POINT LOMA NAZARENE UNIVERSITY

Creationist-Believing Students' Scientific Knowledge and Reasoning about Evolution

A thesis submitted in partial satisfaction of the

requirements for the degree of

Master of Science

in General Biology

by

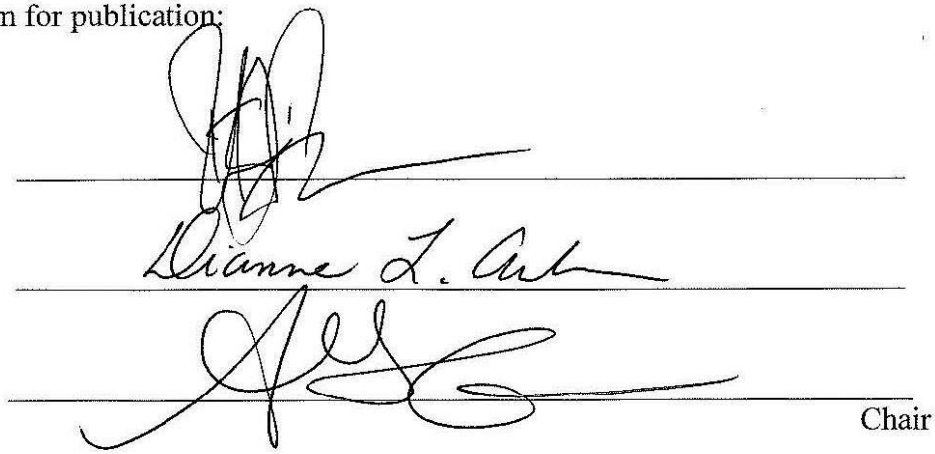
Richard Truman Peterson

Committee in charge:

April Maskiewicz Cordero, Ph.D., Chair
Dianne Anderson, Ph.D.
Robert Thompson, Ph.D.

2019

The thesis of Richard Truman Peterson is approved, and it is acceptable in quality and form for publication:



Chair

Point Loma Nazarene University

2019

I dedicate this thesis to my partner, Timothy S. Bond,
it was only through your unwavering support, and
push to help me achieve my dreams, that I was
able to accomplish this and so much more.

Table of Contents

List of Figure and Tables

Abstract of the Dissertation

Creationist-Believing Students' Scientific Knowledge and Reasoning about Evolution

by

Richard Truman Peterson

Master of Science in General Biology

Point Loma Nazarene University, 2019

April Maskiewicz Cordero, Ph.D., Chair

This purpose of this study arose from a pilot-study problem observed of acceptance of microevolution among those who identified as holding a creationist worldview or as having misgivings about the theory of evolution, which can be classified as a level of evolution acceptance, while these individuals still maintained a complete rejection of macroevolution, particularly when it came to primate/ human evolution. This study made use of the framework of Borderging et al. (2016), and targeted this demographic at a small-private Christian university to assess this demographic's relationships with, 1. the nature of science, 2. to determine how an epistemology of appealing to authority could correlate to the acceptance of macroevolution, and 3. to determine if religiosity has a correlative relationship with evolution acceptance. This study used a mixed-methods

approach of both quantitative and qualitative assessments to answer these questions and attempted to address some of the limitations in the study of Borderging et al. (2016). My study found that these students had strong understandings of the nature of science, were not trusting of scientists, demonstrated a strong linear relationship and statistical significance between appealing to authority and rejection of macroevolution, and had no linear relationship between religiosity and their respective level of evolution acceptance. This is important for science education research as it demonstrates that religiosity may not play a role in a student's level of evolution acceptance, and that the potential epistemology to target for further research in evolution acceptance is the role of authority how it affect student's in choosing what to understand and accept.

Introduction

While evolution is not a controversial topic within the world of scientific and academic research, it is still a hot-button issue within our contemporary culture (Ha, Haury, & Nehm, 2011). Being able to address some students' misgivings toward coursework focused on the theory of biological evolution is critically important because understanding evolutionary theory is essential for understanding biology (Borgerding, Deniz, & Anderson, 2016; Dobzhansky, 2013).

Growing up, I attended a private non-denominational Christian K-8 school for six years, and later, during my high school years, I attended a non-denominational Christian youth group. In both of these environments, science and religion were mostly at odds with each other. Coming from a semi-practicing Roman Catholic family, I was unaware that different worldviews on the origins of the universe co-existed within different Christian traditions. It was not until I became more active in Roman Catholicism that I realized believing in a literal six-day creationist story that took place roughly ten thousand years ago, was not a central tenant of Christianity. Transitioning from my pre-college environment where the mention of evolution brought along controversy and scorn, to my college academic and religious environments where support existed for a more open-minded view towards the theory of evolution and how it can be compatible to religion, was cognitively challenging. Growing up with a unique dual-experience of hearing both sides of the science and religion argument, I can empathize with students who hold alternative theories for the origins of the universe that conflict with the findings of biology.

During my time in a religious environment that held a creationist worldview, I began to notice a problem that I am now using as the guiding factor for this study. I observed that there was widespread acceptance of microevolution among those who identified as holding a

creationist worldview, and this could be classified as a level of evolution acceptance. But that these same creationist-identifying people maintained a rejection of macroevolution, particularly when it came to primate/ human evolution. This selective belief in biological evolution has always been fascinating to me; how can you pick one portion of theory, understand and accept it, yet disregard the other portion? Yet, this is exactly how some people approach the theory of evolution and the origins of the universe. The current science education literature on distinguishing micro-and macroevolution states that the difference is due to nomenclature alone, because macroevolution is microevolution over an extended period of time (Novick, Schreiber, & Catley, 2014). Regardless if this distinction, or misunderstanding, is the result of a disproportionate focus in K-12 curriculum on micro-instead of macroevolution, or a deep-seated rejection due to sociocultural and religious beliefs, there are still gaps in most students' knowledge, both religious and non-religious students, about the theory of evolution and the origins of the universe (Catley, 2006; Pobiner, 2016). Therefore, continued research on how to effectively approach and teach the theory of biological evolution and the origins of the universe for K-16 students is needed so that we can further bridge the many divides surrounding this controversial topic. This study adds to the current literature on evolution education by assessing how one's religiosity, along with one's acceptance of appealing to authority, can shape a students' worldview on the origins of the universe and how they come to accept, or not accept, the theory of micro-and macroevolution.

