Paul II on October 22, 1996, *(*John, P., 1997).

Focus group studies with pre-service secondary science teachers showed the teachers from a private Catholic college demonstrated a more thoughtful view than many colleagues from secular schools and the authors contribute this to, among other reasons, the time for thoughtful introspection about the compatibility of their own personal beliefs and the science of evolution, (Berkman & Plutzer, 2015). "It is perhaps not surprising that the Catholic college students had given this more thought and had arrived at more mature reflections on this," (Berkman & Plutzer, 2015, p. 266).

Worldview Theory and the Creation-Evolution Continuum

Worldview theory explains knowledge as a broad umbrella covering both metaphysical processes of knowing and epistemological processes of thinking, (Cobern, 1996). High school biology teachers may craft very well designed and pedagogically sound lessons on evolutionary theory and students may well comprehend evolutionary theory as a result of those inspired lessons. Yet, despite these efforts, there will likely still be students that value a different way of knowing as more true than science, and will therefore reject the theory of evolution, "public acceptance of evolution—or any other scientific idea—doesn't turn on the logical weight of carefully considered scientific issues. It hinges instead on the *complete* effect that acceptance of an idea, a world view, a scientific principle, has on their own lives and *their* view of life itself," (Miller, 1999, p. 167). In fact, students are more likely to reject evolution when evidence

presented apparently conflicts with their worldview or belief system, this so-called worldview backfire effect was observed by Batson in a 1975 study where Christians were presented with evidence that Jesus was not resurrected and their belief was strengthened rather than weakened when evidence was presented to challenge their worldview, (Batson, 1975). Worldview "provides the environment for reason: the capacity for rational thought, [and] orders the intellect: the capacity for knowledge," (Cobern, 1996, quote taken from figure 2 p. 592). Within this definition the overarching nature of worldview encompassing both epistemological thinking processes and metaphysical processes of knowing is demonstrated. Students possess a worldview which influences what knowledge students will come to understand and perhaps hold as true and valid. As students become more scientifically literate, their understanding of the nature of science informs students' perspectives on acceptance or rejection of scientific ideas. "The argument from worldview is that in some cases, it is not that the students fail to comprehend what is being taught, it is simply that the concepts are either not credible or not significant. The instruction must also include a discussion of the metaphysical foundation that supports scientific epistemology and how this foundation relates to other ways of knowing," (Cobern, 1996, p. 601). Science educators teaching within the framework of educating students about the nature of science are able to distinguish the standards of scientific thinking with other ways of knowing. Science teachers are capable of honoring students' diverse worldviews while still maintaining a strict adherence to their duty to educate students about scientific content and science as a way of knowing, (Reiss, 2009). This includes the very science of epistemology itself which explores the study of knowledge. Cobern makes the important argument for the inclusion of the nature of science instruction that is indeed an integral part of the science standards in the state of Florida, adopted in 2007 and known as the Next Generation Sunshine State Standards.

Teachers in Florida follow state adopted standards which belong to courses approved by the Florida Department of Education. By statute, certain instruction is mandated as required instruction. This statute, F.S. 1003.42, ensures that students in public schools learn about the United States' founding documents like the Constitution and the Declaration of Independence and other important information that has been mandated as required instruction through this statute. Just as the American ideal of democracy is preserved through an educated public that understands democracy as outlined in the founding documents and it is hoped that students accept values like freedom, jurisprudence, and fairness which are embedded within this required instruction it should also be realized that true scientific literacy involves students understanding and accepting science as a way of knowing about the natural universe. Included in the document *Evolution on the Front Line: An Abbreviated Guide for Teaching Evolution* are benchmarks for scientific worldview for kindergarten through grade 12. The scientific worldview is embedded in the nature of science; three beliefs are specifically identified in the document as belonging to a scientific worldview and through science instruction, students will come to develop a more scientific worldview. The three beliefs belonging to a scientific worldview identified in *Evolution on the Front Line: An Abbreviated Guide for Teaching Evolution* Chapter 1: The Nature of Science are:

> One is that by working together over time, people can in fact figure out how the world works. Another is that the universe is a unified system and knowledge gained from studying one part of it can often be applied to other parts. Still another is that knowledge is both stable and subject to change.

By teaching students both about the content of scientific knowledge and about the nature of science, acceptance of scientific ideas will improve and the overall scientific literacy will also

increase. Increasing scientific literacy is a primary goal of science education, (AAAS Project 2061).

David E. Long of Valdosta State University discusses the difficult problem of turning a cultural tide, and dealing with individual students who entrench more deeply into their beliefs when those beliefs are challenged by someone like a high school biology teacher giving a lesson on evolution, (Long, 2011). Personally held beliefs are not easily changed, (Kahan et al, 2007), and it is unlikely that students who possess such beliefs will come to reject them because of a great set of lessons delivered on evolution. Indeed, when and if they do reject such beliefs it is usually a difficult social arena to navigate, (Long, 2011). More likely than rejecting their faith, students will compromise to just know the standards because that is what is expected for them to pass. This ability to understand evolutionary concepts without accepting them has been called cognitive apartheid, (Hermann, 2012). Worldview theory encompasses both the epistemological processes of thinking and comprehension as well as the metaphysical process of knowing and apprehension, "Of critical importance is the fact that comprehension does not necessitate apprehension. One may well reject a concept that he or she fully comprehends while someone else apprehends it as knowledge," (Cobern, 1996, p. 592). To apprehend is to accept as true, so a student may align with a scientific worldview prior to entering a biology class and perhaps accept evolutionary theory without necessarily understanding the specific mechanisms or comprehending all there is to know about evolutionary theory. Another student may demonstrate strong reasoning skills and comprehend all of the complexity of evolutionary theory, but perhaps due to a worldview that may value scientific knowledge less than other ways of knowing, the student may fail to ever apprehend or accept the theory of evolution as the best explanation for life on Earth. When viewed through the lens of the consideration of the students' own creation

and origin, namely human evolution, students may already have an entrenched belief based on their unique worldview. This may cause the student to reject the theory of evolution as valid even if the student comprehends the theory very well. The survey instrument utilized in the current study, the Inventory of Student Evolution Acceptance, or I-SEA, is designed to measure acceptance of the theory of evolution, as the name of the survey suggests. The data gleaned from this study will help to inform educators' practice addressing the affective domain, which includes a discussion of what students value and organize into their own consistent set of beliefs, (Krathwohl, Bloom, and Masia, 1964). This consistent set of values and beliefs which may become apparent in students as they progress through their academic career could be categorized itself as belonging to a worldview.

One way to consider the potential worldview of students as it relates to evolution is through the use of the Creation-Evolution Continuum, (Scott, 2004) which more accurately represents the range of beliefs and worldviews that exist beyond the false dichotomy of a student either simply believing in evolution or Creationism. The application of the term worldview may not be apt when discussing a student's beliefs about creation, rather these beliefs may be classified as belonging to a more religious worldview or a more scientific worldview moving from Creationism to Evolution on the continuum.

The potential danger in framing this issue in terms of worldview theory is the perception for adversarial juxtaposition between science and religion, suggesting they may be incompatible. While worldview theory helps to inform and frame the research, it is worthwhile to note that a religious worldview and a scientific worldview do not mutually exclude one another. Evolutionary biologist and key witness in the 2005 Kitzmiller v. Dover case, Ken Miller has previously written about the "common ground" of religion and evolutionary theory (Miller,

1999). Kathryn Pritchard of the Archbishops' Council in the Church of England wrote about the need for increased communication and collaboration between those in scientific fields and those in theology in discussing a project entitled Scientists in Congregations. Pritchard discusses the, "backdrop of a popular narrative of science-faith conflict that pervades contemporary culture," (Pritchard, 2016), and the need to work towards bridging the divides that may exist between people who work in the laboratory and those who work in the church. Science educators have the opportunity to address science as a way of knowing through the study of the nature of science and can distinguish what characterizes science and its processes from other important ways of knowing that sometimes address questions that scientists could never hope to answer because it is difficult to design experiments to test hypotheses for many questions.

Eugenie Scott, former head of the National Center for Science Education, has discussed the use of a Creation-Evolution Continuum to demonstrate to students the variety of beliefs which exist about creation. While the scientific merits of these Creationist ideas would be inappropriate content in a science class, the use of the continuum to demonstrate the nature of science as a way of knowing would be appropriate. A similar concept model developed by Nelson in 1986, also includes a range of beliefs and worldviews, (Nelson, 1986). By examining how Creationist belief systems have changed over time as more scientific evidence was discovered and subsequently accommodated into the Creationist beliefs, the modern set of belief systems and their reliance on different levels of Biblical literalism and interpretation is better understood. Some belief systems rely on strict literalism of very specific Biblical passages as is the case of Flat-Earthers who can point to passages of the Bible such as Revelations 7:1 that describe the four corners of the Earth, and conclude that Earth is flat due to a worldview that includes as a value the inerrancy of the Bible. The use of the Creation-Evolution Continuum to

understand how worldview frames acceptance or rejection of a scientific theory is helpful in determining how various levels of scientific evidence are accommodated into a religiously-oriented worldview as more evidence accumulates over time.

Scott describes the belief systems at the far end of the Creationism part of the spectrum where Flat-Earthers and Geocentrists sit. The people who hold to these beliefs often rely on strict Biblical literalism that leads to conclusions such as Earth is flat and the center of the universe because passages in the Bible have been interpreted to reach such conclusions and "scientific views are of secondary importance," (Scott, 2004). Moving towards the evolution end of the Creation-Evolution spectrum, next to Geocentrism is Young-Earth Creationism. Young-Earth Creationists represent a more substantial proportion of Americans; some reports have as many as 40% of Americans believing in a young age of the Earth, (Rosenau, 2013). Young-Earth Creationism is championed by organizations like the Institute for Creation Research and Answers in Genesis which both attempt to provide scientific evidence for Biblical accounts. The founder of the Institute for Creation Research, Henry Morris, and the chief executive officer of Answers in Genesis, Ken Ham, have each offered scientific explanations for the Biblical account of creation, although neither withstands scientific scrutiny and nearly three decades have passed since the Supreme Court banned the teaching of creation science, (Edwards v. Aguillard, 1987). Young-Earth Creationists typically hold a view that Earth is not more than 10,000 years old because this age matches a chronology laid out in one interpretation of the Bible.

Next to Young-Earth Creationism on the Creation-Evolution Continuum is Old-Earth Creationism which may itself manifest in various forms. One of the troubles with Young-Earth Creationism is the denial of so much evidence from modern fields of science including geology, physics, chemistry, and astronomy as well as biology. By accepting the Earth is ancient, learners

are able to accept the conclusions of much of modern science, and maintain skepticism toward evolutionary biology as the explanation for the creation of life. A study of recent polling data demonstrates a complexity of beliefs that exist regarding the interrelationship of science and religion, specifically as it relates to acceptance or rejection of the theory of evolution, (Gwon, 2013). People more often reject the theory of evolution when it is related specifically to human evolution and even more when a divine explanation of creation is offered, "Clearly evolution loses significantly when respondents realize that we're talking about *our* species, and even more dramatically when the questions seems to involve God," (Miller, 2008, p. 89).

The set of beliefs that belong to Old-Earth Creationism identified by Scott are Gap Creationism, Day-Age Creationism, Progressive Creationism, and Intelligent Design Creationism, (Scott, 2004). Day-Age Creationists believe that each day in the account of creation included in Genesis is longer than a 24 hour day, while Gap Creationists believe there was a long time gap between Genesis 1:1 and Genesis 1:2, (Scott, 2004). Both belief systems accept conclusions from modern geology of an Earth about four billion years old, as well as accept conclusions and the science of supporting disciplines of physics and chemistry whose methods allow for some of the measurements of the age of Earth. Both Gap Creationism and Day-Age Creationism believe in a literal interpretation of the Bible and the account of creation in the book of Genesis with the Day-Age Creationists allowing for the slightest of metaphorical interpretation of the word day to mean a time period longer than 24 hours, such as the word day as used in the phrase 'In the day of George Washington…' where day could mean many years. Gap creationists believe in a literal interpretation of the word day and believe in the six day creation described in the book of Genesis, but install a time gap between the first two chapters of Genesis. Progressive Creationism is located closer to evolution on the Creation-Evolution

Continuum than Day-Age Creationism because Progressive Creationists accept the evidence of the fossil record that shows the emergence of new species at different times in Earth's history, but reject the Darwinian theory of evolution which accounts for such appearances through descent with modification. Rather, Progressive Creationists believe that God created different kinds of organisms at different times throughout Earth's history. Thus, a Progressive Creationist may accept microevolutionary processes as valid, and still reject the theory of evolution as a whole. This belief system allows for the accommodation of scientific evidence that shows different organisms showing up at different times in the fossil record; the Progressive Creationists view these appearances as creation events. This idea is taken a step further with Intelligent Design Creationism. Intelligent Design Creationism is closer to the Evolution end of the continuum than Progressive Creationism because believers in Intelligent Design Creationism adopt the language of science and attempt to explain the complexity observed in nature as the effect of an Intelligent Agent—God-- who designed life with such complexity. The scientific arguments put forth by Intelligent Design are thoroughly refuted by evolutionary biologist Kenneth Miller in the book *Only a Theory*, (2008). Many believers of Intelligent Design distance what they view as a science from the religious view of Creationism, despite the clear history of the religious motivation and foundation of Intelligent Design Creationism, (Forrest, 2007; 2004). The extent to which those who believe in Intelligent Design accept various conclusions about life science arrived through the framework of evolutionary theory varies. Many believe in microevolution, and perhaps point to the mechanism of microevolution as the work of a creator enabling various degrees of change within a species, without ever becoming a new species. Evolutionary developmental biology has demonstrated that speciation—macroevolution—is simply the consequence of microevolution, (Carroll, 2005, as cited in Miller, 2008). This

realization among many other quite cogent arguments led Miller to conclude: "the scientific case for intelligent design has failed," (Miller, 2008, p.133). The I-SEA instrument was designed to provide data at a detailed enough level to parse out students who may accept microevolution, and still reject macroevolution and human evolution, (Nadelson & Southerland, 2012). By considering this data through the framework of worldview theory, science educators may better inform their future lessons and adopt a strategy of honoring worldview through a discussion of the nature of science which increases both belief and understanding of evolution.

Further toward the Evolution end of the Creation-Evolution Continuum are those that accept the theory of evolution, but have varying degrees of religious orientation associated with their acceptance of the theory of evolution. The belief system of Evolutionary Creationism demonstrates how religious worldview and scientific worldview may overlap. Both Evolutionary Creationists and those who believe in Theistic Evolution accept the conclusions drawn from the theory of evolution but hold that evolution is the mechanism God used to create the diversity of life observed on Earth. Scott notes that Theistic Evolution is the official position of the Catholic church, (Scott, 2004). John Glenn, American astronaut and hero, sums up a view of theistic evolution in an interview given to the Associated Press in 2015, just a year before he passed away. The quote can be found on the Fox News website published under the headline *John Glenn: Evolution should be taught in schools* (foxnews.com/science/2015/05/20/john-glenn-evolution-should-be-taught-in-schools.print.html, Retrieved February 11, 2017):

> I don't see that I'm any less religious by the fact that I can appreciate the fact that science just records that we change with evolution and time, and that's a fact. It doesn't mean it's less wondrous and it doesn't mean that there can't be some power greater than any of us that has been behind and is behind whatever is going on.

Every belief system included in the Creation-Evolution Continuum except for the last belief at the far end of the continuum—that of Materialist Evolutionism—include a belief in God and the differences between Flat-Earthers to Theistic Evolutionists is the degree to which those believers hold to Biblical literalism and the manner in which God created life. Theistic Evolution may represent the belief held by students with a strong religious worldview who may initially reject the theory of evolution, but after studying biology throughout college, come to accept both religious and scientific ways of knowing. Materialist Evolutionists are further on the spectrum because their worldview is nonreligious. Scott aptly notes in her article that although scientists work within a set of practices that restrict the scope of investigation to the natural universe and thus supernatural causation goes beyond the scope of science, science itself cannot conclude on the existence of supernatural causation. The Materialist Evolutionist belief is one outside of the scope of scientific practice, which is neutral to religion. Materialist Evolutionists adopt a nonreligious worldview that concludes: "the laws of nature are all there is: the supernatural does not exist," (Scott, 2004). In a recent suit filed by Citizens for Public Education against the Kansas Board of Education, the argument brought forth in the complaint claimed that the current Next Generation Science Standards are framed in a way that endorses a Materialist Evolutionist stance and thus is every bit as dogmatic and religious as evolution, (COPE v. Kansas Board of Education, 2013). The complaint was thrown out and the Supreme Court denied to hear the appeal in November 2016.