Literature Review

A Brief Background on the Controversy of the Theory of Evolution and Religion in America and around the Globe

A recent Pew Center Religious Landscape Survey, released in February of 2017, showed that, of those surveyed, roughly 60% of adults in the United States of America accept that "humans have evolved over time" (Masci, 2017). When examining the beliefs of those that Pew categorizes as "evangelical Protestants" the number drastically decreases to roughly 38%, with 57% believing that "humans and other living things have always existed in their present form". This ratio is also common amongst American Mormons and Jehovah Witnesses. In contrast, this ratio is in the minority amongst American Jews, Catholics, mainline Protestants, and religiously unaffiliated persons (Masci, 2017). The data from this survey also show that roughly half of those surveyed "that attend church at least once a week," and are considered to be more observant than not of their religion, believe there to be a conflict between science and religion.

Divisions within the American religious landscape on the topics of the theory of evolution and origins of the universe are nothing new and have been prevalent since the 19th century (Cox, 2014; Finke & Starke, 1997). However, the division surrounding evolution acceptance is not just a uniquely "American battle" fought between the irreligious and some Christian groups in America. Rather, the issues and controversies surrounding the theory of evolution go beyond just a specific region and/or religion. Overall, there is a larger issue of understanding, acceptance, and rejection of evolution that has been seen in a variety of different cultures and religions across the globe (Deniz, Donnelly, & Yilmaz, 2008; Pobiner, 2016). As the Pew Center research on the Religious Landscape Survey mentioned, these debates have

entered into other major global religions, such as Islam: “Muslims in many nations are divided on the topic [of evolution], [with] majorities of Muslims in countries such as Afghanistan, Indonesia and Iraq reject[ing] evolution” (Masci, 2017, para. 9).

It has also been observed that a significant number of people who reject, or have deep-rooted misunderstandings about the theory of evolution, may wrongly believe that their respective denomination’s faith is incompatible with the theory of evolution. However, the doctrines of their respective religious traditions may be very consistent with the theory of evolution as a possible explanation on the origins of the universe (Colburn & Henriques, 2006). Therefore, the theory of evolution is unique in that it can trigger a strong and intense personal and cultural responses, making it something that is not just seen at school board meetings, legislative sessions, or pulpits; instead it is something that personally affects a very wide portion of the global population as they interact with science and their personal faith traditions (Pobiner, 2016).

The Issues Surrounding the Theory of Evolution and Education

It has been argued that most of the contentious issues around the theory of evolution stem from educational models that do not properly convey evolution concepts in a manner that is free from controversy (Deniz et al., 2008). In fact, teaching evolution is so controversial in many places that often times teachers will not approach the topic or are not willing to fully understand it themselves because of their own preexisting notions and religious identifications (Deniz et al., 2008; Goldston & Kyzer, 2009). As the literature stands, much of science education research has been focused on the goal for students to understand and/ or accept the theory of evolution (Borgerding et al., 2016; Ingram & Nelson, 2005; Sinatra, Southerland, Mcconaughy, & Demastes, 2003). Ha, Huary, and Nehm (2011) explain that, according to the “neuroscience

perspective" as articulated by Burton (2009), understanding rests on two things: 1. possessing knowledge on a topic that can lead to proper comprehension of said topic, and 2. having a "feeling" of knowing caused by personal cognitive intuition. This unconscious cognitive process can impact the student's ability to readily accept the theory of evolution (Ha et al., 2011). According to Sinatra et al. (2003), many in the field of science education define acceptance as the sole responsibility of an individual to take the most current scientific facts, theories, and evidence, then "[systematically evaluate the] evidence," validate it, and then in-turn, accept what has been presented to them. However, even the relationship between understanding and acceptance is debated within the science education literature, as the following examples demonstrate. Some in the field believe that acceptance of the topic must come first before understanding can take place, but others believe that understanding must come first before someone can accept the topic (Sinatra et al., 2003). Yet, others argue that the approach of having understanding *and* acceptance be the co-instantaneous objective for science education research may not be helping discourse in this field as the evidence for a relationship between understanding and acceptance is inconsistent and questionable at best (Ha et al., 2011). Nevertheless, it has been shown in the past that there can be common correlations between understanding and acceptance for many other less "controversial" scientific concepts (Ingram & Nelson, 2005; Sinatra et al., 2003).

Additionally, there are further concerns that the language used when describing understanding and acceptance to students, particularly the usage of the word "belief," is problematic within the context of scientific knowledge on the theory of evolution (Ha et al., 2011). The word "belief" tends to be associated with religion and worldviews, and as such, there is a growing desire by researchers to cease its usage and to further assess, clarify, and standardize

the definitions of words, such as the terms acceptance and understanding, when conducting research on learning about the theory of evolution (Deniz et al., 2008; Sinatra et al., 2003).

Even outside of the realm of religion and science/evolution acceptance and understanding, there are divisions in the way most students are taught about micro-and macroevolution. It has been postulated that the ability for students to understand and/ or accept the theory of evolution is impacted by their understanding of the relationship between micro-and macroevolution in the education setting (Ha et al., 2011). However, micro-and macroevolution are two sides of one coin, therefore, why do students struggle with these concepts when taken together? One reason, according to work of Novick, Schreiber, and Catley (2014), is that most education on the theory of evolution in the United States focuses on natural selection, and because natural selection mainly explains the context of microevolution, students may be developing an inability to grasp other evolutionary concepts, such as macroevolution, particularly deep time and tree thinking (Novick and Catley, 2006; Novick et al., 2014). Another reason is that when macroevolution is presented to students via visual aids and textbooks, the phylogenic trees tend to be constructed in a way that does not lead to student understanding due to many of them making it look like evolution is a linear progression rather than a network of changes and adaptations from a common ancestor (Novick et al., 2014). With respect to "deep time," Novick and Catley (2006), claim that most students do not understand how vast the timeline is of evolutionary biology events (e.g. the emergence of mammals, the appearance of the first fossils, etc.). Additionally, general evolution education suffers from issues with conceptual understanding. (Anderson, Fisher, & Norman, 2002; Novick et al., 2014). Many students, even after completing a unit of instruction, are shown to not have internalized (i.e.

understand) the information and instead create or hold to pre-existing alternative conceptions about the topics and concepts included in instruction (Anderson et al., 2002).

How is Current Science Education Research Trying to Address these Issues?