Scott advocates for the use of the Creation-Evolution Continuum in science class as a way to discuss the nature of science and the range of beliefs that exist. If students have a false impression that belief in evolution is tantamount to atheism, the Creation-Evolution Continuum could serve to demonstrate belief systems that both accept the theory of evolution and belief in

God, as in Theistic Evolution. Educators that approach the teaching of the theory of evolution first through an exploration of the nature of science may encounter less resistance to students who possess worldviews and beliefs that may cause initial rejection of the theory of evolution. Because comprehension is not in and of itself sufficient for students to accept a theory like evolution, an examination of the affective domain helps to inform science educators, "even those who possess the requisite knowledge and reasoning skills are likely to reject evolution, if affective goals are central in belief formation," (Griffin, 2007).

By focusing on the nature of science and the affective domain, science educators may construct powerful ways of thinking in students to examine science as a way of knowing distinct from but not superior to other ways of knowing—this concept is known as the bounded nature of science, "Through such an approach, students come to understand that science is one powerful way of understanding the world, but not the only way. This explicit emphasis on epistemology gives students who hold religious beliefs counter to mainstream science the emotional room to understand science, to examine the value that they place upon a knowledge claim, and to understand why they place such value," (Southerland & Scharmann, 2013, pp.64-65).

The Nature of Science and the Affective Domain

"The appeal of creationism is emotional, not scientific," (Miller, 1999, p. 173). Research going back to the late 1980s suggested that students' failure to accept the theory of evolution could be explained by their failure to understand the nature of science, (Johnson & Peeples, 1987). Thus, a strong emphasis of the science standards in Florida, as in many other states, is on the nature of science.

David Krathwohl is a coauthor of Benjamin Bloom's often referenced taxonomy which was the subject of their *Handbook I: The cognitive domain* (Bloom & Krathwohl, 1956).

Krathwohl was the lead author of *Handbook II*, which dealt with the affective domain, (Krathwohl, Bloom, & Masia, 1964). Modern neuroscience can inform educational practice and the lens of educational neuroscience helps to explain how emotions impact learning by, for example, acting as a rudder for what students may value as important, (Immordino-Yang, 2016). Valuing is the third level of Krathwohl's affective taxonomy, (Krathwohl, 1964), and coupled with worldview theory, educators may understand how the values students hold influence what knowledge they value as important and what knowledge they will accept as true.

The nature of science standard that discusses science as a way of knowing is also framed in a way that recognizes the limits of scientific ways of knowing because the wording of the standard is to have students identify what questions can be answered through science and what questions can be addressed by other ways of knowing. The other ways of knowing that are mentioned in the standard are art, religion, and philosophy. To engage students into a discussion of worldview, and the related concepts of epistemology and metaphysics enriches their learning experience and achieves a noble goal of education-- to have students learn and grow to their full potential.

The inclusion of specific nature of science standards in Florida courses from elementary school through high school are designed to teach students about the practice of science and the characteristics of scientific knowledge. Another big idea in the nature of science is the role of theories, laws, hypotheses and models. Also, specific nature of science standards exist to address the role of science in society. By emphasizing these nature of science standards which are required to be addressed in Florida, students may increase their acceptance of the theory of evolution.

A wealth of research exists in the field of evolution education that supports the idea that increased understanding of the nature of science leads to increased understanding of evolution. (Butler, 2010; Johnson, & Peeples, 1987; Lombrozo, Thanukos, & Weisberg, 2008; Rutledge & Warden, 2000; Scharmann, 1990; Scharmann, et al., 2005; Southerland & Scharmann, 2013;). It is not surprising that the title of the National Academy of Science publication discussing evolution was *Teaching About Evolution and the Nature of Science,* (1998). In this publication, the nature of science is featured prominently, just as it is in the Next Generation Science Standards. One of the goals of the document is to clearly define key terms as they are used in science to educate learners about the nature of science. The use of terminology like law and theory in science have specific meanings and understanding these definitions as used in science is part of understanding science as a way of knowing and increasing scientific literacy. The incorporation of nature of science topics into science standards is based on sound recommendations from experts in fields of science and science education. The adoption of the Next Generation Sunshine State Standards in Florida in 2007 means that many students participating in the current study matriculated through the Florida public educational system when the Next Generation standards were in place, for at least part of their academic career. The average year of graduation for students in the current study was 2012.

In order for instruction in the nature of science to be most effective, research proves such instruction should be explicit, reflective, and applicable, (Scharmann, et al., 2005). Rather than incorporating the nature of science implicitly through the day to day laboratory work conducted in class, nature of science instruction should be addressed explicitly to have the greatest impact on student learning.

Examining the metaphysical argument of science as a way of knowing and studying the epistemological tools that scientists employ to gain their understanding of nature is certainly appropriate instruction in science, just as the techniques of artists and musicians are perfected in fine arts classes. Worldview theory encompasses the nature of science by enveloping the complementary ideas of the practice of science: science as a verb, which relies upon the epistemological thinking processes of reason to carry out investigations, collect and organize data for analysis so that conclusions can be reached that can then be incorporated into a body of knowledge: science as noun. Scientific knowledge is durable, robust, and yet open to change and therefore tentative—all nature of science ideas. If students begin to value science as a way of knowing, they may align with a more scientific worldview and this is a goal of science education that science educators and educational leaders must work toward together to achieve. An understanding of the nature of science is a fundamental component of scientific literacy and improves acceptance of the theory of evolution, (Clough, 1994). High school biology teachers with a stronger knowledge of the nature of science have also been shown to have higher levels of acceptance of the theory of evolution, (Rutledge & Warden, 1999). Improved understanding of the nature of science certainly serves to translate into instructional gains in many scientific disciplines because the nature of science is included within each of the branches of science. Instruction in the nature of science, in addition to increasing student acceptance of potentially controversial subject matter like evolution, has also been demonstrated to be effective in increasing understanding of global climate change, (Matkins, et al., 2002).

While Trani (2004) found a moderate level of understanding of the nature of science among a population of Oregon high school biology teachers as a whole, the research also demonstrated that lack of understanding evolution could also be attributed to lack of

understanding the nature of science in the minority of science teachers who demonstrated such lack of understanding, (Trani, 2004).

Instruction in the nature of science improves science learning in other content within the sciences, and by understanding the nature of science students are able to better appreciate the complexity of the issues surrounding topics like the teaching and learning of the theory of evolution, (McComas et al., 2002). In order to fully understand the different dimensions of the teaching and learning of the theory of evolution, students should be equipped with the knowledge of the nature of science. The goal of helping a student become scientifically literate is achieved through the student developing an understanding of both the nature of science and science content knowledge.

Educational Leadership for Scientific Literacy

Educational leaders are faced with the difficult task of preparing their teachers to provide students with the best possible education. In science education, a focus on the nature of science includes instruction on theories. Theories are the most powerful explanations that scientists have to offer. Focusing core science curricula on the dominant theories in the scientific disciplines is therefore abundantly appropriate. Chemistry students should not be deprived of the right to learn about atomic theory and chemistry teachers should not be confused with some competing theory of matter put forth by lawyers with no scientific expertise. Physics students study theories of gravity that have changed over time from Kepler and Galileo, to Newton, and ultimately to Einstein's General Theory of Relativity which has enjoyed a century of experimental success and validation. When ninth grade biology students fail to learn both what it means to be a theory and

the essential theory that dominates the field of biology because teachers are being "cautious" (Berkman & Plutzer, 2011), the whole scientific literacy of America is harmed.

As recently as 2007, Florida has adopted stronger standards to deal with what was a previous failure in the teaching of evolutionary theory, (Thomas, 2007). As quickly as 2008, and repeatedly in 2009 and 2011, Florida has faced the threat of legislation that would weaken the teaching of those essential science standards.

Organizations like the Discovery Institute's Center for Science and Culture are carefully crafting their legal position; moving away from the establishment clause of the first amendment-- which signifies an insurmountable hurdle-- to the free speech clause. Florida's 2008 Senate Bill 2692, the Academic Freedom Act, is an example of reframing the losing legal argument of establishing religion into a more credible one-- protecting free speech. The danger of their success would be a worsened picture of biology science education.

As the Discovery Institute continues to fund what they consider research supporting intelligent design at the Biologic Institute, (biologicinstitute.org, n.d.), the argument that intelligent design is a valid scientific theory that is actively being researched may be made. The Discovery Institute claims the research they publish is peer-reviewed and they contain a link to journal articles supporting intelligent design on the Discovery Institute's website, (http://www.discovery.org/id/peer-review/). The strategy to try to introduce intelligent design as a competing theory with evolution, as spelled out in the Wedge Document, (Forrest, 2004), is still at work even over a decade after the Dover trial ruled the teaching of intelligent design unconstitutional. The Discovery Institute may find success in the future where they've found little in the past—in the courtroom. If the Discovery Institute is able to convince a judge that there is a clear secular purpose to studying intelligent design alongside evolution because it is an

active field of research the Lemon Test will be passed and science will be hurt. One of the important conclusions of Dover was that intelligent design is a "science stopper" (Dr. Padian, Kitzmiller v. Dover Area School District, 2005). Kenneth Miller, in a few chapters in his book *Only a theory*, thoroughly dismantles intelligent design as a scientific theory, (Miller, 2008).

Dr. Barbara Forrest, through her research, has rightly coined the term intelligent design creationist movement to describe this so-called theory to remind everyone of the true history of the movement and the motivations of the supporters which are clearly religiously motivated. Judge Overton in McLean v. Arkansas described Mr. Ellwanger's "candor" regarding how to negotiate the legal arena to avoid using religious terminology that would be harmful to the cause of the creation science proponents, (McLean v. Arkansas, 1982). This legal and political maneuvering lives on today in organizations like the Discovery Institute who present intelligent design as a valid scientific theory that is different from Creationism, but only publicly, "ID is not science, as it proponents misleadingly portray it to the public and to policymakers, but rather religion, as they portray it candidly to their conservative Christian constituency," (Forrest, 2007). Educational leaders should be aware of the intentional manipulation of our system of public education being carried out by the Discovery Institute so that bad science does not find its way into public school classrooms.

Educational leaders have the awesome opportunity and responsibility to help prepare humanity for the future. Creating a climate of scientific inquiry that utilizes a standards-based approach to addressing the nature of science throughout K-12 instruction will better prepare students for college level instruction. By providing students with the thinking skills and learning tools to understand science as a way of knowing among other important ways of knowing, all students may come to accept the theory of evolution when otherwise some would not.

Educational leaders sensitive to the diversity of beliefs that exist and steadfast in the pursuit of inspiring learning in students can create a climate of scientific inquiry anchored in the study of the nature of science as a way of knowing about the natural universe amongst other important ways of knowing. Educational leaders should work to create a climate of scientific inquiry that respects diverse worldviews, without compromising on delivering the lessons in biology class that address both the content of the theory of evolution and the nature of science ideas that explore what it means to be a theory. The educational research that has examined the affective domain suggests a strong influence on what students come to accept as true on affective or emotional goals. The values students place on different ways of knowing are part of the students' worldview that is shaped and reshaped throughout life. One of the goals of science education is to help students' develop a scientific worldview as this way of knowing is viewed as essential to scientific literacy. The greater the overall scientific literacy of the population, the better equipped future generations will be to understand and develop solutions to problems facing humanity in the upcoming centuries; this idea is itself a nature of science standard included in the big idea relating science and society.

CHAPTER THREE: METHODOLOGY

Introduction

The study employed methods appropriate for a causal-comparative analysis to determine the difference between the type of high school biology course students attended and the levels of acceptance of the theory of evolution in college-attending high school graduates. The study also examined the difference between student acceptance of evolution and frequency of attending worship services. The student level of acceptance of evolution was measured by the Inventory of Student Evolution Acceptance (I-SEA).

Differences in scores on the I-SEA for groups of students who took Advanced Biology courses, Biology I Honors, and Biology I were tested for statistical significance by conducting an analysis of variance. The results of this analysis help inform educational policymakers and educational leaders regarding course offerings. The student scores on the Inventory of Student Evolution Acceptance were also compared to students' frequency of attending worship services. This variable was designed to measure, in the population being studied, the previously found strong link between religiosity and rejection of the theory of evolution in some groups, (Gwon, 2012; Rissler, 2014).

Instrumentation and Sources of Data

The primary instrument utilized to collect data on student acceptance of the theory of evolution for the study is the Inventory of Student Evolution Acceptance (I-SEA). The I-SEA is a 24 item survey divided into three subscales designed to measure student acceptance of microevolution, macroevolution, and human evolution. Respondents were asked to rate their

agreement with each item on a 5 point Likert scale. Overall scores, as well as scores on each of the subscales contained within the Inventory of Student Evolution Acceptance are displayed on a frequency distribution to visualize the dispersion of the data. As a general guideline the following levels of acceptance of evolution are used for categorizing evolution acceptance based on scoring of the I-SEA: The highest possible score for the entire 24 item survey is 120; the lowest possible score is 24. A score of 24 will receive its own category as this score is only achieved by students who strongly disagree with the pro-evolution stance on every survey item. Scores of 25-47 will indicate respondents who tended to choose strongly disagree or disagree with survey items. Scores of 48-71 represent survey respondents who tended to disagree or mark undecided on average. Scores of 72-95 represent average responses of undecided to agree. Scores of 96-119 represents average responses of agree to strongly agree and a score of 120 is only achieved by strongly agreeing with each pro-evolution statement on the instrument. For each subscale, a possible score range of 8-40 exists and a similar breakdown will follow for each subscale. A score of 8 would be achieved only by strongly disagreeing with all the pro-evolution items within the subscale. Scores of 9-15 would result from respondents strongly disagreeing or disagreeing with most items on the subscale. Scores of 16-23 would result from respondents who tended to disagree or mark undecided for items. Scores of 24-31 result from undecided to agree dispositions on average. Scores of 32-39 result from respondents tending to either agree or strongly agree with items on the subscale and a score of 40 is achieved only when a respondent strongly agrees with all items indicating extremely strong acceptance of the component of evolution measured by the subscale.

Within each subscale, three of the eight total items are designed to measure students' agreement with evidence for the theory. For example, in the microevolution subscale one of the

items reads, “I think there is an abundance of observable evidence to support the theory describing how variations within a species can happen,” (Nadelson & Southerland, 2012).

Demographic questions were added to the 24 Likert style items on the I-SEA to determine the respondents’ gender, race, year graduated high school, high school attended, and type of high school—whether traditional public, public charter, private, or home school. Survey respondents were asked if they took any advanced biology classes or biology-related electives like environmental science or ecology. Students were also asked their frequency of attending worship services and the choices of less than weekly, or weekly or more were offered. The I-SEA was scored for each respondent and the level of acceptance of evolution was determined.

When the I-SEA was developed it was demonstrated to be both valid and reliable. The reliability calculation for the I-SEA showed a Cronbach’s alpha of 0.95. The human evolution Cronbach alpha was slightly lower at 0.94 and the Cronbach’s alpha for the microevolution and macroevolution subscales were 0.90 each. Thus the instrument is highly reliable overall, as well as at the subscale level allowing for more detailed analysis as the developers of the instrument intended, (Nadelson & Southerland, 2012). Exploratory and confirmatory factor analyses, as well as correlation and pair-wise comparisons were conducted during the development and refinement of the I-SEA and the instrument was also expert validated by a panel of 10 college-level biology faculty, (Nadelson & Southerland, 2012). The I-SEA instrument is both a valid and reliable instrument to determine the levels of acceptance of evolution among the target population of college students studying biology.

Population and Sample

The population of interest in the study is college students studying biology. In order to collect data from this target population, first biology instructors were recruited to help assist in

the data collection by offering the opportunity to participate in this research to their biology students. Biology instructors will be identified as those instructors from the participating institutions that belong to the faculty in the biology department and teach a course related to the biological sciences to students during either the Fall 2016 term. A convenience sample of biology students enrolled in participating institutions during the 2016-2017 school year were utilized for the purposes of this study.