An emerging consensus in science education literature is to conduct research that examines, and tries to bridge the divide, between understanding and acceptance of the theory of evolution, and to place equal weight on the presentation of micro-and macroevolution. Yet, there is also a growing desire to conduct research into why the dissonances continue to exist for students, particularly around human evolution (Pobiner, 2016). When conducting research, one must be cognizant of one of the pitfalls that continues to create distrust between researcher and participant: the continued narrative by many evolution-accepting members of the public that self-identified creationists, those who reject evolution, are merely irrational or uneducated (Pobiner, 2016). The literature also states that some high-achieving biology major students that understand but still reject the theory of evolution shows us that this issue is not about the educated versus the uneducated, but rather that acceptance is more complex and affects a variety of people from diverse backgrounds (Ingram & Nelson, 2005). Brumby (1984) found that even graduate medical students have questions and/or misgivings surrounding the theory of evolution and origins of the universe.

Ha et al. (2011) propose that a potential new factor that could impact the ability of students to understand and accept evolution is the research on student's own feeling of certainty, i.e. their own intuitive feeling on the topic combined with what is presented to them in an education setting. This "feeling of certainty" factor further helps explain if a participant is able to readily accept controversial hypotheses and ideas about scientific events via "intuitive [cognition]." The researchers assess a student's "feeling of certainty" and compare it against a

set of variables such as education, religious identity, acceptance of evolution, and scientific knowledge (Ha et al. 2011). They found that this "feeling of certainty" exhibited an effect on the ability of students to assess their knowledge of evolution along with their acceptance of evolution. Therefore, Ha et al. (2011) stress in their research the importance for science education researchers to be aware of how non-conscious intuition within student-participants can affect their feeling of certainty about a topic presented in class.

Evolution Acceptance Several surveys measuring student acceptance of evolution have been created and critiqued in the past 40 years (Barnes, Dunlop, Holt, Zheng, & Brownell, 2019). Recently, Smith, Snyder, and Devereaux (2016) produced a widely acclaimed quantitative examination of evolution acceptance known as the "Generalized Acceptance of EvolutioN Evaluation (GAENE)." Their research dove back into the understanding and acceptance divide, but they decided to solely focus on whether a student accepts the theory of evolution or not, and therefore created a test devoid of measuring understanding or being "tainted with religious beliefs" (Smith, Snyder, & Devereaux, 2016). By doing this, they created an instrument that can further aid in research that examines evolution acceptance, and what may be causing a rejection of this theory on the part of the students.

Others studies have begun to focus on why students create, and hold tightly to, alternative conceptions about the theory of evolution that only further propagate their lack of understanding and/or acceptance of micro-and/or macroevolution (Anderson et al., 2002; Demastes, Good, & Peebles, 1996; Evans & Anderson, 2013). According to To, Tenenbaum, and Hogh (2016), alternative conceptions on a topic are usually made when a student makes use of multiple epistemologies, primarily scientific knowledge they have, and their own intuition, to create an "answer" to a concept that they believe to be correct, when in fact it is incorrect. Therefore,

examining how students' epistemologies may be impacting how they approach the relationship between these three components: 1. religion and science, 2. understanding and acceptance of evolution, and 3. micro-and macroevolution is an important next-step in science education research. Epistemology is a philosophical term defined as a "study of the nature, origins, and limits of human knowledge," and how a person investigates and processes concepts that are presented to them (Martinich & Stroll, 2019). In short, epistemology is one's understanding of how we know what we know in a particular domain.

Borderging et al. (2016) recently began examining how students conflate rational and validated facts with their own opinions and/or beliefs, and how those shape their interactions with science and evolution. Through a mixed methods approach they used the Measure of Acceptance of the Theory of Evolution (MATE) survey (Rutledge & Warden, 1999) to measure students' evolution acceptance, and the Learning Context Questionnaire (Kelton & Griffith, 1986), 1. to measure how students do or do not appeal to authority, their personal certainty on what they accept, 2. their personal identification with the nature of science (i.e.. did they consider themselves to be "science people" or "scientists"), and 3. how they can hold multiple viewpoints to see how it affects their ability to interact, positively or negatively, with the theory of evolution, and how evolution and religion can, or cannot, be reconciled (Borderging et al., 2016). They also examined the interconnectedness of epistemological beliefs of students and how that can potentially be used to assess student acceptance of the theory of evolution. To assess epistemology of the students, the qualitative Learning Context Questionnaire interview was administered and then the responses were coded into various subcodes, used for the purpose of this study, and then the responses were also categorized to Perry developmental levels, that

measure intellectual and ethical development via four categories (dualists, multiplists, relativists, and dialecticals) (Perry, 1999).

In their conclusion, Borderging et al. (2016) stated a number of limiting factors in their research, including the fact that they did not collect data on the individual student's religiosity–a measure of the strength of someone's belief in their religion. They also noted their use of the Measure of Acceptance of the Theory of Evolution (MATE) survey by Rutledge and Warden (1999), while acknowledging critiques of how this assessment may blur the difference between belief and knowledge on the topic of evolution. They suggested that the GAENE solves this issue and encouraged those conducting further research to use this instrument.

Researching student's epistemologies, and how and what shapes their understanding and acceptance of scientific concepts presented to them, is a growing and important pursuit in the world of science education research. This may be a crucial step to solving the problems identified in the literature about students' acceptance of the theory of evolution.

Theoretical/ Conceptual Framework My research attempts to address some of the limitations mentioned in Borderging et al. (2016) by assessing how a student's epistemological worldview affects their acceptance of the theory of evolution. This study will use the GAENE as well as measure students' religiosity to see if these factors linearly correlate with acceptance or rejection of the theory of evolution. A situated perspective on learning guided the research in this project (Brown, Collins, & Duguid, 1989). This theory postulates that learning is not merely an individual activity, but rather, that learning occurs through, and within, a societal context. Over the past few decades this learning theory has developed in response to a desire to see reforms in how science education interacts with a growing and diverse student population (O'Loughlin, 2007). With a focus on understanding the influence of students' pre-existing and/or prior-held

beliefs, students' cultural context, and student worldviews on various science concepts, this perspective lends itself well to the target demographic for this study (She, 2004). Conducting research through this lens, contributes to the literature on the problems, inconsistencies, and gaps that exist within science education, especially in regards to the challenges students have with learning and accepting the theory of evolution.

Research Questions

Taking into consideration the above literature, and the addressed limitations of Borderging et al. (2016) and my own experiences with people accepting microevolution but rejecting macroevolution via an unpublished pilot study, the following questions guide this thesis work:

1. Many students self-identify as having a creationist worldview of the origins of the universe, and/ or as having misgivings with accepting every aspect of the theory of evolution and maintain alternate concepts about what they accept. After evolution instruction, some students understand and accept the concepts of microevolution but still reject the concepts of macroevolution (i.e. the diversification of species and primate/ human evolution).
    a. How do these particular students understand the nature of science?
    b. Is their rejection of macroevolution correlated with an epistemology of appealing to authority, as defined in the work of Borderging et al. (2016)?
2. How does a student's measured religiosity index relate to their acceptance of the theory of evolution according to the GAENE? Is there a direct correlation between religiosity and rejection of macroevolution (i.e. the diversification of species and primate/ human evolution) within the target demographic that was assessed in research question 1b?

Methods

Study Setting and Participants

This research was conducted at a small Christian university in southern California with an undergraduate student population of approximately 2,640. This university is situated in a suburban neighborhood of a larger metropolitan city. The student population has a racial/ ethnic breakdown of 58.6% Caucasian, 21.8% Hispanic/ Latino, 7.6% Multi-Racial, 5.8% Asian American, 1.9% African American/ Black, 1.0% Pacific Islander, and .3% Native American. The gender breakdown of the university is 63.5% women and 36.5% men (Institutional Research, 2017). At this university, all students have a general education requirement to take one course each in both the biological and physical sciences (PLNU, 2018)

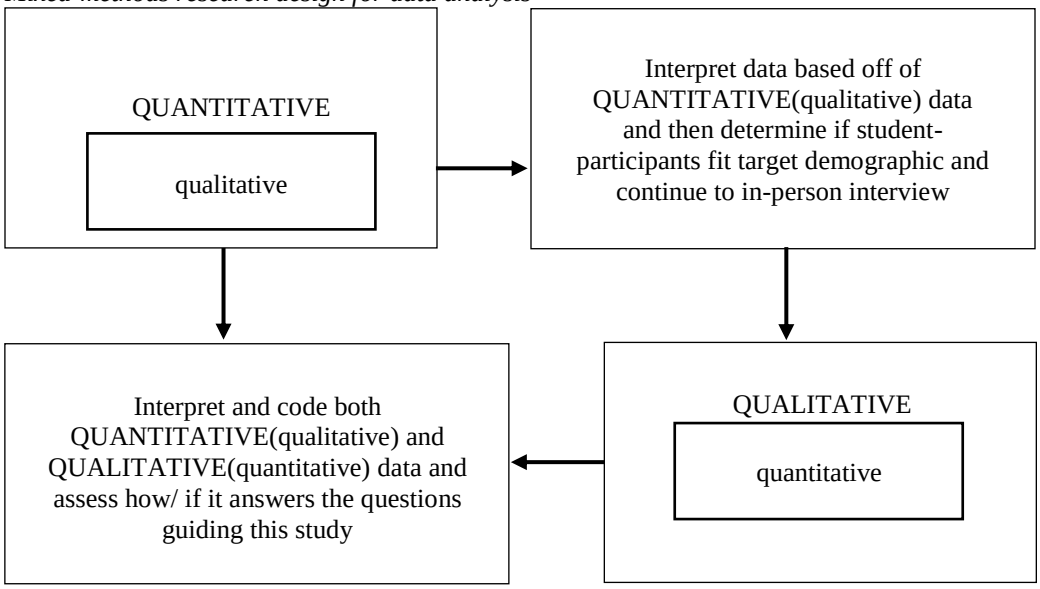
Research Design

The situated perspective takes into consideration how the issues of culture, background, discourse, and power structures affect the way students process and learn scientific knowledge and concepts (O'Loughlin, 2007). Examining the preconceived opinions and knowledge that students possess about the theory of evolution and origins of the universe could lead to education models that better understand their students and how to better facilitate the acquisition of conceptual knowledge. This way of assessing a student's knowledge was a principle guiding factor for this study.

This study also followed the Embedded Design for mixed-methods research. The Embedded Design is where one data type, quantitative or qualitative, takes a supporting role while the other data type is being used for data collection (Creswell, Plano Clark, Gutmann, & Hanson, 2003). For the purpose of this research, the tasks were divided into two data types, a

quantitative questionnaire with supporting qualitative questions, and a qualitative personal interview that made use of quantitative coding during the data analysis process (Figure 1).

Figure 1
Mixed-methods research design for data analysis



Students from three lower division biology courses were the participants for this study. Two of these biology courses, "Human Biology and Bioethics" and "Introduction to Biology" were non-major general education courses. The other course was a major- specific course entitled, "Ecological and Evolutionary Systems." All three of these courses addressed concepts related to the theory of evolution. All data collection was performed after the units involving the theory of evolution and origins of the universe were taught.

Approximately 85 students participated in "Part I: *Evolution Research Participant Survey*" of this study, which included both multiple choice questions and open-ended questions. The survey was administered to the students via their professors as optional after they had completed a unit on the theory of evolution. Students in Ecological and Evolutionary Systems, and Human Biology and Bioethics, were offered extra credit by their respective professors if they completed the survey, while students in Introduction to Biology were not offered extra

credit by their professor for the completion of the survey. Due to this it was observed that most of the students that participated in the survey came from the courses that offered extra credit, therefore, limiting the sample of students that could potentially fit the target demographic of this study from the course that did not offer extra credit. Upon analysis of the initial data, students that fit the target demographic of understanding and accepting microevolution but still rejecting (i.e. not accepting) macroevolution, post-instruction, were selected for in-person qualitative interviews. This was determined by whether students answered "I don't know," "disagree," or "strongly disagree," for questions 3, 4 and 8 of the GAENE (Appendix C), and how they responded to open-ended questions assessing if they understood and accepted microevolution and accepted macroevolution based on the cladogram diagrams in Appendices E-G. After using the previous factors to determine who would be eligible for "Part II: In-person Interview," 15 students were selected and interviewed. However, it must be noted that one of the interviewed student-participants did not thoroughly understand the questions presented to them in the Evolution Research Participant Survey and therefore they did not truly match the demographic that was being targeted for an in-person interview. That student's data was removed from further analysis.

All research that was conducted with the student-participants followed the Institutional Review Board (IRB) standards for the university where this study took place. Care was ensured as to inform the students of the private nature of everything that they were presenting to the researcher via their survey and interview responses. In addition, all students were instructed that they could leave this study at any time or have their data removed from the study if they so desired.

Instrument Development

This study was primarily focused on student epistemology and the relationships between their religiosity, evolution acceptance, and self-identification within the field of science. As such, the tasks for this study were a set of diverse set of quantitative and qualitative measures for the student-participants to complete, divided into two parts, with some parts that will be elaborated on below and in the appendix materials.