Several institutions in the Central Florida area were invited to participate in the study and Institutional Review Board applications were sent to those institutions to request permission to conduct the study. Only students attending institutions that approved the Institutional Review Board application and also contained biology faculty willing to assist in the data collection are included in the study.

Florida has an estimated population of over 20 million people according to the US Census Bureau. In Florida, approximately 55% of the population identified as white, 25% as Hispanic or Latino, and 17% as black or African-American. 3% of the Florida population identified as Asian and 2% identified as belonging to more than one race.

Data Collection

To determine the different levels of acceptance of evolution, the chance to participate in this study by completing the Inventory of Student Evolution Acceptance was offered to college students studying biology during the Fall 2016 term. Biology instructors at the participating institutions were invited to participate in the research by helping to assist in the administration of the survey to their students. Biology instructors were identified as those professors belonging to the Biology or Biomedical Sciences Department at the participating institutions who taught a class related to biological science during the Fall 2016 term. The survey instrument was

administered to students willing to participate during an appropriate time determined by the professor administering the instrument, such as after a scheduled class session, or during a lab session. Printed blank copies were provided to each professor who agreed to assist in the data collection. An electronic version of the survey was also created using Qualtrics, and a unique password protected link was generated for each class a professor requested the electronic version. The password was shared with the biology professor so students could access the survey when the professor provided the link and password. Professors followed the specific protocol developed for administration of the instrument and collected the completed anonymous surveys. These were then be returned to the principal investigator for analysis.

Data Analysis

The Inventory of Student Evolution Acceptance was scored according to the guidelines set forth by the creators of the instrument, where certain negatively worded items receive reverse scoring so that each of the 24 items receives a score of 1-5 where 1 indicates low acceptance and 5 indicates high acceptance. Each completed survey therefore receives a score between 24 and 120. A frequency distribution showing the relative abundance of participants receiving various scores was created and examined for trends of different levels of acceptance.

The frequency distribution was delineated according to scoring guidelines described earlier. Descriptive statistics are also reported including sample mean and standard deviation.

A paired samples t-test will be conducted to determine if there is any statistically significant difference between scores on the three subscales measured by the Inventory of Student Evolution Acceptance. The paired samples t-test will be conducted pair-wise to test each of the three subscales against the other two, similar to the method described by Nadelson and

Southerland, (2012). The following computational formula can be used for a paired sample t test, (Steinberg, 2011):

$$t=\frac{\bar{D}-\mu}{\sqrt{\frac{\sum D^2-\frac{(\sum D)^2}{n}}{n(n-1)}}} \quad (1)$$

Where D is a difference between a student's scores on two subscales for as measured by the I-SEA, $\bar{D}$ represents the mean of the difference scores for all participants, and μ is the mean difference scores for the population which is assumed to be zero under the null hypothesis, (Steinberg, 2011), n is the sample size.

An analysis of variance was conducted to test if there is a statistically significant difference between students who took an advanced biology course in high school, students who took Biology I Honors, and students who took Biology I in levels of acceptance of evolution as measured by the Inventory of Student Evolution Acceptance. Following the analysis of variance, a post-hoc test known as the Tukey HSD was conducted to determine the nature of any significant difference between groups compared with the analysis of variance.

The analysis of variance is calculated with the following ANOVA F test (Steinberg, 2011):

$$F=\frac{\frac{\sum_1^k\frac{(\sum X_g)^2}{n_g}-\frac{(\sum X_{tot})^2}{N}}{(k-1)}}{\frac{\sum_1^N X^2-\sum_1^k\frac{(\sum X_g)^2}{n_g}}{(N-k)}} \quad (2)$$

Where k represents the number of groups, in this case three: those students who took advanced biology, those who took Biology I Honors, and those who took Biology I. X represents student scores on the I-SEA. N represents the sample size and n_g represents the sample number for that

group, and Xg represents the student score for that group. Xtot is the total sum of student scores. The Tukey Highly Significant Difference (HSD) test is calculated as follows:

$$HSD=q\sqrt{\frac{\frac{\sum_1^N X^2-\sum_1^k\frac{(\sum X_g)^2}{n_g}}{(N-k)}}{n_g}} \quad (3)$$

A t-test was used to test the difference between student scores on the I-SEA for students who attend worship services weekly or more and those that attend less than weekly. The t-test is calculated with the following formula:

$$t=\frac{(M_1-M_2)}{\sqrt{\left(\frac{SS_1+SS_2}{n_1+n_2-2}\right)\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}} \quad (4)$$

Where M_1 is the mean score for the group that attends worship services weekly or more, M_2 is the mean score on the I-SEA for the group that attends worship services less than weekly. SS represents the sum of squared differences between each student score and the mean for that group, n represents the sample sizes for each group. In order to determine the effect size of any statistically significant results obtained, a calculation of Cohen's d was made for each t-test showing significant results. Cohen's d is calculated using equation 5 and it reports an effect size which is important for the current study where large sample sizes may perhaps demonstrate statistically significant results with perhaps low effect sizes.

$$\text{Cohen's } d = (M_2 - M_1)/SD_{\text{pooled}} \quad (5)$$

Where SD is the standard deviation and SD_{pooled} is given by equation 6:

$$SD_{\text{pooled}} = \sqrt{\frac{SD_1{}^2+SD_2{}^2}{2}} \quad (6)$$

A summary of the research questions and method of analysis for each question are displayed in Table 1. The data source for each question is the I-SEA instrument, and the included demographic questions. The survey instrument is included in Appendix D.

Table 1: Research Questions, Data Sources, Variables, and Methods of Analysis

Research Question	Data source	Variables	Method of Analysis
(1) What is the difference in the levels of acceptance of the theory of evolution among college students?	I-SEA	I-SEA Score	Frequency distribution descriptive statistics
(2) What is the difference in acceptance of three components of the theory of evolution: microevolution, macroevolution, and human evolution, among college students?	I-SEA	I-SEA subscale scores	Related samples t-test
(3) What is the difference in acceptance of evolution for students that took an advanced biology course during high school, Biology I Honors, and Biology I?	Survey Instrument	Independent Variable: high school biology course type Dependent Variable: student I-SEA score	ANOVA
(4) What is the difference in acceptance of evolution for students who attend worship services weekly or more and those who attend worship services less than weekly?	Survey Instrument	Independent Variable: frequency of attending worship services Dependent Variable: student I-SEA score	t-test

Descriptive statistics will be used to analyze the data related to the first research question. The remaining research questions will be analyzed using t-tests and analyses of variance. The Inventory of Student Evolution Acceptance is the data source for the dependent variable in all research questions. The data was collected during the Fall 2016 term, and all students participating in the research were given informed consent documents along with the survey instrument. Participation in the study was both anonymous and voluntary. The electronic version of the survey also included the informed consent document as the first question of the survey. The data was collected from students enrolled in courses related to biological science including general biology, cellular biology, genetics, zoology, embryology, environmental science, and biochemistry.

CHAPTER FOUR: DATA ANALYSIS

In order to determine the levels of acceptance of the theory of evolution among college students studying biology, the Inventory of Student Evolution Acceptance, I-SEA, was administered to undergraduate college students studying biology in the Central Florida area. A total of 546 surveys were collected. Of the 546 surveys collected, 57 were discarded due to incompleteness. A survey was only considered incomplete if any of the 24 I-SEA items were left unanswered. If a student either omitted an answer to a demographic question or declined to answer, but subsequently answered all 24 I-SEA items, such a survey would be included. The analysis presented here reflects data from the 489 completed surveys.

Table 2: Descriptive Statistics for all 489 survey respondents. The mode value of 120 is also the highest possible score on the I-SEA meaning more students achieved this maximum score than any other score. The positive Kurtosis value indicates the data has a sharp peak, and the negative value of skewness indicates a few outlier scores towards the low end of the I-SEA scoring spectrum. The average score of 103.2 is indicative of high acceptance of evolution on average for students surveyed.

Descriptive Statistics	
Mean	103.2
Standard Error	0.64
Median	106
Mode	120
Standard Deviation	14.2
Sample Variance	201.8
Kurtosis	2.85
Skewness	-1.38
Range	94
Minimum	26
Maximum	120
Count	489

Research Question 1 Analysis

The Inventory of Student Evolution Acceptance, I-SEA, was developed to measure levels of students' acceptance of the theory of evolution. The I-SEA consists of 24 statements which are scored on a 5 point Likert scale. Scores can range from 24 to 120. A score of 24 would only be obtained if a student adopted the strongly disagree disposition for the pro-evolution stance on all 24 items. No student surveyed in the current study obtained a score of 24. A score of 120 is only achieved if a student adopts the strongly agree disposition for the pro-evolution stance on all 24 I-SEA items. The average score on the I-SEA for the entire sample, N=489, for this study was 103, and the standard deviation, SD = 14. This corresponds to the category of high acceptance of evolution. A total of 34 students surveyed in this study achieved a score of 120 on the I-SEA. While these 34 students represent just 7% of the total sample, 78% of students surveyed scored 96 or higher which can be categorized as demonstrating very high acceptance of the theory of evolution. Professional biologists overwhelmingly accept the theory of evolution, with only about 2% of professional biologists rejecting the theory of evolution (Funk & Rainie, 2015). Only 20 students surveyed in the current study scored below a 73 on the I-SEA, comprising 4% of the students surveyed who could be classified as having low to very low acceptance of the theory of evolution. This figure roughly agrees with the percentage of scientists who reject evolution. The remaining 18% of students scored between 73 and 95 on the I-SEA and constitute a group with moderate to high acceptance of the theory of evolution.

When examining the individual subscales measured by the Inventory of Student Evolution Acceptance—microevolution, macroevolution, and human evolution, the results of this study agree with preliminary findings obtained by the creators of the I-SEA. The study population demonstrated stronger acceptance of microevolution than either macroevolution or

human evolution and less acceptance for human evolution than either microevolution or macroevolution, (Nadelson & Southerland, 2012).

In the development of the Inventory of Student Evolution Acceptance, the authors demonstrated the instrument was valid and reliable in showcasing a range of levels of acceptance in a "diverse group of students," (Nadelson & Southerland, 2012, p. 1658), without offering specific numerical breakdowns of I-SEA scores and corresponding levels of acceptance. Rather, the authors felt that such a task would be a worthwhile direction for future research, "The determination and interpretation of the levels of evolution acceptance of specific groups of students would be a fruitful direction for future research and excellent application of the I-SEA," (Nadelson & Southerland, 2012, p. 1658).

In the examination of the data obtained in the current study, a rationale was adopted where the average score on the five point Likert scale corresponds to level of agreement; scores of one are strongly disagree and therefore would indicate low acceptance of evolution. Scores of five are strongly agree and would indicate high acceptance. A response of three would indicate undecided. If survey respondents agree or strongly agree with the pro-evolution stance on a majority of I-SEA items then this can be characterized as corresponding to high levels of acceptance of evolution. Conversely, if students on average disagree or strongly disagree with the pro-evolution stances on the I-SEA items then this would be characterized as low or a very low level of acceptance of evolution. The exact numerical breakdown of I-SEA score and corresponding level of acceptance of evolution is presented in Table 3; the thresholds set in Table 3 represent the levels of acceptance set for the analyses conducted in the current study.

Table 3: Levels of acceptance of evolution and corresponding number of students from the study population belonging to each category.

Score range	Level of agreement	Level of Acceptance	Number of students	Percentage of study population
24	Strongly disagree with all	Extremely low/rejecting	0	0%
25-47	Strongly disagree-disagree	Very low	2	0.4%
48-72	Disagree-undecided	Low-moderate	18	3.6%
73-95	Undecided-agree	Moderate-high	90	18%
96-119	Agree-strongly agree	Very high	345	71%
120	Strongly agree with all	Extremely high	34	7%

One suggested approach to study the scores of the I-SEA is to examine extreme positions. A score of 24 is only achieved when a respondent adopts the anti-evolution stance on all 24 I-SEA items, so that score perhaps deserves its own place as extremely low or very low. This unique score could also be collapsed into the very low acceptance category. If a respondent were to adopt a position of disagree on average with the pro-evolution stances on the I-SEA items then a score of 48 would be achieved, this is right at the boundary of low to low-moderate levels of acceptance. A score of 72 may represent a respondent who adopts the undecided position for all 24 items, although this may very well not be the case for scores of 72. A score of 72 may just be the result of scores which average to this value. A score just above 72 would be moderate-high and scores just below 72 would be moderate-low. A score of 96 would result from agreeing with the pro-evolution stances on all 24 I-SEA items and this is considered high acceptance with

scores above 96 and up to 119 representing high levels of acceptance as respondents would have agreed or strongly agreed with most of the pro-evolution stances on the I-SEA items. A score of 120 is only achieved by strongly agreeing with all pro-evolution stances on all 24 I-SEA items. This unique score also rightly deserves its own category. In the current study, the mode score was 120; 34 out of 489 students surveyed or 7% of the study population maximized their score on the I-SEA.

Similarly, a score breakdown and corresponding levels of acceptance of each construct measured by the Inventory of Students Evolution Acceptance may be categorized. Such a breakdown is presented in Table 4. The same rationale for the levels of acceptance can be applied to each subscale, so that scores on each subscale could be compared and categorized as low, moderate, or high acceptance of the construct measured. In the current study, a wide disparity was shown to exist for human evolution acceptance between students who attend worship services weekly or more and those who attend worship services less than weekly. Because the I-SEA contains three subscales—macroevolution, microevolution, and human evolution, researchers and educators can utilize the power of I-SEA as it was intended to provide fine-grained measures of student evolution acceptance. The data afforded by the I-SEA can inform classroom instruction, and may be used to test the effectiveness of classroom interventions designed specifically to increase acceptance of one construct or another.

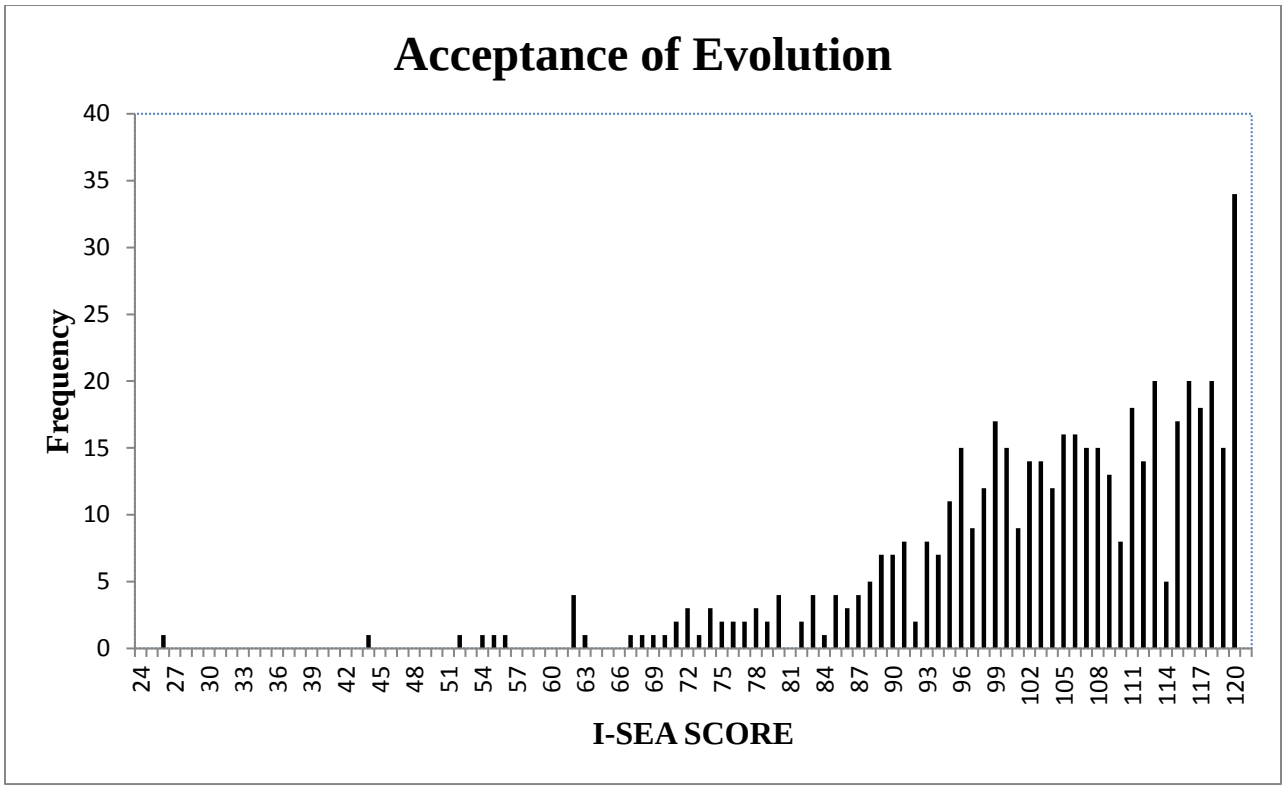

Figure 1: Frequency distribution of all 489 I-SEA scores. The number of students achieving each score is shown with the height of the vertical bars above each I-SEA score achieved displayed on the horizontal axis. The data is negatively skewed with a few outlier scores at the far left of the scoring spectrum. The data peaks at the maximum possible score of 120 showing the most students achieved this score than any other score. 78% of students achieved scores above 96, a threshold for strong acceptance of evolution.

Scores on the I-SEA can range from 24 to 120. The peak at 120 represents 34 students who maximized their score on the I-SEA indicating strong acceptance of evolution. Visual inspection of the data suggests overall acceptance of evolution tends to be high among the college students studying biology sampled in this study.

One of the most powerful tools of the I-SEA instrument is the ability to separate out from the broader I-SEA scale, the individual subscales constructed within the instrument. Figure 2 shows a histogram of the data for the macroevolution subscale of all 489 respondents. Macroevolution represents the consequences of evolutionary processes over a long timescale, perhaps hundreds of millions or even billions of years.

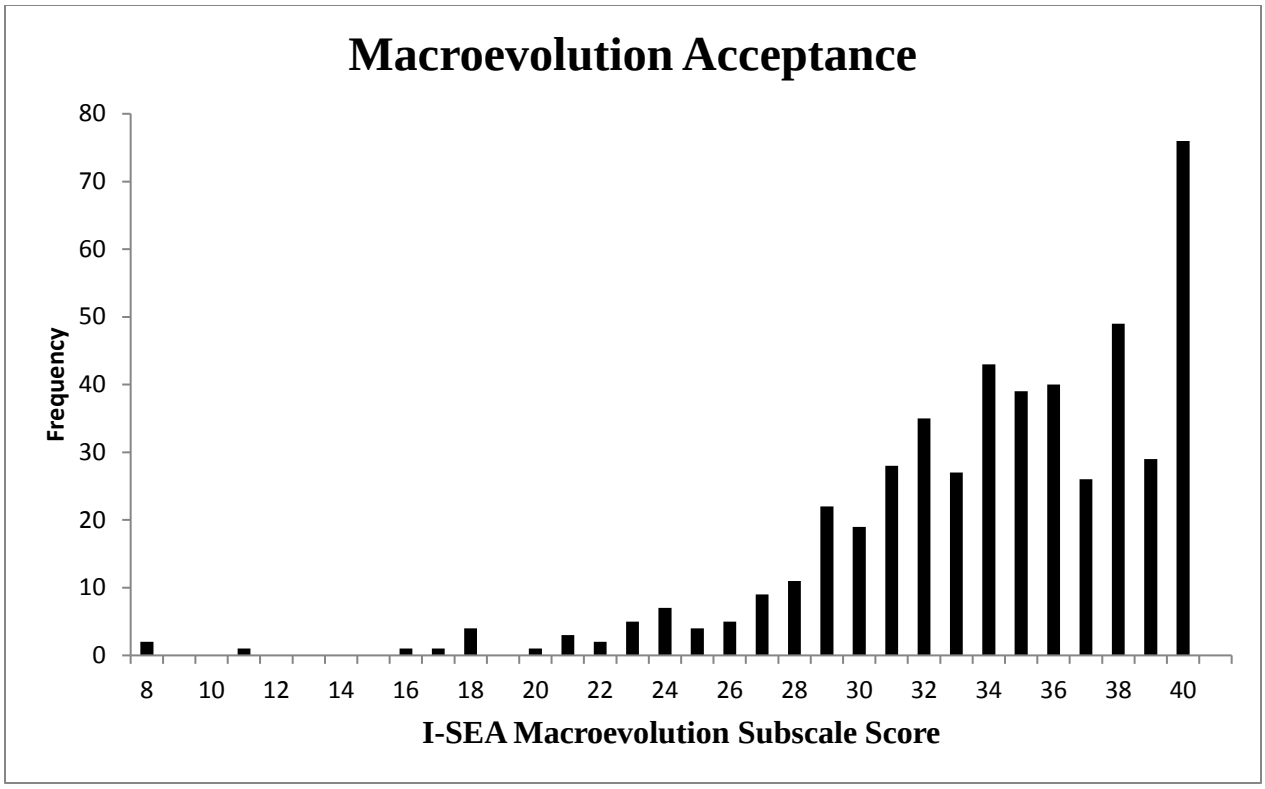

Figure 2: Frequency distribution of the macroevolution subscale. Scores on each subscale can range from 8-40. The majority of scores above 32 indicates strong overall acceptance of macroevolution.

One of the highest scored items on the I-SEA for the current study population was item 11 which is an item contained in the microevolution subscale and is designed to measure students acceptance of evidence for the construct of microevolution. Because the average score for this item was the second highest measured with an average score of 4.59 out of 5 possible, the data agrees with the claim that microevolutionary processes are quite observable and therefore difficult not to accept.

Table 4: Levels of acceptance of macroevolution and corresponding number of students from the study population belonging to each category.

Score Range	Level of agreement	Level of acceptance	Number of students	Percentage of study population
8	Strongly disagree with all	Extremely low	2	0.4%
9-16	Strongly disagree	Very low	2	0.4%
17-24	Disagree	Low-moderate	23	4.7%
25-31	Agree	High	98	20%
32-39	Strongly agree	Very high	288	59%
40	Strongly agree with all	Extremely high	76	16%

The students represented at the very low scoring end of the I-SEA spectrum constitute a very small percentage of the entire study population. 95% of the college students studying biology surveyed earned scores of 25 or higher on the I-SEA macroevolution subscale indicating agreeing with the pro-evolution stance on average for the I-SEA items. 75% of the surveyed population earned scores of 32 or higher on the I-SEA macroevolution subscale indicating strongly agreeing with the pro-evolution stance on I-SEA items on average.

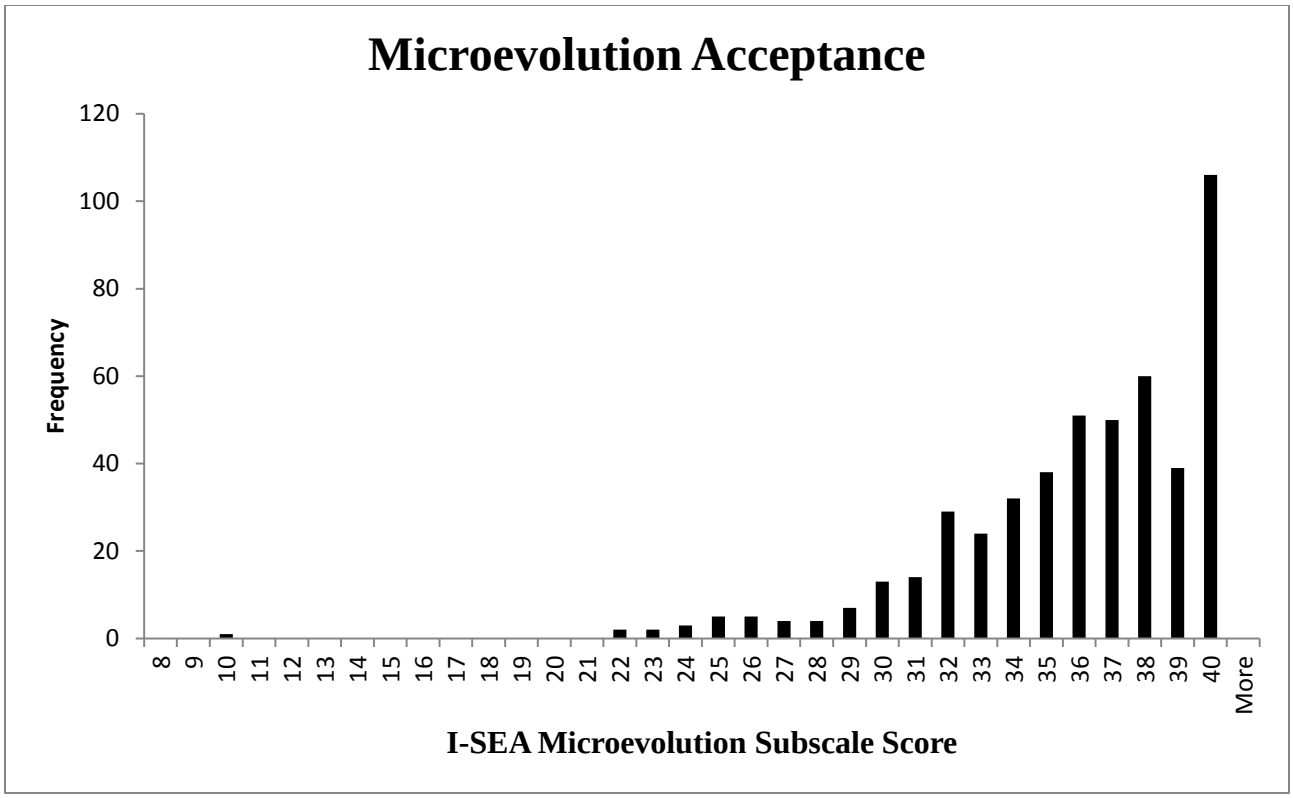

Figure 3: Frequency distribution of the microevolution subscale. Microevolution explains evolutionary changes within species that occur over several generations. Microevolution was the most accepted construct within evolutionary measured. 88% of students surveyed scored 32 or higher indicating strong acceptance of microevolution.

The average score on the microevolution subscale was 35.87 out of 40 total possible. The standard deviation was 4.0. Microevolution is the most well accepted component of the theory of evolution. 88% of students surveyed in the study scored 32 or higher on the microevolution subscale indicating very high acceptance. 22% of students earned the highest possible score on this subscale, a score of 40 which is only earned if students adopt the strongly agree disposition for all the pro-evolution stances on the microevolution subscale. On the other subscales—macroevolution and human evolution—only 16% of students score 40.

Table 5: Levels of acceptance of microevolution and corresponding number of students from the study population belonging to each category.

Score Range	Level of agreement	Level of acceptance	Number of students	Percentage of study population
8	Strongly disagree with all	Extremely low	0	0%
9-16	Strongly disagree	Very low	1	0.2%
17-24	Disagree	Low-moderate	7	1.4%
25-31	Agree	High	52	~11%
32-39	Strongly agree	Very high	323	66%
40	Strongly agree with all	Extremely high	106	~22%

Nearly 99% of the college students studying biology surveyed fell into the category of high or very high acceptance of microevolution. Nearly a quarter of all students surveyed, about 22%, earned the highest possible score on the microevolution subscale which is only achieved by strongly agreeing with all of the pro-evolution stances on the I-SEA items. Where in other constructs, there tends to exists a small, but still noticeable minority of students who form a middle group of low to moderate acceptance, in the microevolution subscale such a middle group virtually vanishes as less than two percent of students earned scores putting them into the category of low to moderate acceptance of microevolution. Each of the other constructs has several more times as many students in the low to moderate category, and microevolution is also the only construct with zero students in the extremely low acceptance category. Extremely low acceptance is categorized by scores of 8 on a construct, which is only earned by strongly disagreeing with all pro-evolution stances on I-SEA items within a given construct.

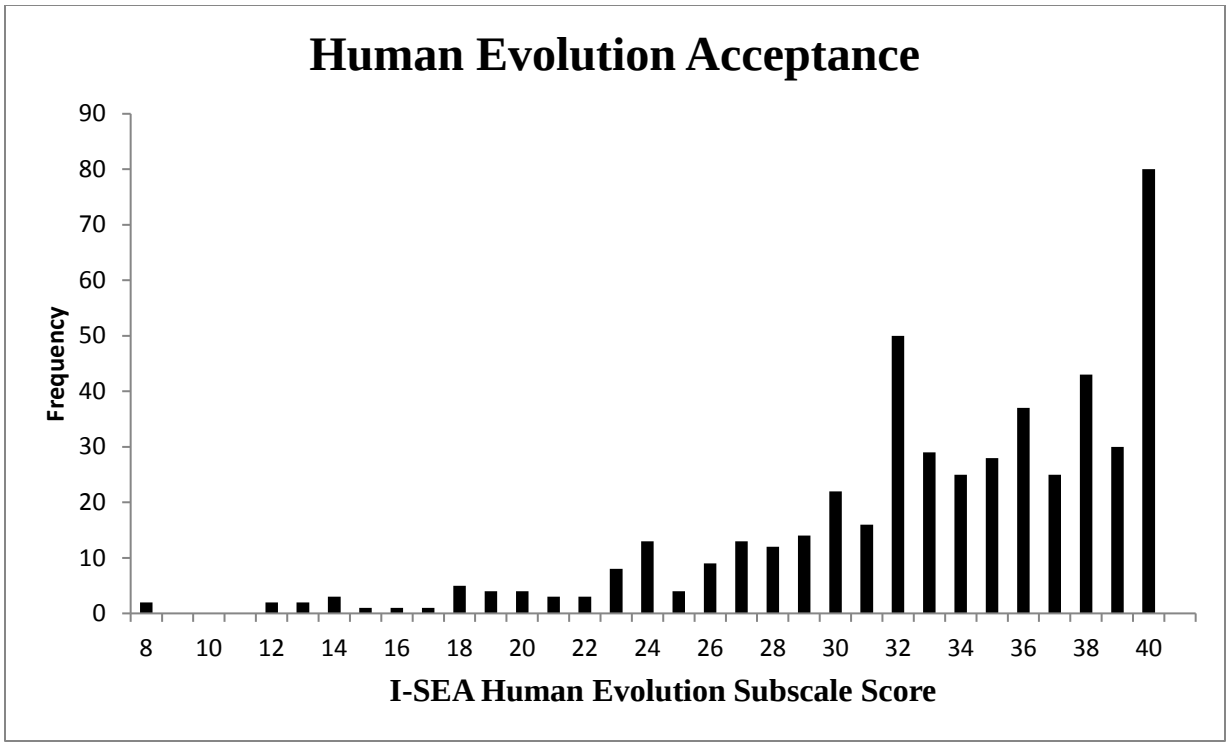

Figure 4: Frequency distribution of the human evolution subscale measured by the I-SEA for N=489. Human evolution was the least accepted construct measured. Only 71% of students had scores of 32 or higher, the threshold for strong acceptance of human evolution.

The average score on the human evolution subscale was the lowest of the three subscales measured by the I-SEA; 33.24 compared to an average of 34.09 for the macroevolution subscale and an average of 35.85 for the microevolution subscale. Some research suggests to focus on human evolution as a means to teach evolutionary theory in the biology classroom, (Pobiner, 2016). Strong arguments can be made for such an emphasis, and the I-SEA would serve as a useful educational tool to assess the quality of such classroom interventions designed specifically to improve student understanding and acceptance of human evolutionary history. The examination of the acceptance of different constructs measured by the I-SEA is explored further in the analysis of the second research question posed in the study.

Table 6: Levels of acceptance of human evolution and corresponding number of students from the study population belonging to each category.

Score Range	Level of agreement	Level of acceptance	Number of students	Percentage of study population
8	Strongly disagree with all	Extremely low	2	0.4%
9-16	Strongly disagree	Very low	9	1.8%
17-24	Disagree	Low-moderate	41	8.4%
25-31	Agree	High	90	18%
32-39	Strongly agree	Very high	267	55%
40	Strongly agree with all	Extremely high	80	16%

Research Question 2 Analysis

The second research question of the study dealt with the acceptance of the components of evolution-- microevolution, macroevolution, and human evolution—as measured by the I-SEA. Using a paired samples t-test to compare student scores on each of the subscales, it is found that a statistically significant difference exists between student scores on each of the constructs.

Students tend to accept microevolution more than macroevolution or human evolution. The average score on the microevolution subscale was 35.87 out of 40 possible. The standard deviation was 4.0. The average score on the macroevolution subscale was 34.08 and the standard deviation was 5.2, and the lowest average score was for the human evolution subscale which had an average score of 33.24 and a standard deviation of 6.2.