Table 1
Part I Assessment – Evolution Research Participant Survey

Assessment component	Portions Used	Modifications
Participant Demographic Information (Appendix A)	Created by the author for this study	Identical to unpublished pilot study
Religiosity Index (Appendix D)	Entire assessment	Four qualitative questions at the beginning to match the course the student-participants were taking
GAENE (Appendix C)	Entire assessment	None
CINS (Appendix B)	First ten questions of the 2013 revision	None
Evolution Diagram Questions (Appendices E-G)	Created by the author for this study but based off of a line-drawing task found in the science education literature (Smith 1992; Demastes et al., 1996).	Minor changes were made from the unpublished pilot study, with one cladogram added (Appendix F) and one cladogram image changed (Appendix G)

Survey Data Collection Part I of this research was collection of quantitative data, with some supporting qualitative questions, using pre-existing assessments as well as questions designed for this study. The survey, entitled the *Evolution Research Participant Survey*, collected demographic-related information of the student-participants, was created for the purpose of this study, also used selected items from the Religiosity Index by Cohen et al., (2008), the complete GAENE (Generalized Acceptance of EvolutioN Evaluation) Version 2.1 by Smith, Snyder, and Devereaux (2016), selected items from the Conceptual Inventory of Natural

Selection (CINS) by Evans and Anderson (2013), and had qualitative questions created for the purpose of this study and based off of three cladogram pictures to assess understanding and acceptance and/or rejection of micro-and macroevolution. This collection of assessments was originally created for the purpose of an unpublished pilot study, and further modified in preparation for this study, as shown in Table 1. The specific questions that were asked in this survey can be found in Appendices A-G.

As displayed in Table 1, the Participant Demographic Information portion was created for the purpose of this study to collect data on the student-participants age, gender, course enrollment, major, evolution position, age of the universe position, and some other qualitative questions to assist in this study (Appendix A). The Religiosity Scale is a mix of qualitative questions needing a written response and quantitative questions that make use of a five-point Likert Scale and can be found in Appendix D. Minor adjustments had to be made to the qualitative questions to pertain to the professor and course of the student-participants of this study as the original ones were study-specific to the class of students that were originally administered this assessment. The first ten questions of the CINS 2013 revision were used and not altered for the purpose of this study, and can be found in Appendix B. The questions for the GAENE were not altered for this assessment and can be found in Appendix C. Lastly, one qualitative task, split into three parts, was created and used to assess the student-participants' acceptance and understanding of the concept of microevolution, acceptance of macroevolution, and to see if they match this study's target demographic for an in-person interview. The first part of this three-part task was focused on the concepts in microevolution and natural selection section by use of a line-drawing task and some qualitative questions to further clarify the student-participants views on this topic (Smith 1992; Demastes et al., 1996). The focus of this

part of the task was to observe the student-participant's knowledge and understanding of natural selection and to see if they can engage in a deeper-level of scientific discourse on these topics via these qualitative measures. The last two parts of this task was on the concepts of macroevolution and the ability to interpret evolutionary diagrams based on the works of Catley and Novick (2009) and Catley et al. (2010) along with some qualitative questions to further clarify the student-participants' views/acceptance on this concept. The diagrams used for this section were specifically chosen because they match the type of diagram called for by Catley and Novick (2009) and Catley et al. (2010) that seek to prevent student-participant misunderstanding and the incorrect identification of anagenesis within the concept of macroevolution. The focus of the diagrams in these last two parts of the task were to assess the student-participant's knowledge of speciation and to see if student-participants were able to engage in a deeper-level of scientific discourse on the topics of whale and primate/ human evolution. Further information, photos, diagrams, and researcher-to-participant questions for these tasks can be found in Appendices E-G. All these assessments, as laid out in Table 1, were formatted into an online "Google Form" for the student-participants to complete on their own time from a link sent to their e-mail by the professor of the course they were enrolled in. It was estimated that this Part 1 assessment would take approximately 30 minutes for student-participants to complete.

Qualitative Data Collection Part two of the study involved an in-person interview. Participants were surveyed students who fit the target demographic as articulated in research question 1, as determined by selecting "I don't know," "disagree," or "strongly disagree," for questions 3, 4 and 8 of the GAENE (Appendix C), and how they responded to open-ended questions assessing if they understood and accepted microevolution and rejected macroevolution on the cladogram diagram task in Appendices E-G. The Views on Evolutionary and Learning

Protocol used in the work by Borgerding et al., (2016) was used in this study and acquired from personal communication with L. Borgerding. This interview protocol was based on the works of Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) and King and Kitchener (1994) to identify student-participant views of evolution within the context of science, student-participant certainty on the concepts presented, the idea of multiple perspectives, and the student-participants' relationship with authority in how it shapes their worldview (L. Borgerding personal communication). Some of the questions were reordered to adjust to the research this study was targeting, however nothing was added or eliminated from the interview protocol (see Appendix H.)

After assessing the factors for in-person interview selection that were mentioned above, it was determined that 15 of the respondents fit the target demographic for this study, i.e. students that understand and accept the concepts of microevolution but reject the concepts of macroevolution (i.e. the diversification of species and primate/ human evolution). The selected students were then asked to participate in an in-person, individual interview that was audio-recorded making use of the Borgerding et al. (2016) interview protocol with minor adjustments for the purpose of this study (Appendix H). Interviews were conducted on campus in one-on-one settings.

Data Analysis

After the completion of Part I, the selection of those to be interviewed using the selection factors mentioned above, and then the in-person interview of Part II, the data from the assessments in Part I were evaluated. The responses for the demographic related questions in the *Evolution Research Participant Survey* were compiled and put into categories. The 15 student-

participants that were interviewed also had their demographic information separated for comparison with the total 85 student-participants surveyed.

The GAENE was scored from a 5-point Likert scale ranging from “strong disagree,” being a “1” on the scale, to “strongly agree,” being a “5” on the scale, and then converted to a 4-point scale with “strongly disagree” and “disagree” being collapsed into one measurement point, “1,” in the 4-point scale, according to guidelines by Smith et al. (2016). This 4-point scale was then summated to a range of 13, as the lowest possible score of evolution acceptance, and 52, as the highest possible score of evolution acceptance. Each possible summated score was then converted to a Rasch score, in accordance to the guidelines by Smith et al. (2016), to a possible score range of -7.30, as the lowest possible score for evolution acceptance, and 7.22, as the highest possible score for evolution acceptance. The summated scores must be converted to Rasch scores for the purposes of ensuring integrity in the statistical analysis (Smith et al., 2016).