The results of the paired samples t-test comparing the macroevolution and microevolution subscales are included in Table 7. The result, $t(488)= 10.39$, $p<0.001$ indicates a statistically significant difference exists between the macroevolution scores and the

microevolution scores. The mean score students for students on the macroevolution subscale was 34.1 SD = 5.2, while the mean microevolution subscale score was 35.9 SD = 4.0. Due to the relatively large sample size, an effect size was calculated which showed a moderate effect, Cohen's d=0.38.

Table 7: t-test result comparing I-SEA subscale scores on the macroevolution subscale and microevolution subscale. Students score statistically significantly higher on the microevolution subscale compared to macroevolution. The effect size is moderate, Cohen's d= 0.38

t-Test: Paired Two Sample for Means		
	Macroevolution	Microevolution
Mean	34.09406953	35.86707566
Variance	27.13457541	16.10319655
Observations	489	489
Df	488	
t Stat	-10.39383605	
P(T<=t) one-tail	2.70465E-23	
t Critical one-tail at p=.05	1.647982077	
P(T<=t) two-tail	5.4093E-23	
t Critical two-tail	1.96483707	

These results indicate students tend to accept microevolution as a construct within evolutionary theory more than macroevolution.

Comparing the scores on the microevolution and human evolution subscales shows the largest disparity between any of the three subscales. The result of the t test: $t(488)= 13.34$, $p<0.001$ indicates a statistically significant difference between scores on the microevolution and human evolution subscales. Students score a mean score of 35.9 SD = 4.0 on the microevolution subscale. This score is significantly higher than the average score of 33.2 SD = 6.2 achieved for the human evolution subscale. The results of the t-test comparing microevolution and human evolution are shown in Table 8. The effect size was shown to be moderate, Cohen's d= 0.50.

Table 8: t-test comparing I-SEA subscale scores on the microevolution subscale and human subscale. The result indicates a statistically significant difference exists between microevolution acceptance and human evolution acceptance.

t-Test: Paired Two Sample for Means		
	Microevolution	Human Evolution
Mean	35.86707566	33.24744376
Variance	16.10319655	39.00217071
Observations	489	489
df	488	
t Stat	13.34948591	
P(T<=t) one-tail	3.58043E-35	
t Critical one-tail at p=.05	1.647982077	
P(T<=t) two-tail	7.16087E-35	
t Critical two-tail	1.96483707	

While there was not as pronounced a difference between macroevolution and human evolution when compared with the difference between microevolution and human evolution, there was still a statistically significant difference between scores on the macroevolution and human evolution subscales as measured by the I-SEA. The results of the t test, $t(488)= 5.35$, $p<0.001$ indicates a statistically significant difference between the scores on these subscales. Students' mean score on the macroevolution subscale, 34.1, was significantly higher than the human evolution mean score, 33.2. The effect size was low however, Cohen's $d = 0.15$. This may suggest the difference, while statistically significant, is only so due to the relatively large sample size.

Table 9: t-test results showing the comparison of I-SEA scores on the macroevolution and human evolution subscales. The result indicates a statistically significant difference exists between macroevolution acceptance and human evolution acceptance.

t-Test: Paired Two Sample for Means		
	Macroevolution	Human Evolution
Mean	34.09406953	33.24744376
Variance	27.13457541	39.00217071
Observations	489	489
df	488	
t Stat	5.341253987	
P(T<=t) one-tail	7.09062E-08	
t Critical one-tail at p=.05	1.647982077	
P(T<=t) two-tail	1.41812E-07	
t Critical two-tail	1.96483707	

The Inventory of Student Evolution Acceptance serves as an incredibly useful classroom tool for biology instructors. The level of specificity in where students tend to accept and reject specific constructs within evolutionary theory provided by the I-SEA proves it a valuable assessment tool to refine instruction. In the current study, the I-SEA was able to show different levels of acceptance for the different constructs measured. This supports the research conducted as the I-SEA was developed, where the same trend of microevolution being the most accepted construct and human evolution being the least accepted construct was also observed, (Nadelson & Southerland, 2012).

Research Question 3 Analysis

The third research question of the study examined a possible connection that may exist between the level of high school biology coursework and level of acceptance of evolution. An analysis of variance, ANOVA, was conducted to determine if there was a statistically significant difference between students who took advanced biology in high school versus Biology I, or Biology I Honors in their current level of acceptance of the theory of evolution as measured by

the I-SEA. The results of the analysis of variance are displayed in Table 10. The students who took Biology I in high school scored an average of 101 out of 120 on the I-SEA. The standard deviation was 15. Students who took Biology I Honors scored slightly higher on average. The average score of students who took Biology I Honors in high school was 103, and the standard deviation was 14.1. Students who took an advanced biology course in high school earned an average score of 105, and the standard deviation was 13.7. While these differences in averages certainly exist, the difference is likely due to chance. Because the analysis of variance demonstrated no statistically significant result. While the difference is indeed likely chalked up to chance, several post-hoc tests were conducted to explore the research question further, the Tukey HSD test was administered and its results compare each of the three groups. The only comparison close to significant exists when comparing the group of students who took an advanced biology course in high school to students who took Biology I.

When comparing these students the Tukey HSD= 3.09, $p<.07$. The result indicates no statistically significant difference exists.

Table 10: ANOVA results for research question three analysis. The result $F(2,480)=2.40$, $p=.09$ indicates no statistically significant difference exists between I-SEA scores for students belonging to different groups based on previous high school biology coursework. The critical F value given in the table is at the $p=.05$

Groups	Count	Sum	Average	Variance
Biology I	130	13139	101.0692	224.9952
Biology I Honors	174	17960	103.2184	198.9578
Advanced Biology	179	18733	104.6536	188.2838

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	968.1338	2	484.0669	2.396405	0.092133	3.014507
Within Groups	96958.6	480	201.9971			
Total	97926.74	482				

In order to probe the question further, a set of t-tests were conducted to compare the mean I-SEA scores for students who previously took various levels of high school biology. The results of the t-tests used to compare student scores on the Inventory of Student Evolution Acceptance for students who took Biology I in high school compared to students who took Biology I Honors are shown in Table 11. The difference in the mean scores is not statistically significant and the effect size is low, Cohen's d=0.12. These results suggest honors level students are either not more likely to accept evolution than non-honors level peers, or may also suggest that no more emphasis on the theory of evolution is placed in an honors level course than in a non-honors high school biology course. Further research here is warranted. It is perhaps worth noting that students who take Biology I and Biology I Honors take the same Biology End of Course examination which constitutes the mandated 30% of their final course grade. This fact may illustrate why the same level of content may be addressed in both an honors level and non-honors level.

Table 11: t-test comparing I-SEA scores for students who took Biology I versus those who took Biology I honors. Cohen's d= 0.12 indicates low effect size. No statistically significant difference exists between these students' I-SEA scores.

t-Test: Two-Sample Assuming Equal Variances		
	Biology I	Biology I Honors
Mean	101.3208955	103.1242938
Variance	222.2045225	200.7003724
Observations	134	177
Pooled Variance	209.956204	
Hypothesized Mean Difference	0	
Df	309	
t Stat	-1.086891341	
P(T<=t) one-tail	0.13896597	
t Critical one-tail p=.05	1.649799826	
P(T<=t) two-tail	0.277931939	
t Critical two-tail	1.967670885	

Students who took an advanced biology course rather than Biology I or Biology I Honors, or took an advanced biology course in addition to Biology I or Biology I Honors did score significantly higher on the I-SEA than students who took Biology I, but these results are only significant at the level $p<0.05$. The full results of the t-test between student scores on the I-SEA for students who took Biology I compared with students who took an advanced biology course in high school are included in Table 12. The t-test, $t(308)=1.99$, $p=0.046$ results indicate a statistically significant result measured at the level $p<0.05$. These results would not be significant measured at the threshold previously used in the study $p<0.001$ and so the null hypothesis that there is no difference between level of acceptance of evolution as measured by the I-SEA for students that took Biology I compared to students who took an advanced biology course in high school is accepted.

Table 12: t-test comparing I-SEA scores for students who took Biology I versus those who took an advanced biology course in high school. Cohen's d=0.23 indicates low effect size, the result is only significant at the level p=0.05. The threshold p<0.001 used for the study caused the researcher to accept the null hypothesis; there is no significant difference between acceptance of evolution for students who took Biology I and those who took Advanced Biology.

t-Test: Two-Sample Assuming Equal Variances		
	Biology I	Advanced Biology
Mean	101.3208955	104.5738636
Variance	222.2045225	187.1602273
Observations	134	176
Pooled Variance	202.2929911	
Hypothesized Mean Difference	0	
Df	308	
t Stat	-1.994882289	
P(T<=t) one-tail	0.023468315	
t Critical one-tail, p=.05	1.649815934	
P(T<=t) two-tail	0.046936631	
t Critical two-tail	1.967696005	

In each of these tests it is clear upon inspection of the data that the average score on the I-SEA for honors students, 103 SD = 14, is higher than the average score for nonhonors students, 101 SD = 15. The fact that this difference is not statistically significant means such a difference could be due to chance. It is also worth noting the average score for students who took an advanced biology course, 105 SD = 14, is also higher than either honors or nonhonors students but again this difference is not significant at the level used as a threshold for the current study. Another important note to consider upon drawing conclusions from the data collected to answer research question three is to consider the college-level instruction in biology that many of the junior and senior level students have received between their high school coursework and when they took the survey for the current study. Such instruction may wash out any effect of high school biology instruction, but rather the differences shown to exist, while not statistically

significant, could be due to the nature of the student who may take an advanced course in high school and not due to the instruction received in the advanced course itself. Further research that focuses on freshmen level students only may shed further light on the question. A preliminary analysis along these lines conducted with the studies' dataset is presented in the additional findings.

One final examination of the data related to the third research question sought to answer if there existed a statistically significant difference between students who took either Biology I or Biology I Honors versus those students who took an advanced biology course. Students who took either Biology I or Biology I Honors were collapsed into one group and compared to students who took an advanced biology course. An analysis of variance and subsequent Scheffe post hoc test revealed no statistically significant difference. The ANOVA result was calculated to be $F(1,481)=3.09$, $p=.08$, and the Scheffe post hoc test was calculated to be Scheffe's T-statistic= 1.76, $p=.08$. These calculations support the previous results.

Research Question 4 Analysis

The fourth research question of the current study examined if there was a difference between levels of acceptance of the theory of evolution as measured by the I-SEA for students who attend worship services weekly or more compared with those who attend less than weekly. The results of the t-test comparing the I-SEA scores for students who attend worship services at least weekly compared to those who attend less than weekly are included in Table 13. The t-test result, $t(86)=6.76$, $p<0.001$ indicates a statistically significant difference exists for these groups. Students who reported attending worship services weekly or more had a mean score of 90 on the I-SEA. The standard deviation was 19. Students who reported attending worship services less than weekly had a mean I-SEA score of 106, and the standard deviation was 12. Furthermore, the

effect size is large, Cohen's d= 0.92 indicating the difference is not just due to the large sample size. These results support previous findings that indicate a strong correlation between religiosity and low levels of acceptance of evolution, (Gwon, 2012; Rissler 2014).

Table 13: t-test comparing I-SEA scores for students who attend worship services weekly or more compared to those who attend less than weekly. Cohen's d=0.92 indicates a large effect size. The result indicates a statistically significant difference exists between these students in acceptance of evolution.

	Weekly or more	Less than weekly
Mean	90.35526316	105.6127451
Variance	361.2721053	136.6162499
Observations	76	408
df	86	
t Stat	-6.763807125	
P(T<=t) one-tail	7.71844E-10	
t Critical one-tail at p=.05	1.662765449	
P(T<=t) two-tail	1.54369E-09	
t Critical two-tail	1.987934206	

A frequency distribution of I-SEA scores for students who reported attending worship services weekly or more shows this subgroup of students have more moderate levels of acceptance of evolution. A few interesting findings can be drawn from the data for this subgroup of students who reported attending worship services weekly or more; this group of 76 students comprises 16% of all students surveyed in the current study. The lowest scores from the entire dataset belong also to this subgroup. The average score was 90 out of 120 possible. The standard deviation was 19. The average score falls into a category of moderate to high acceptance, indicating average responses of undecided to agree with the pro-evolution stances on I-SEA items. Examining figure 5 reveals about half, or 43%, of the students in the subgroup of attending worship services weekly or more score above a value of 96 which is the threshold for high acceptance. Just over half of the students surveyed in this subgroup scored below this

threshold. This even balance of students who tend to accept evolution and those who have lower levels of acceptance exists only in those students who report attending worship services weekly or more. The tendency to accept human evolution less than other components is exaggerated in students who report attending worship services weekly or more.

Human evolution is the least accepted construct measured by the I-SEA, and the low acceptance of human evolution is more pronounced in students who report attending worship services weekly or more. The average score on the human evolution subscale for the entire population surveyed was 33 out of 40, similar to the average score for students in the subgroup who reported attending worship services less than weekly who scored an average of 34 out of 40 possible on the human evolution subscale of the I-SEA. The average score on the human evolution subscale for the subgroup of students who reported attending worship services weekly or more was 27. A t-test to compare these scores yields a value $t(87)=6.9$, $p<.001$, which indicates a statistically significant difference exists between these groups on levels of human evolution acceptance.

Such a disparity is also evident upon examining average I-SEA scores on the other subscales—microevolution and macroevolution, between students who reported attending services weekly or more, and those who reported attending worship services less than weekly: The average score on microevolution was 32 for students who reported attending worship services weekly or more and the average score for students who reported attending worship services less than weekly was 36 out of 40 possible on the microevolution subscale. A similar difference exists for the macroevolution subscale: the average score on the macroevolution subscale for the students who reported attending worship services weekly or more was 30 and the average score for students in the group who reported attending worship services less than

weekly was 34 out of 40 possible on the macroevolution subscale. The difference between scores on the human evolution subscale is the most pronounced and indicates that students who attend worship services more than weekly not only tend to accept evolution less than their peers, but accept human evolution the least, as has been shown in previous studies, (Gwon, 2012; Funk & Alper, 2015). The average score on the human evolution subscale for students who attend worship services weekly or more was 28 SD = 8.1 , The average score on the human evolution subscale for students who reported attending worship services less than weekly was 34 SD = 5.2.

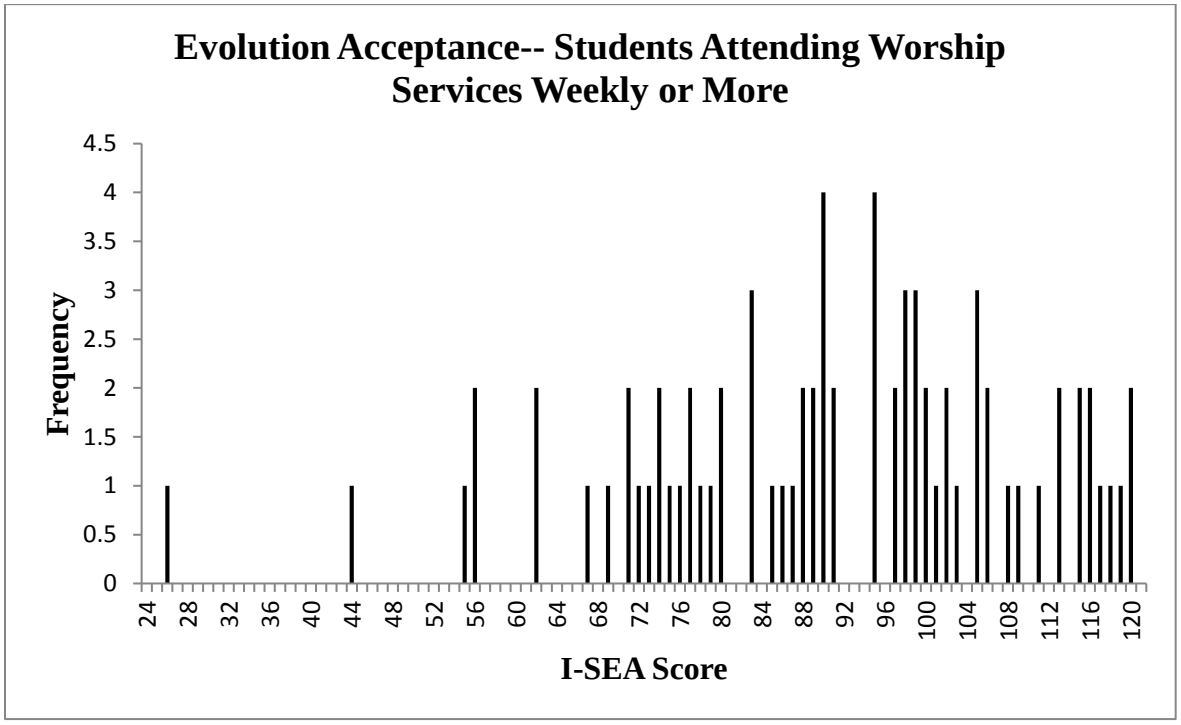

Figure 5: Frequency distribution of I-SEA scores obtained for students who reported attending worship services weekly or more. The distribution is flatter, and less skewed compared to the entire dataset indicating more even distribution of responses and more responses close to the average. In this group of students, 43% of students scored 96 or higher indicating strong acceptance of the theory of evolution. Note: The relatively few students who reported attending worship services changes the scale of the vertical axis compared to previous frequency distributions presented in this study.

For students who reported attending worship services less than weekly, the average score on the I-SEA was 106 out of 120 possible. The standard deviation was 11.7. For students who

reported attending worship services less than weekly, 86% of students scored 96 or higher on the I-SEA placing them into a category of very high acceptance. Only 2% of students within this group of students who reported attending worship services less weekly fell into the category of low acceptance of evolution due to offering responses that tended to disagree on average with the pro-evolution stance on I-SEA items. 15% of students who reported attending worship services weekly or more fall into the category of low acceptance, with scores below 72 on the I-SEA. Only 43% of the biology students surveyed who attend worship services weekly or more demonstrate very high levels of acceptance of evolution.

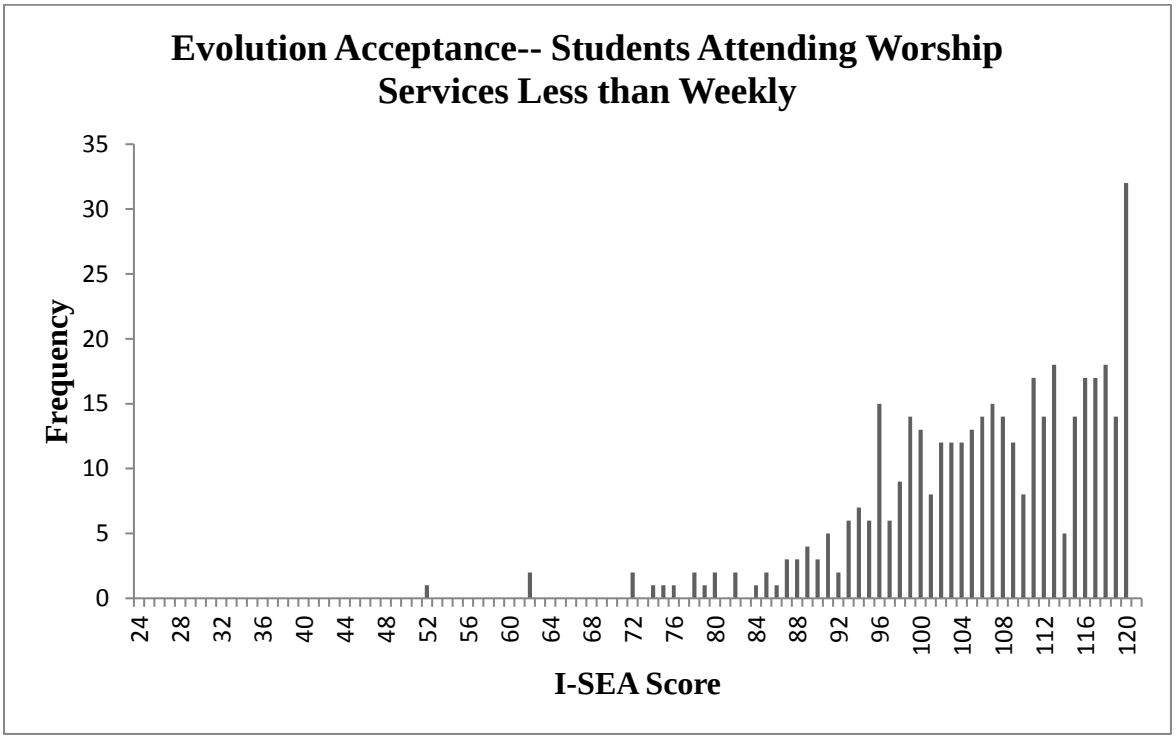

Figure 6: Frequency distribution of I-SEA scores obtained for students who reported attending worship services less than weekly. In this group of students 84% of students earned scores on the I-SEA of 96 or higher indicating strong acceptance of evolution.

The unique demographics represented by the student body of the colleges included in this study offer evolution education researchers insight into a population of students from the

Southeastern United States, Central Florida area. A summary of the population of students surveyed in the current study is included in Table 14.

Table 14: Overview of study population divided by race/ethnicity, gender, and frequency of attending worship services. 52% of students identified as white, 25% Hispanic, the remaining 25% of the population consisted of students who identified as black 7%, Asian 9%, two or more races 3.7%, Arabic 1%, or other 1.8%

Ethnicity/Race	% of total sample	N	average I-SEA score
White	52%	255	105.3
Hispanic	25%	124	101.3
Black	7%	34	97.6
Asian	9%	44	100.9
Two or more races	3.70%	18	106.7
Arabic/Middle Eastern	1%	5	96
Other	1.80%	9	97.9
Gender			
Female	66%	323	102.5
Male	34%	166	104.6
Frequency of Worship Service Attendance			
Less than weekly	83%	408	105.6
Weekly or more	16%	76	90.35
declined to answer	1%	5	102.4

The highest average score obtained on the I-SEA by any racial/ethnic category was 106.7, earned by students who reported two or more races when asked how they would describe their race/ethnicity. Just over half of the students surveyed identified as white, and 25% of students reported belonging to Hispanic/Latino racial/ethnic category. More than half of the students surveyed were female.

The I-SEA was designed to provide fine-grained measures of student evolution acceptance to researchers. The current research has utilized the I-SEA to demonstrate statistically significant differences exist between student acceptance of various constructs within evolutionary theory measured by the I-SEA-- microevolution, macroevolution, and human

evolution. The level of high school biology coursework, whether advanced, honors, or nonhonors biology were taken in high school did not translate into statistically significant differences in levels of acceptance of evolution for students surveyed in the current study. Students who reported attending worship services weekly or more scored statistically significantly less on the I-SEA and thus tended to have lower levels of acceptance of evolution than peers who reported attending worship services less than weekly.

Additional Findings

Students surveyed in this study were asked how often they attend worship services and two answer choices were presented: less than weekly, and weekly or more. While never attending worship services is certainly less than weekly, some students wrote in 'never' as an alternate response to the question. The average score on the I-SEA for these 56 students was high, 113 out of 120 possible. The standard deviation was 7.7. A t-test was conducted to compare the scores of the students who self-reported never attending worship services to those who reported attending worship services weekly or more; the result $t(105)= 9.19$, $p<.001$ indicates a statistically significant difference exists. The students who reported never attending worship services scored statistically significantly higher and therefore have higher levels of acceptance of evolution.

Not only did the students who reported never attending worship services score statistically significantly higher on the I-SEA than those students who reported attending worship services weekly or more, the students who reported never attending worship services scored statistically significantly higher than students who reported attending worship services less than weekly also. The difference in mean score on the I-SEA between students who reported attending worship services less than weekly and those who wrote in never was not as pronounced

as the difference between the students who reported attending worship services weekly or more and those who reported never attending, but the difference is still statistically significant. The result of the t-test conducted to compare the I-SEA scores between students who reported attending worship services less than weekly and those who wrote in never was $t(107)=7.19$, $p<0.001$, which indicates a statistically significant difference exists.

Another manner in which the I-SEA may be utilized is to separate out data obtained from students to determine if perhaps students have low acceptance of the construct or evidence for the construct. Three of the eight items on each subscale contained on the I-SEA are designed to measure students' acceptance of evidence for the construct being measured. Biology instructors may therefore determine if students reject the construct or perhaps even the lines of evidence which support the construct. Table 15 shows the average response for each of the 24 I-SEA items for the current study population. In general, the average scores for items that measured acceptance of evidence for the construct were lower than average scores for other I-SEA items that did not measure acceptance of evidence.

Table 15: Average Scores for all 24 I-SEA items for N=489. Three statements in each of the subscales was designed to assess students' beliefs about the evidence for the construct.

I-SEA Item	Average Score	Question Type
1	4.54	Construct
2	4.32	Evidence for construct
3	4.34	Evidence for construct
4	4.05	Construct
5	4.49	Construct
6	4.19	Evidence for construct
7	4.25	Construct
8	3.96	Construct
9	4.45	Construct
10	4.40	Construct
11	4.59	Evidence for construct
12	4.54	Construct
13	4.66	Construct
14	4.35	Evidence for construct
15	4.60	Construct
16	4.29	Evidence for construct
17	3.94	Evidence for construct
18	4.15	Construct
19	4.34	Evidence for construct
20	4.07	Construct
21	4.23	Construct
22	4.24	Construct
23	4.06	Evidence for construct
24	4.21	Construct

The lowest average score of all 24 I-SEA items was for item 17, an item designed to measure students' acceptance of evidence for the construct of human evolution. A t-test was conducted to compare the average score on this item between students who attended worship services less than weekly and those who attended weekly or more. The result, $t(91)=6.95$, $p<.001$, indicates a statistically significant difference exists between these groups. The results of the t-test are displayed in Table 16. This result suggests those who attend worship services weekly or more tend to have lower acceptance of evidence for human evolution more so than students who attend worship services less than weekly.

Biology instructors who utilize the I-SEA to obtain student data may find the ability to parse the data in such a way as to examine the students who score high on acceptance of the constructs measured and evidence for those constructs useful because instruction could be geared towards educating students specifically about the evidence which supports the constructs.

Table 16: t-test comparing responses on I-SEA item 17—an item designed to measure student acceptance of evidence for the construct of human evolution. The result, $t(91)=6.95$, $p<.001$, indicates a statistically significant difference exists.

	Less than weekly	Weekly or more
Mean	4.108958838	3.039473684
Variance	0.888584593	1.638421053
Observations	413	76
df	91	
t Stat	6.945630167	
P(T<=t) one-tail	2.73418E-10	
t Critical one-tail	1.661771155	
P(T<=t) two-tail	5.46836E-10	
t Critical two-tail	1.986377154	

The power of the fine-grained measures of student data afforded by the I-SEA are apparent in the examination of the comparison of average scores on item 17 between two students groups—those who attend worship services weekly or more and those who attend less than weekly-- who have significantly different levels of acceptance of evolution and human evolution, in particular.

In a recent study conducted at the University of Northern Iowa, students were administered the I-SEA as the study examined Biblical literalism and acceptance of evolution in Christian University students, (Chamberlain, 2015). In this study it was found that of the 79 students who were all incoming freshmen, the average I-SEA score among Protestants was 80.45 and the average I-SEA score among Roman Catholics was 81.70. These scores are dramatically lower than the average scores obtained by students in the current study, although comparisons

drawn should bear in mind the different populations of these studies. As more researchers continue to utilize the I-SEA as an instrument in evolution education research, a growing body of research will allow for comparisons of different populations. The Northern Iowa study surveyed only 79 incoming freshmen at a Christian University. Most of the participants in the current study were junior and senior level undergraduates majoring in biology or biomedical science. By comparing the I-SEA scores between these populations, some interesting questions may emerge, while keeping the differences in samples to bear in mind as well.

While the current study contained very few freshmen level students, the few freshmen who were surveyed were compared to the junior and senior level students. The result of the t-test, $t(460) = .73$, $p = 0.23$ indicates no statistically significant difference exists. The results of the t-test are presented in Table 17.

Table 17: t-test comparing freshmen students' mean I-SEA score to juniors and seniors. While the freshmen mean was less, the result was not statistically significant.

	Freshmen	Juniors and Seniors
Mean	100.4615	103.3674833
Variance	85.26923	203.0990296
Observations	13	449
Pooled Variance	200.0252	
Hypothesized Mean Difference	0	
df	460	
t Stat	-0.73033	
P(T<=t) one-tail	0.23278	
t Critical one-tail at p=.05	1.648173	
P(T<=t) two-tail	0.465561	
t Critical two-tail	1.965134	

The fact that the difference in average I-SEA scores between freshmen and junior/senior level undergraduates was not statistically significant may indicate the importance and influence of biology instruction prior to entering college. Educational leaders must strive to create an

environment of scientific inquiry where students of diverse worldviews can experience the process of science as they learn the characteristics of scientific knowledge as well as the content belonging to their specific science courses. Emphasizing explicit instruction in the nature of science is one area where educational leaders can directly connect to all science educators under their leadership, because the nature of science standards belong to all science courses in the state of Florida—from kindergarten to twelfth grade.

The analyses conducted and the results presented in this chapter will be interpreted and conclusions drawn from the results will be presented in chapter five. The conclusions include recommendations for practice as set against the backdrop of the picture of evolution education in America and particularly, in the State of Florida, as presented in the literature review. Recommendations for future research are also included.

CHAPTER FIVE: CONCLUSIONS AND IMPLICATIONS

Summary of Conclusions

The State of Florida states in its science standards: "The scientific theory of evolution is the fundamental concept underlying all of biology." This Next Generation Sunshine State Science Standard was adopted in 2007, the same year a National Survey of High School Biology Teachers was administered. The results of the 2007 National Survey of High School Biology Teachers showed only 28% of high school biology teachers strongly advocate for the theory of evolution, and found 13% of high school biology teachers illegally teach Creationism or Intelligent Design. The majority of high school biology teachers fall into a group named the "cautious 60%" (Berkman & Plutzer, 2011), who avoid the subject of evolution altogether and thereby cheat their students out of an appropriate science education. Educational leaders would benefit from professional development and training regarding both the Federal and State mandates in place regarding evolution education. Coupling this knowledge of Federal and State law with educational best practices to provide the best possible science education for all students is the goal.

The purpose of this study was to explore student acceptance of evolution in a novel student population-- college students attending university in the Central Florida area. A majority of students surveyed in the study attended high school in the state of Florida, and the average year of high school graduation for the study population was 2012. A majority of the students surveyed in the study are majoring in biology or biomedical science. The Inventory of Student Evolution Acceptance, I-SEA, was administered with the help of university biology instructors and lab assistants, to undergraduate students studying biology. An analysis of 489 completed surveys demonstrated the following:

1) The college students enrolled in a biological science course who were surveyed in this study largely accept the theory of evolution. 78% of the students surveyed scored 96 or higher on the Inventory of Student Evolution Acceptance, I-SEA, indicating average responses of agreeing or strongly agreeing with the pro-evolution stance on I-SEA items. 2) Microevolution was shown to be the most accepted construct measured by the I-SEA within evolutionary theory. Macroevolution was the second most accepted construct measured and human evolution was the least accepted construct within evolutionary theory. 3) Previous high school coursework was not shown to be a statistically significant factor in evolution acceptance. 4) The frequency of attending worship services was shown to be a highly significant factor in students' acceptance of evolution.

The data obtained from this study shows a snapshot in time of the levels of acceptance of evolution of nearly five hundred college students studying biology in Central Florida. This snapshot shows acceptance of the theory of evolution among Central Florida college students is high and the percentage of students with low or very low levels of acceptance of the theory of evolution sampled in this study nearly matches the figures widely reported amongst professional scientists. In the current study, 4% of students demonstrated low or very low levels of acceptance of the theory of evolution and approximately 2% of professional biologists similarly reject the theory of evolution, (Funk and Rainie, 2015).

Only 15% of the students surveyed in the study reported attending worship services at least weekly, and these students tended to accept evolution the least. The students who reported never attending worship services had a mean score of 112 out of 120, the highest of any group analyzed in the study. The divide between religious and scientific worldview seems to be prevalent, although compatibility of science and religion is certainly not absent. From

evolutionary biologist and Catholic Ken Miller to religious thinkers like Pope John Paul II who declared no incompatibility between belief in God and belief in evolution, to the great American hero and Presbyterian John Glenn, who advocated the teaching of evolution in schools, there are countless examples of those who find no conflict between religious and scientific thinking.