The Religiosity Scale by Cohen et al., (2008), was scored according to the methods used in those studies, which entails summating the 5-point Likert scale, “strong disagree,” as a “1” on the scale, to “strongly agree,” as a “5”, and then averaging the summated score by the number of questions. This provides a scale of “1” being the least religious, to “5” being the most religious. The qualitative questions in this assessment were not analyzed, rather just used to get a preliminary idea of how the student-participants religious beliefs interacted with the evolution section within their course, and how they viewed their professor’s way of teaching evolution prior to being interviewed, if selected for an in-person interview.

The responses to the CINS were scored on a scale of 0-10 with each of the ten questions worth one point, as a measure of understanding microevolution and natural selection. This scoring was conducted in accordance with the scoring guidelines as instructed by Evans and

Anderson (2013). The last qualitative assessment in the *Evolution Research Participant Survey*, the evolution diagram questions that focused on micro-and macroevolution were not analyzed, but they were used as a method of determining if the student-participants fit the target demographic of understanding and accepting the concepts of microevolution but rejecting the concepts of macroevolution.

Table 2
In-Person Interview Qualitative Grouping-codes and Subcodes per Borgerding et al. (2016)

Grouping Code	**Subcode**
Identification with science	I'm a scientist
	I'm a rational/logical thinker
	No mention
Authority	I appeal to authority, adopting the same/similar view, for my early evolution position
	I appeal to authority, adopting the same/similar view, for my present evolution position
	I reject all authority
	No mention of authority
Evolution Acceptance	Accept
	Partial accept
	Reject
Compatibility of Evolution & Religion	Compatible
	Incompatible
Tentative NOS & Evolution	All science has gaps – evolution is good science even with gaps
	All science has gaps – evolution is good science even with gaps – but I don't believe it
	Doesn't recognize uncertainty in science – evolution is bad science since it has gaps
	Doesn't recognize uncertainty in science – evolution is just good science

The 15 interviews were transcribed, and quotes were selected to justify coding and analysis. The interview coding scheme was modified from the one used by Borgerding et al., (2016). The original scheme is shown in Table 2, and the modified scheme is shown in Table 3. To answer research question 1a, further coding pertaining to the 'Nature of Science' (NOS) was desired. The 'Nature of Science' is a term used in science education literature as an umbrella term for what is believed to be the most important aspects of science that a student must learn to

be able to have a strong understanding of what the study of science entails (Describing the nature of science, 2011). For the purpose of this study it was determined that the ability to understand the reliability and variability of science is crucial, along with the ability to trust the findings from science and scientists. Students' tentative understanding of the Nature of Science and how it relates to their view of the theory of evolution was also measured via the coding scheme in Table 3.

Table 3
Modified In-Person Interview Qualitative Grouping-codes used in this study

Grouping Code	**Subcode**	
Identification with science	1	I'm a scientist
	2	I'm not a scientist
	3	I'm a rational/logical thinker
	4	No mention
Reliability of NOS	1	Scientific findings are reliable
	2	Scientific findings are not reliable
Variability of NOS	1	Scientific findings are variable
	2	Scientific findings are not variable
Trustworthiness of NOS	1	Science is trustworthy
	2	Science is not trustworthy
Scientists within the NOS	1	Scientists are trustworthy
	2	Scientists are not trustworthy
Authority	1	I appeal to the authority of my parents/ family for my present evolution position
	2	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position
	3	I appeal to the authority of my peers/ friends for my present evolution position
	4	I appeal to the authority of the scientific community for my present evolution position
	5	I reject all authority
	6	No mention of authority
Evolution Acceptance	1	Accept
	2	Partial accept
	3	Reject
Compatibility of Evolution & Religion	1	Compatible
	2	Incompatible
	3	No Mention
Tentative NOS & Evolution	1	All science has gaps – evolution is good science even with gaps
	2	All science has gaps – evolution is good science even with gaps – but I don't believe it
	3	Doesn't recognize uncertainty in science – evolution is bad science since it has gaps
	4	Doesn't recognize uncertainty in science – evolution is just good science

The data collected from the *Evolution Research Participant Survey* was split into those who were and were not selected for an in-person interview. Data sets from the target demographic and those that did not match the target demographic were compared via statistical methods to see if a significant difference existed between them. The coded in-person interview data was then used and compared against data collected from the *Evolution Research Participant Survey,* to answer the research questions guiding this study.

Results

Demographic Data of the Surveyed and of Interviewed Participants

Table 4 shows the year in college, academic major, gender, and age demographics for the students that completed the survey across the three biology courses. The surveyed student-participants consisted of 85 students (55 female, 30 male), with students from predominately STEM majors (53 students), social science (17 students), and health science-related (5 students) majors (Table 4). Table 5 shows a comparison of the same demographic information contained in Table 4, between students who were selected for an in-person interview and those that were not. Of the 15 students selected for an in-person interview, two were from the Ecological and Evolutionary Systems course (for biology majors), 12 from the Human Biology and Bioethics course (general education biology course), with only one from the Introduction to Biology (general education biology course) course. The student from the Introduction to Biology course misunderstood many of the questions in the survey, so while she was selected for an in-person interview, the responses she provided illustrated that she did not sufficiently meet the criteria sought for an in-person interview because she accepted large scale evolution. Her data was excluded from Table 5 and from further analysis in this study. The remaining 14 in-person interviewees (13 female, 1 male) included STEM majors (2 students), social science majors (7 students), business majors (4 students), and health science majors (1 student). It must be noted though that when compared to the overall distribution of academic majors of the total surveyed population, as seen in Table 5, more interviewed student-participants came from business or social science academic backgrounds, fewer students from STEM majors, and nearly the same from health science majors.

Table 4

Demographics of total students surveyed

	Year in College				Major					Gender		
Class	Freshman (%)	Sophomore (%)	Junior (%)	Senior (%)	Arts & Humantities (%)	Business (%)	Health Sciences (%)	STEM (%)	Social Science (%)	Female (%)	Male (%)	Average Age
Ecological and Evolutionary Systems (n = 57)	82.5	12.3	3.5	1.8	0.0	1.8	7.0	86.0	5.3	61.4	38.6	19.3 (SD = .87)
Human Biology and Bioethics (n = 26)	57.7	30.8	11.5	0.0	11.5	23.1	3.8	15.4	46.2	69.2	30.8	18.5 (SD = .71)
Introduction to Biology (n = 2)	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	0.0	18.8 (SD = .82)
Total (n=85)	74.1	18.8	5.9	1.2	3.5	8.2	5.9	62.4	20.0	64.7	35.3	18.9 (SD = .86)

Table 5

Comparison of interviewed and non-interviewed student demographics

	Year in College				Major					Gender		
	Freshman (%)	Sophomore (%)	Junior (%)	Senior (%)	Arts & Humantities (%)	Business (%)	Health Sciences (%)	STEM (%)	Social Science (%)	Female (%)	Male (%)	Average Age
Interviewed (n = 14)	64.3	21.4	14.3	0.0	0.0	28.6	7.1	14.3	50.0	92.9	7.1	19.1 (SD = .83)
Non-interviewed (n = 70)	77.1	17.1	4.3	1.4	5.7	5.7	5.7	71.4	11.4	58.6	41.4	18.9 (SD = .86)

Table 6

Religious identification, position on the origin of the universe, and position on the age of the universe of the total student-participants surveyed

	Religious Indentification			Position on the Origins of the Universe						Position on the Age of the Universe		
Class	Christian (%)	Non-Christian (%)	Athiest/ Agnostic (%)	Intelligent Design (%)	Naturalistic Evolution (%)	Theistic Evolution (%)	Old-Earth Creationist (%)	Young-Earth Creationist (%)	Uncertain (%)	6,000 to 10,000 years old (%)	Millions to Billions of Years Old (%)	I don't know/ Never thought about it (%)
Ecological and Evolutionary Systems (n = 57)	91.2	1.8	7.0	12.3	3.5	70.2	1.8	3.5	8.8	8.8	87.7	3.5
Human Biology and Bioethics (n = 26)	100.0	0.0	0.0	0.0	3.8	57.7	11.5	3.8	10.5	7.7	61.5	30.8
Introduction to Biology (n = 2)	50.0	0.0	50.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	100.0	0.0
Total (n=85)	92.9	1.2	5.9	8.2	4.7	65.9	4.7	3.5	12.9	8.2	80.0	11.8

Table 6 shows the religious identification, position on the origin of the universe, and position on the age of the universe of the 85-total student-participants that were surveyed. Of the 85, 79 identified as some denomination of Christianity, 56 identified themselves as holding a theistic evolution worldview on the origin of the universe, and 68 believed the universe to be "millions-to-billions of years old". These trends of religious identity, holding a theistic evolution worldview, and believing the universe to be "millions-to-billions of years old," were observed across the Ecological and Evolutionary Systems and the Human Biology and Bioethics courses. These trends were not observed in the Introduction to Biology course with half self-identifying as Christian and the other half identifying as "atheist/ agnostic", and with half holding a theistic evolution worldview while the other half held a naturalistic evolution worldview. All those surveyed from this course believed the universe to be "millions-to-billions years old".

Of the 14 student-participants selected for an in-person interview, after meeting the criteria for this study, all self-identified as being Christian. This was not representative of the 85-total student-participants surveyed as that group had one self-identify as "non-Christian" and four self-identify as "atheist/ agnostic," with the rest self-identifying as some denomination of Christianity (Table 6 and 7). Of those interviewed, the percentage holding "old-earth creationist," "young-earth creationist," or "uncertain" positions on the origins of the universe was a higher percentage when compared to total surveyed population (Table 7). This same trend holds for the positions on the age of the universe; a higher percentage of the interviewees believed the universe to be "6,000-to-10,000 years old" or "I don't know/Never thought about it," when compare to the total surveyed population (Table 7).

Table 7

Comparison of interviewed and non-interviewed student's religious identification, position on the origin of the universe, and position on the age of the universe

	Religious Indentification			Position on the Origins of the Universe						Position on the Age of the Universe		
	Christian (%)	Non-Christian (%)	Athiest/ Agnostic (%)	Intelligent Design (%)	Naturalistic Evolution (%)	Theistic Evolution (%)	Old-Earth Creationist (%)	Young-Earth Creationist (%)	Uncertain (%)	6,000 to 10,000 years old (%)	Millions to Billions of Years Old (%)	I don't know/ Never thought about it (%)
Interviewed (n = 14)	100.0	0.0	0.0	0.0	0.0	50.0	14.3	7.1	28.6	21.4	57.1	21.4
Non-interviewed (n = 70)	92.9	1.4	5.7	10.0	4.3	70.0	2.9	2.9	10.0	5.7	84.3	10.0

Table 8

Primary source of evolution education and changes in views on evolution of the total student-participants surveyed

	Primary Evolution Education Setting					Change in View On Evolution	
Class	Public School (%)	Private School-religious (%)	Private School-non-religious (%)	Personal Investigation (%)	Biblical Studies/ Church (%)	Yes (%)	No (%)
Ecological and Evolutionary Systems (n = 57)	56.1	36.8	3.5	1.8	1.8	84.2	15.8
Human Biology and Bioethics (n = 26)	61.5	34.6	0.0	3.8	0.0	46.2	53.8
Introduction to Biology (n = 2)	50.0	50.0	0.0	0.0	0.0	100.0	0.0
Total (n=85)	57.6	36.5	2.4	2.4	2.4	72.9	27.1

Table 9

Comparison of interviewed and non-interviewed student's primary source of evolution education and changes in views on evolution

	Primary Evolution Education Setting					Change in View On Evolution	
	Public School (%)	Private School-religious (%)	Private School-non-religious (%)	Personal Investigation (%)	Biblical Studies/ Church (%)	Yes (%)	No (%)
Interviewed (n = 14)	64.3	35.7	0.0	0.0	0.0	28.6	71.4
Non-interviewed (n = 70)	55.7	37.1	2.9	2.9	1.4	81.4	18.6

With respect to schooling, most student-participants (57.6%) across the three courses surveyed self-reported that they had attended a public school during their primary exposure to the concepts of micro-and macroevolution (Table 8). Likewise, an overwhelming majority self-reported that at some point in their lifetime they had experienced some type of change in their views on the topic of evolution.

Of the 14 student-participants selected for an in-person interview, a higher percentage had received their primary educational exposure to the theories of micro-and macroevolution in a public-school setting when compared with those not interviewed (Table 9). Of those interviewed, only 28.6% had experienced a change at some point in their lives on their personal positions on the theory of evolution, compared to the 81.4% of the non-interviewed student-participants (Table 9).

Response to Research Question 1

The average score for the CINS across the total student-participants surveyed was 7.9 ± 2.1 (maximum is 10), with the highest level of understanding coming from the Ecological and Evolutionary Systems course, 8.5 ± 1.4, and the lowest level of understanding coming from the Human Biology and Bioethics course, 6.6 ± 2.8 (Table 10). The average GAENE Rasch score across the student-participants surveyed was 2.10 ± 1.11 (range -7.3 to 7.22), with the Ecological and Evolutionary Systems students having a higher average measure of evolution acceptance, 2.59 ± 1.92 compared to the Human Biology and Bioethics course, 1.03 ± 1.77 (Table 10). The average Religiosity Index score was 4.3 ± .67 across the total student-participants surveyed (Table 10). The scores between the Ecological and Evolutionary Systems course and Human Biology and Bioethics course were nearly consistent between the two with the index scores being 4.2 ± .67 and 4.3 ± .57, respectively (Table 10).