Recommendations for Practice

1) Utilize the Inventory of Student Evolution Acceptance in biology instruction.

The Inventory of Student Evolution Acceptance has proven to be an effective tool in demonstrating the differences in levels of acceptance of the theory of evolution in students. Biology instructors would benefit from the data obtained by administering the I-SEA to their students in order to gauge prior knowledge and acceptance of different constructs within evolutionary theory. The I-SEA could be used in a pre-/post-test design to assess the effectiveness of classroom interventions which may be designed to cover specific constructs of evolution, including those measured by the I-SEA—macroevolution, microevolution, and human evolution. Utilizing the I-SEA as a tool to inform biology instruction during a course covering biological science represents perhaps the most promising direction for future research-practitioners. Because the I-SEA was developed and has been shown to provide fine-grained measures of student acceptance of evolution and specific constructs therein, the I-SEA is a very valuable educational tool to provide biology instructors useful data regarding their student population.

Data obtained from the I-SEA may help biology instructors hone their instruction on specific topics that need to be addressed as identified by the I-SEA and the efficacy of such refinement could be gauged using the I-SEA in a pre-test/post-test manner. Here the I-SEA shows tremendous potential to impact future research and instruction in evolution.

The results of the macroevolution and microevolution surveys indicate that students may accept the underlying mechanisms of evolution, but fail to accept their long term conclusions. Macroevolution being just the consequences of microevolutionary processes would suggest agreement in acceptance of these subscales. The fact that the subscale scores differ so greatly is important for biology instructors who may use the I-SEA as an instrument to focus curricular decisions. Such a disparity between scores on the microevolution and macroevolution subscales may indicate a need to emphasize the connection between microevolution and macroevolution, and perhaps focus lessons specifically on long term consequences of evolutionary processes.

Macroevolution may be less accepted than microevolution due to a difficulty in understanding deep time, (Catley & Novick, 2009). Macroevolution is the result of microevolution, the idea that small changes within species over enough time will lead to more dramatic changes and eventually new species is the way evolution works. The distinction of microevolution and macroevolution is indeed artificial, but very useful both pedagogically to introduce complex phenomenon in a sequence that makes sense and in terms of categorizing phenomenon in evolutionary biology research. The direct observation of microevolution in organisms whose relatively short lifespan allow for experiments where successive generations may be produced within a few weeks or months perhaps makes its conclusions harder to refute.

Microevolution is the most accepted construct within evolutionary theory. Science educators can utilize this knowledge to inform instruction and lesson delivery. If students tend to accept microevolution then perhaps the sequencing of lessons could be considered in terms of connecting the two related concepts of microevolution and macroevolution. Indeed, macroevolution is simply the consequence of microevolution. The authors of the I-SEA write, “It is our argument that what is considered ‘traditional’ in a biology classroom should be expanded

to embrace both micro and macroevolution. By devoting more instructional time to macroevolutionary events in addition to microevolution, and focusing students on the very different forms of evidence for each, biology instructors can allow students to better understand evolution broadly conceived," (Southerland & Nadelson, in Rosengren et al., 2012, p.366).

The results of the human evolution subscale of the I-SEA indicate a need to emphasize human evolution in biology classrooms in order to increase overall acceptance of this construct. Novel approaches such as focusing specifically on human evolution, (Pobiner, 2016), as a means to improve student acceptance of this construct could be assessed using data obtained from the I-SEA pre- and post- intervention. The Smithsonian hosts a website dedicated specifically to teaching and learning human evolution, (www.humanorigins.si.edu/education/introduction-human-evolution, accessed April 13, 2017). The Smithsonian has also developed an entire curriculum entitled Teaching Evolution through Human Examples, a resource freely available for educators on the Smithsonian website (www.humanorigins.si.edu/education/teaching-evolution-through-human-examples, Accessed April 13, 2017).

The human evolution subscale results help to inform biology instruction by highlighting opportunities for student growth. Macroevolution and human evolution tend to be the components of the theory of evolution students accept least. By focusing on human evolution as an example of evolution, biology instructors may break down misconceptions and help students connect their understanding of microevolution to the evolution of humankind, (Pobiner, 2016).

The finding that human evolution is the least accepted construct has important consequences in the biology classroom where educators may decide to utilize human evolution as a means to bring relevance to the topic of evolution. Because students are themselves human, the relevance of studying human evolution is immediately obvious. Biology teachers should be

cognizant of the fact that some students may be most resistant to learning about this particular component, human evolution, compared to the broader theory of evolution. Utilizing the I-SEA as a tool in the biology classroom to gauge student acceptance of certain components of the theory of evolution before and after instruction would prove a useful means of assessing the effectiveness of certain lessons and classroom interventions geared towards the specific constructs measured by the I-SEA.

Biology instructors may use the data obtained by the I-SEA to focus specifically on the lines of evidence that support human evolution, while simultaneously educating students about the nature of science and the strict standards of scientific evidence. Recent peer-reviewed studies that focus specifically on human evolution and the evidence collected to support these explanations may prove worthwhile subject matter to examine the scientific method as it relates specifically to human evolution. A study published in 2017 examining the relationship between pelvic breadth and stride length in human evolution tested a hypothesis dating back to the famous protohuman fossil Lucy, (Rosenberg et al., 2017). The interesting history of famous protohuman fossils such as Lucy is itself great subject matter in the biology classroom. Modern world wide projects such as the National Genographic project, (genographic.nationalgeographic.com), utilize the data storehouse known as the cellular nucleus to map genetic changes in living people's DNA to trace genetic ancestry. Students will typically be curious about human origins because it is a relevant story. New insights into human evolution are being revealed all the time as new discoveries are made. In 2015, it was reported that evidence of protohuman species using stone tools as far back as 3.3 million years ago was discovered, (Harman, et al., 2015). These recent discoveries help showcase to students how

cutting edge science is conducted contributing both to the body of scientific knowledge, but also to the students' understanding of the nature of science.

The Inventory of Student Evolution Acceptance serves as an invaluable tool to inform instruction in the biology classroom. Because evolution is the centerpiece of biological science, focusing on the theory of evolution as an organizing framework for instruction serves biology students well, (Nelson, 2008). The theory of evolution also serves as an excellent example for teaching students about the nature of science, and because an emphasis on the explicit instruction in the nature of science has been shown to improve student understanding of the theory of evolution, (Scharmann, Smith, & James, 2005; Butler, 2010; Southerland & Scharmann, 2013), it seems reasonable to dedicate resources to organizing biology instruction around the complementary foci of the nature of science and the theory of evolution.

2) Science educators would benefit from professional development opportunities and training to focus on explicit instruction in the nature and philosophy of science to improve evolution acceptance.

Understanding the nature of science is a primary goal of achieving scientific literacy. Explicit instruction in the nature of science has been shown to be an effective strategy for increasing scientific understanding and increased understanding and acceptance of the theory of evolution specifically, (Scharmann, Smith, & James, 2005; Butler, 2010; Southerland & Scharmann, 2013). Addressing the nature of science appeals to both the cognitive and affective domain. Because the nature of science covers topics of epistemology students may draw an affective connection to learning about the thought processes that contribute to values and truths students hold about the world. Appealing to the affective domain is appropriate to educate students about what to learn and why it is important to be learned, (Krathwohl, 1967). Students

possess unique worldviews which are shaped within the social context of home and family prior to entering school and continue to be influenced and shaped by family and peer groups throughout schooling. Education influences students' ways of thinking and knowing and in turn students' worldviews are continually reshaped as they are exposed to new ways of thinking and knowing: science educators focus on developing both the ways in which scientists think—by focusing on the scientific method, for example, and the nature and philosophy of science as a way of knowing about the natural universe based on observation, experimentation and logical inference.

The impact of worldview on what people come to accept as true and valid is very real and physical evidence alone is often insufficient to overcome the influence of worldview when that worldview apparently conflicts with the evidence, (Batson, 1975).

One finding of the study suggests low levels of acceptance of evolution is related to a student's' tendency to attend worship services which is likely strongly related to the student's' worldview. Science educators can tap into the power of thinking and knowing by leveraging the power of the lessons contained within the already required instruction of the nature of science. Exploring the bounded nature of science allows students the freedom to explore different ways of knowing and understand the rules that restrict and define certain ways of knowing like science. Giving students this "place to stand," (Scharmann, 1990), may improve overall levels of acceptance of evolution by getting to the students who may otherwise reject the theory based on both a perceived conflict in their worldview, and an ignorance of epistemology itself. Students may never realize the power in studying different ways of knowing and understanding if their worldview contains the belief that there is only one correct way to understand the world. Here, the mission of the science educator is perfectly clear—to help create the learning environment

where horizons and minds can open and flourish. Science educators should not hope to have students reject their own worldview, but rather should educate students about the process of science, science as a way of knowing, the characteristics of scientific knowledge, the role of hypotheses, laws, theories, and models in science, and the impact of science on society-- all themes covered within the nature of science.

The extent to which worldview is malleable is perhaps as unique as each student. One goal of the lofty forward thinking plan Project 2061 of the American Association for the Advancement of Science is to increase scientific literacy in students and orient students toward a more scientific worldview. Such a position has been attacked by an anti-evolution group, Citizens for Objective Public Education, COPE, who filed a lawsuit against the Kansas Board of Education in 2013. In the complaint filed, COPE stated that the Next Generation Science Standards would violate the Establishment clause by effectively endorsing a "nontheistic religious worldview," (COPE v. Kansas Board of Education, 2013). This complaint was rejected and the Supreme Court denied to hear COPE's appeal in November 2016. The wealth of literature, reviewed in part in chapter two, and research conducted on what works in the science classroom consistently points to emphasis on explicit and implicit instruction in the nature of science. The Next Generation Sunshine State Standards, which Florida adopted in 2007, include the nature of science as a separate strand of standards and these standards are embedded in all science courses in Florida public schools. The goal is to educate students about the nature of science as a way of knowing about the natural universe. The bounded nature of science is a concept embedded within the Florida nature of science standards and deals with educating students about the questions which are outside the boundaries of science--questions which other ways of knowing such as philosophy, religion, or art may be better equipped to answer. Offering

students who hold a worldview of Biblical literalism, or Young-Earth Creationism the previously mentioned "place to stand" (Scharmann, 1990), in the biology classroom allows students to learn about the theory of evolution without having to reject their existing belief structure. This study in part demonstrates the success of such standards being in place as the average year of graduation for students sampled in this study, 2012, puts the majority of students sampled in Florida public high schools after the 2007 adoption of the Next Generation Sunshine State Standards which included revamped standards addressing evolution.

3) Educational leaders should receive professional development and training of Federal mandates in place regarding evolution education, especially the unconstitutionality of teaching Intelligent Design-Creationism.

Case law related to evolution education dates back to at least 1925 with the famous Scopes Monkey Trial. Of particular importance to educational leaders is the recent precedent handed down in Kitzmiller v. Dover Area School Board (2005), which effectively bans the teaching of intelligent design as an alternative to the theory of evolution. Judge Jones III decision in this case is good reading for educational leaders because much of the relevant prior case law is summarized by Judge Jones III in his ruling. One critical takeaway from the 59 page decision is, "The evidence at trial demonstrates that ID [intelligent design] is nothing less than the progeny of creationism," (Kitzmiller v. Dover, 2005). This decision is a continuation of a pattern of Federal level decisions including the notable Supreme Court decision Edwards v. Aguillard, (1987) which effectively bans the teaching of Creationism as an alternative to the theory of evolution. Educational leaders must be aware that science teachers who choose to teach either Creationism or intelligent design as science in a science classroom are violating the law and worse; they are misrepresenting one of the most elegant and powerful ideas in all of science to

students. Students taught intelligent design as science are being cheated out of an appropriate education; a science teacher violates the law and public trust in an egregious way when nonscientific ideas like Creationism or intelligent design are presented as science in a science classroom. Berkman and Plutzer found as many as 13% of high school biology teachers teach intelligent design or Creationism in their classroom, a failure in science education and science educational leadership alike.

4) Education leaders should receive professional development and training on the State level mandates in place regarding evolution education, including the requirement of biology instruction and the requirement of nature of science instruction and evolution instruction in Florida public high school biology courses.

Florida statutes require students attending Florida public high schools to receive instruction in biology. Florida statutes also require students to take a Biology end-of-course examination in their high school career which constitutes 30% of their final course grade in Biology. Educational leaders who wish to cultivate a climate of scientific inquiry where the biological science are taught as an integral part of a vision for science education which includes an emphasis on the nature of science throughout students' academic career and a focus on the theory of evolution for organizing instruction in biological science. The Florida Department of Education approves courses and standards which belong to those approved courses. The very first sentence of the science standard which covers biological evolution in the high school Florida Next Generation Sunshine State Standards reads: "A. The scientific theory of evolution is the fundamental concept underlying all of biology," (Retrieved from http://www.cpalms.org/Public/PreviewIdea/Preview/586, accessed April 2, 2017). An educational leader who takes the language of this standard to heart not just because it is the law,

but realizes it is the best way to develop a culture of scientific thinking will honor the students and teachers who follow their leadership.

In addition to the requirement of providing instruction in biological science including teaching the theory of evolution, as at least nine course standards belonging to Biology I are specific content standards related to the theory of evolution, biology instructors must also educate students about the nature of science. Several nature of science standards belonging to big ideas including the practice of science, the characteristics of scientific knowledge, the role of theories, laws, hypotheses, and models, and science and society are imbedded in the Biology I and Biology I Honors courses. The State of Florida approves these courses and the required standards and by statute students must take biology in high school to earn a diploma. Biology is the one science subject where students are also required to take an end-of-course examination and the test item specifications published by the State of Florida specifically address the fact that intelligent design and creationism will not be assessed on the Biology End-of-Course examination.

Because the nature of science is a common theme belonging to all of the disciplines within science, educational leaders have a unique opportunity to focus professional development and training opportunities for science educators under their leadership to address these important nature of science standards from kindergarten through twelfth grade.

Recommendations for Future Research

1) Researchers studying evolution education would benefit from comparing student data obtained from the Inventory of Student Evolution Acceptance, I-SEA.

The levels of acceptance of evolution and the corresponding I-SEA scores presented in the current study are based on the rationale that strongly agreeing with the pro-evolution stance on I-

SEA items, on average, suggests high levels of acceptance of the theory of evolution and the constructs measured by the I-SEA—microevolution, macroevolution, and human evolution. An argument could be made to set different thresholds for the I-SEA scores that correspond to each level of acceptance.

Another suggested method to breakdown the I-SEA scores in order to determine different levels of acceptance of evolution would be to mirror the breakdown of scores on a similar instrument, the Measure of Acceptance of the Theory of Evolution, or MATE, (Rutledge & Warden, 1999). The MATE restricts very high acceptance to scores between 89 and 100 on the 100 point scale the MATE yields. These scores represent the top 15% of possible scores, and if a similar breakdown were applied to the I-SEA then very high acceptance would be restricted to scores between 106 and 120. The mirrored breakdown of scores on the I-SEA to resemble the scores indicative of very high, high, moderate, low and very low levels of acceptance of evolution as determined by the author of the MATE, (Rutledge & Warden, 1999; Rutledge & Sadler, 2007), is found in Table 18 below.

Table 18: Parallel score breakdown for two instruments used to measure acceptance of evolution, the MATE (information in table taken from Rutledge & Sadler, 2007) and the I-SEA.

Score range (MATE)	Score range (I-SEA)	Level of acceptance
89-100	106-120	Very high
77-88	91-105	High
65-76	76-90	Moderate
53-64	61-75	Low
20-52	24-60	Very low

Table 19: Subscale scores and corresponding levels of acceptance for each subscale on the I-SEA—macroevolution, microevolution, and human evolution.

Subscale score range	Level of acceptance
36-40	Very high
31-35	High
26-30	Moderate
21-25	Low
8-20	Very low

One benefit of using the breakdown mirroring the MATE instrument is the potential ability to compare levels of acceptance in both the I-SEA and MATE more easily. The MATE, for example, keeps a majority of very low scores in the range of very low acceptance where any score between 20 and 52 is considered low acceptance. When a similar approach for categorizing levels of acceptance of evolution is applied to the I-SEA, scores between 24 and 60 are considered very low. This range is obtained by taking the percentage of total points that high scores on the MATE represent and applying a similar percentage breakdown to the I-SEA, which is scored between 24 and 120 rather than 20-100 for the MATE. For example, scores in the range of 89-100 represents 12 possible scores out of 81 total possible scores on the MATE; the MATE can score 20-100 inclusive. These top twelve point totals constitute about 15% of the possible scores and 15% of the 97 possible scores on the I-SEA, which can score 24-120 inclusive, yields about 15 points per level. This is certainly conducive to a subscale breakdown as shown in Table 19. Score intervals of 15 points are utilized for the very high, high, moderate, and low levels of acceptance categories. The remaining lowest scores are categorized as very low. It is this line of reasoning that yields the breakdown found in Table 18 where each level represents 15 possible

scores: 106-120 inclusive for very high acceptance and so on. Once each score range was set by dedicating an even fifteen points per level, the remaining points at the very low end of the scoring spectrum fell into the very low acceptance category. This scoring breakdown parallels that of the MATE, an instrument that has been utilized in evolution education research for over a decade, (Wagler & Wagler, 2013). In using the MATE, researchers often go by the levels of acceptance of evolution assigned by Rutledge, the author who developed the MATE, however, reasoning for assigning such levels appears to be absent: "Upon examination of Rutledge's (1996) dissertation, we could find no justification for the values assigned to each scoring category," (Dorner & Scott, 2016, pp.5-6).

The apparent arbitrariness to the levels of acceptance assigned in the MATE instrument may indicate the argument for the breakdown of scores used in the analysis of the current study. Both score breakdowns are offered for consideration in future research. The argument in favor of the MATE-like breakdown would be to maintain a level of consistency in the body of research that exists which has made use of the MATE. While this body of research has been called into question on grounds of researchers' failure to revalidate the MATE with novel populations who were surveyed using the MATE, (Wagler & Wagler, 2013), the utilization of the MATE in an intervention type of study where the MATE is used as a means to assess student growth or teaching effectiveness is evidence itself of the MATE's validity in those populations, (Rowe et al., 2015, p.10):

> Two related experimental approaches for assessing the construct validity of a test are intervention studies and differential group studies…we used both approaches in this study…we argue that the power and consistency of our results are strong validation of the success of the intervention.

An argument made in favor of the MATE-like breakdown may be to set a higher threshold for very high acceptance, so that fewer students are captured in the uppermost category. The two suggested point breakdowns and corresponding levels of acceptance presented here yield quite different results and so the consideration of how to assign various levels of acceptance based on I-SEA scores is worthwhile. The MATE-like threshold for very high acceptance on the I-SEA is a score of 106. For students who scored just below this threshold at 103, which was the average score, should they also be considered in the highest category? One may frame the question thusly: Biology majors scored an average of 103 on the I-SEA in the current study and so should the average score be included in the very high level of acceptance? Should a higher threshold for very high acceptance be set similar to that of the MATE instrument? This scoring breakdown wouldn't capture those students who scored near the average value of 103, as the threshold is 106. Researchers who have utilized the MATE instrument in the past may perhaps prefer a breakdown that sets a higher threshold for very high acceptance. As more researchers utilize the I-SEA instrument in evolution education research, and more data is collected on different student populations, the appropriate assignment of levels of acceptance of evolution may be forthcoming and the suggestions presented in the current research are humbly offered for consideration. It is worth noting that utilizing the MATE-like breakdown for the data collected in the present study yields just 1% of students falling into the very low acceptance category. 4% of students fall into the low acceptance category. 10% of students would fall into the moderate acceptance. 34% of students would be categorized in the high acceptance category and 51% would fall into the very high acceptance category.

Table 20: Percent of students falling into each level of acceptance category based on the MATE-like breakdown of scores—this higher threshold for acceptance yields only 51% of students in the very high acceptance category.

Score range (I-SEA)	Level of acceptance	Percent of students in current study
24-60	Very low	1%
61-75	Low	4%
76-90	Moderate	10%
91-105	High	34%
106-120	Very high	51%

Examination of the percentage of students falling into each level of acceptance category based on the two scoring breakdowns presented yields slightly different results when looking at the percentage of students who fall into the very high level of acceptance category. Both suggested breakdowns produce about the same percentage of students categorized as having low or very low levels of acceptance of evolution. While the scoring breakdown adopted for the analysis of the current study yields 78% of students in the very high level of acceptance of evolution category, when a higher threshold for very high acceptance is set, such as a breakdown mirroring the MATE, only 51% of students in the current study would be categorized as having very high acceptance.

2) Determine why students answer the way they do on the I-SEA to help determine contributing causes to acceptance or rejection of ideas in students.

Another suggestion for future research would be to determine why students answer in the manner they do on the Inventory of Student Evolution Acceptance. This limitation was acknowledged by the authors of the I-SEA and still represents an area for future research where the I-SEA could be used in conjunction with interview data to delve deeper into the reasons

given for student responses on various I-SEA items. Such research would contribute greatly to the growing body of research on evolution education that will surely continue to gain data from the I-SEA instrument. Interviewing students who represent the broadest range of worldviews and belief structures would provide useful data for science educators interested in the questions of how worldview is formed and persists throughout development in the range of diverse learners present in a classroom at any given time.

3) Study the relationship between acceptance of climate science and political worldview.

The National Center for Science Education, which has historically defended science education from attacks from organizations like the Institute for Creation Research, Answers in Genesis, or the Discovery Institute that seek to undermine science education by weakening the teaching of the theory of evolution, has in recent years expanded its mission to defend against similar attacks regarding climate science. A fruitful direction for future research would be to explore the extent worldview impacts belief in climate science and what strategies in teaching evolution translate into addressing climate science. While religious worldview may play a dominant role in acceptance or rejection of evolution, it is perhaps political or economic philosophy that may be the dominant feature of worldview impacting belief in climate science, (Hornsey et al., 2016). These hypotheses would be worthwhile to explore further.

Studying student acceptance of other scientific theories such as the big bang theory and the theory of relativity and the correlation of acceptance of these theories with students' worldview would be an interesting direction for future research.

While the current study focused on a population of students studying biology, another student population of interest for further research would be pre-service biology teachers, or students studying science education. Students who major in education tend to be more religious

than students studying other disciplines, (Long, 2011). Based on the conclusions drawn from the current study, it is hypothesized students studying education will tend to demonstrate lower levels of acceptance of evolution than peers majoring in other disciplines.

Frank Wilczek, winner of the Nobel prize in Physics in 2004 and author of *A beautiful question: Finding nature's deep design*, (2015) has put forth a theory of learning of which all educators should be made aware:

> My theory that promotion of learning underlies, and is the evolutionary cause of, our sense of beauty in important cases, and the application of that theory to musical harmony, which offers a rational explanation for Pythagoras's discoveries in music, form a constellation of ideas I've entertained privately for a long time but present here for the first time publicly.

Humans desire to learn to discover the beauty in nature. In *A Beautiful Question*, Dr. Wilczek goes on to masterfully elaborate on his theory and draws upon specific biographical examples from the history of science including Pythagoras, Plato, and Newton and reminds the reader that the beauty of nature is just as often subtle as it is grand in the breathtaking obvious ways we think about beauty in nature. The illustration of the worthwhile pursuit of science to discover the symmetry and efficiency of nature (Wilczek, 2015) taps into a wellspring of motivation for students to learn math and science because this sense of beauty addresses the affective as well as the cognitive domains of learning and these two domains work synergistically, (Mottet, 2015).

An emerging interdisciplinary field known as educational neuroscience, (Szucs & Goswami, 2007) or neuroeducational research, (Howard-Jones, 2010) seeks to develop a common ground for cognitive scientists and educators to work together to improve student learning. Howard-Jones identifies a methodology for neuroeducational research that is based on "three fundamental types of evidence that can help us understand learning," (Howard-Jones, 2010, p. 99). These evidence types include biological, social, and experiential. Measureable

physiological responses have been detected when participants in one study were asked “Do you believe in evolution?” (Bland & Morrison, 2015). Such evidence falls into a biological type of evidence and can be corroborated with other lines of evidence. Emotional responses to questions like “Do you believe in evolution?” underscores a challenge of teaching evolution to a diverse group of learners who hold unique worldviews and perspectives. By addressing the affective and cognitive domains simultaneously, the nature of science provides the philosophical and epistemological framework upon which students can explore scientific theories beyond their mere content, but rather understood through the unique historical context in which the theory was developed, tested, and refined. Exploring the complex and interrelated factors which contribute to students understanding and acceptance of scientific theories, and the relationship to overall scientific literacy through the lens of educational neuroscience may prove a worthwhile direction of further investigation.

APPENDIX A: INSTITUTIONAL REVIEW BOARD APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246 Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **David H. Schleith**

Date: **August 11, 2016**

Dear Researcher:

On 08/11/2016, the IRB approved the following activity as human participant research that is exempt from regulation:

Type of Review:	Exempt Determination
Modification Type:	Addition of study on Qualtrics, changes to consent and protocol
Project Title:	A Study of Central Florida College Students' Acceptance of the Theory of Evolution, Microevolution, Macroevolution, and Human Evolution
Investigator:	David H. Schleith
IRB Number:	SBE-16-12420
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Kamille Chaparro on 08/11/2016 08:44:10 AM EDT
IRB Coordinator

APPENDIX B: PERMISSION TO USE INVENTORY OF STUDENT EVOLUTION ACCEPTANCE

RE: Request permission to use I-SEA
Louis Nadelson <louis.nadelson@usu.edu>
Sat 5/28/2016 7:34 PM
To: davidschleith <davidschleith@knights.ucf.edu>; louisnadelson@boisestate.edu <louisnadelson@boisestate.edu>; ssoutherland@fsu.edu <ssoutherland@fsu.edu>;
Hey David,

Go for it! Thanks for checking. I am sure you have the proper citation. Are you working with Dr. Boote at UCF? If so tell him I said Howdy!

Good luck with you research!

Louis

Sent from my Verizon Wireless 4G LTE smartphone

-------- Original message --------
From: davidschleith <davidschleith@knights.ucf.edu>
Date: 05/28/2016 1:23 PM (GMT-07:00)
To: louisnadelson@boisestate.edu, ssoutherland@fsu.edu
Subject: Request permission to use I-SEA

Hello,

My name is David Schleith. I am a high school physics and astronomy teacher at Eau Gallie High School in Brevard County, Florida. I'm pursuing my doctorate in educational leadership from the University of Central Florida and the topic that I've been researching for some time for my dissertation is the teaching and learning of the theory of evolution.

I'd like to request permission to utilize the Inventory of Student Evolution Acceptance for my study.

I would also certainly be open to any input, insight or advice you might be able to offer...I appreciate your help.

Thank you.

Regards,

David Schleith

APPENDIX C: INFORMED CONSENT FORM

Student Evolution Acceptance Survey

Informed Consent

Principal Investigator: David Schleith, doctoral student

Faculty Advisor: Ken Murray, J.D. Ph.D.

Investigational Site(s): University of Central Florida

Introduction: Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. You are being invited to take part in a research study which will include about 1000 people in the Central Florida area. You have been asked to take part in this research study because you are a student in a biology class. You must be 18 years of age or older to be included in the research study.

The person doing this research is David Schleith, a doctoral student at University of Central Florida.

Because the researcher is a graduate student he is being guided by Ken Murray, a UCF faculty advisor in the College of Education and Human Performance

What you should know about a research study:

- Someone will explain this research study to you.
- A research study is something you volunteer for.
- Whether or not you take part is up to you.
- You should take part in this study only because you want to.

- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you.
- Feel free to ask all the questions you want before you decide.

Purpose of the research study: The purpose of this study is to determine the levels of acceptance of the theory of evolution among college students.

What you will be asked to do in the study: Participants in this study should respond to the items on the survey instrument to the best of their ability. The survey consists of 24 statements and respondents are asked to either strongly disagree, disagree, agree, or strongly agree with each statement or choose undecided. In addition to the 24 items, participants are asked to answer 10 additional questions related to demographics and prior education. Biology professors will distribute and collect the surveys at an appropriate time such as at the end of a class session.

You do not have to answer every question or complete every task. You will not lose any benefits if you skip questions or tasks.

Location: Biology classroom

Time required: We expect that you will be in this research study for the time it takes to complete the survey, approximately 10-20 minutes.

Risks: There are no reasonably foreseeable risks or discomforts involved in taking part in this study.

Benefits: There are no expected benefits to you for taking part in this study.

Compensation or payment:

There is no compensation or other payment to you for taking part in this study. There is no compensation, payment or extra credit for taking part in this study.

There is no direct compensation for taking part in this study. It is possible, however, that extra credit may be offered for your participation, but this benefit is at the discretion of your instructor.

If you choose not to participate, you may notify your instructor and ask for an alternative assignment of equal effort for equal credit. There will be no penalty.

Anonymous research: This study is anonymous. That means that no one, not even members of the research team, will know that the information you gave came from you.

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints, or think the research has hurt you, talk to David Schleith, Graduate Student, Educational Leadership Program, College of Education and Human Performance, (407) 823-0000 or Dr.

Ken Murray, Faculty Supervisor, Department of Educational Leadership (407) 823-2233 or by email at ken.murray@ucf.edu.

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

APPENDIX D: SURVEY INSTRUMENT

Please indicate your level of agreement with each of the statements below.
1=strongly disagree 2= disagree 3= undecided 4= agree 5= strongly agree

Statement	1	2	3	4	5
1. I think that new species *evolved* from ancestral species					
2. I think that the fossil evidence that scientists use to support evolutionary theory is weak and inconclusive.					
3. There are a large number of fossils found all around the world that support the idea that organisms *evolve into new species* over time.					
4. I think all complex organisms evolved from single celled organisms.					
5. I think that new species evolve from a lot of small changes occurring over relatively long periods of time.					
6. There is little or no observable evidence to support the theory that describes how one species of organisms evolves from *a different* ancestral form.					
7. The forms and diversity of organisms have changed dramatically over time.					
8. I think that all organisms are related (or share a common ancestor).					
9. I think that organisms, as they exist now, are perfectly adapted to their natural environments and so will not continue to change.					
10. All groups of organisms will continue to change.					
11. There are a large number of examples of organisms that have undergone evolutionary *changes within the species* (i.e. antibiotic resistance in bacteria, production of new strains of the flu virus).					
12. Species were created to be perfectly suited to their environment, so they do not change.					

Please indicate your level of agreement with each of the statements below.

1=strongly disagree 2= disagree 3= undecided 4= agree 5= strongly agree

Statement	1	2	3	4	5
13. I don't accept the idea that a species of organism will evolve new traits over time.					
14. I think there is an abundance of observable evidence to support the theory describing how *variations within* a species can *happen*.					
15. *Species* exist today in exactly the same *shape and* form in which they always have.					
16. There is overwhelming evidence supporting the theory of evolution to explain how *variations in* a species *develop* over time.					
17. There is reliable evidence to support the theory that describes how humans were derived from ancestral primates.					
18. Although humans may adapt, humans have not/do not evolve.					
19. I think that the physical structures of humans are too complex to have evolved.					
20. I think that humans and apes share an ancient ancestor.					
21. I think that humans evolve.					
22. Humans do not evolve; they only change their behavior.					
23. The many characteristics that humans share with other primates (i.e., chimpanzees, gorillas) can best be explained by our sharing a common ancestor.					
24. Physical variations in humans (i.e., eye color, skin color) were derived from the same processes that produce variation in other groups of organisms.					

Please answer the following

1. What year did you graduate high school?

2. What high school did you attend?

3. What year(s) did you study biology in high school? Circle all that apply.

freshmen sophomore junior senior

4. What level of biology did you take in high school? Please check all that apply.

__Biology I

__Biology I Honors

__ Advanced Placement (AP) Biology

__ International Baccalaureate (IB) Biology

__ Advanced International Certificate of Education (AICE) Biology

__ Other _____

5. Did you take any biology-related electives in high school like environmental science or ecology?

If yes, please list._____

6. Please indicate if your high school was a…

__ traditional public school

__ public charter school

__ private school

__home school

7. How would you describe your race/ethnicity?

8. What is your gender?

9. How often do you attend worship services?

__ Weekly or more

__ Less than weekly

10. What is your major?

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