Table 10
CINS, GAENE, and Religiosity Index scores of the total student-participants surveyed

	CINS	GAENE	Religiosity Index
Class	Average Score	Rasch Score (average)	Average Score
Ecological and Evolutionary Systems (n = 57)	8.5 (SD = 1.4)	2.6 (SD = 1.9)	4.2 (SD = .67)
Human Biology and Bioethics (n = 26)	6.6 (SD = 2.8)	1.0 (SD = 1.8)	4.3 (SD = .57)
Introduction to Biology (n = 2)	9.5 (SD = .70)	2.0 (SD = 1.2)	2.6 (SD = 1.7)
Total (n=85)	7.9 (SD = 2.1)	2.1 (SD = 1.1)	4.3 (SD = .67)

The student-participants that were selected for an in-person interview had a lower level of understanding of microevolution and natural selection according to their average CINS score of 6.6 ± 2.9, when compared to the non-interviewed student-participants who had an average score of 8.2 ± 1.8 (Table 11). While I did not use the CINS scores to select participants for in-person interviews, as I had designed this study to pull interviewees from GAENE and cladogram diagram responses, I had hoped that the average CINS score of those interviewees would be "7," as this was deemed to be a sufficient threshold of understanding for these concepts and to meet the requirements of the statement in question 1. However, note that one in-person interviewee, P11, was incredibly hostile to any measurement assessment that dealt with evolution and scored a 1 out of 10 on the CINS (Table 12). If we remove this outlier from the average CINS scores for the interviewees, the average becomes 7.0 ± 2.5, therefore meeting the threshold of understanding that this study was aiming to achieve. As expected, the student-participants selected for an interview had a much lower average GAENE Rasch score for evolution acceptance, .67 ± 2.35, when compared with the non-interviewed student-participants, 2.37 ± 1.81 (Table 11). The average religiosity score of the interviewees was 4.2 ± .59 compared to 4.3 ± .61 of the non-interviewed group, therefore both groups possessed a relatively equal measure of religiosity (Table11).

Table 11 displays the two-tailed p-values of the interviewed vs. non-interviewed student-participant scores that were collected for the CINS, GAENE, and Religiosity Index. For the purpose of this study, a significant difference between groups must have a p-value ≤ .05. Cohen's d, the effect size, was also calculated for these from the data collected in these assessments. This study followed the effect size ranges of 0.00 – 0.20 for a small effect size, 0.20 – 0.50 for a medium effect size, and any value greater than 0.50 for a large effect size (Salkind, 2010). There was not a significant difference between those interviewed and not interviewed on the CINS, p = .063, with an effect size of 0.67, showing that there was a large magnitude of difference on understanding of microevolution and natural selection between the interviewed and non-interviewed groups. There was a significant difference between the GAENE scores of the interviewed vs. the non-interviewed student-participants, p = .02 with an effect size of .81, showing that there was a large magnitude of difference on acceptance of evolution between the interviewed and non-interviewed groups. There was not a significant difference in the scores of the Religiosity Index for these two groups with a p-value of .76. The effect size was .090 showing that there was a small magnitude of difference between the interviewed and non-interviewed student-participants.

Table 11

Comparison of interviewed and non-interviewed student's CINS, GAENE, and Religiosity Index assessment scores, along with a two-tailed p-value and effect size between the two groups for each assessment

	CINS	GAENE	Religiosity Index
	Score Average	Rasch Score (average)	Average Score
Interviewed (n = 14)	6.6 (SD = 2.9)	.67 (SD = 2.4)	4.2 (SD = .59)
Non-interviewed (n = 70)	8.2 (SD =1.8)	2.4 (SD = 1.8)	4.3 (SD = .61)
p-Value (two-tailed)	0.063	0.021	0.76
Effect Size (Cohen's d)	0.67	0.81	0.090

Table 12 is a compilation of individual quantitative data and qualitative codes for the 14 student-participants that were interviewed. It displays the assessment scores of the CINS,

GAENE, and Religiosity Index, the self-identified categories for the origins of the universe and the age of the universe, and it shows how these student-participants were coded when it came to their relationship with authority, their own qualitatively assessed acceptance of evolution, and if they view evolution and religion as compatible.

Response to Research Question 1a

Question 1a asked: How do these particular students understand the nature of science? Upon the completion of the in-person interviews (Appendix H) the student's answers were coded, as discussed in the methods section (Table 3). None of the students interviewed identified themselves as "I'm a scientist," and 57.14% of students identified themselves as "I am not a scientist" within the nature of science task (NOS) (Table 13). The rest identified as either "rational/logical thinker" (28.57%) or made no mention of having an identification with science (14.29%). A majority of those interviewed understood and accepted the reliability, variability, and trustworthiness of the NOS, 85.71%, 100%, and 78.57%, respectively (Table 13). However, 57.14% of those interviewed believed scientists within the NOS to be untrustworthy. All interviewees understood the tentative nature of evolutionary science and how it possesses gaps, but they were evenly divided, 50%/50%, on whether that means it is good science or if the tentative nature of science is one of the factors for why they should not fully accept evolution as the best possible explanation for the origins of the universe, and particularly primate/ human evolution (Table 13).

Response to Research Question 1b

Question 1b asked: Is their rejection of macroevolution correlated to an epistemology of appealing to authority, as defined in the work of Borderging et al. (2016)? For those interviewed, 71.43% believed that evolutionary science and religion can be compatible within their

worldview, but only 21.43% fully accepted both micro-and macroevolution as the best scientific explanation for the origins of the universe and the speciation of animals, particularly primate/ human evolution (Table 13). Those that partially accepted the theory of evolution had various ways of partial acceptance: 55.56% accepted evolution as the best scientific explanation but still struggled with it on a personal level, while 44.44% had no issue with the theory except when it came to primates and believed that human being were unique creatures created according to their own personal Christian denominational beliefs/ interpretations. I extrapolated from the interview responses that the majority of the student-participants based their acceptance or rejection of the theory of evolution on some sort of authority in their life; 7.14% basing it on familial authority, 50.00% basing it on religious authority, and 14.29% basing it on scientific authority regardless of their religious beliefs (Table 13).

To assess if authority correlated with rejection of macroevolution, I tried to identify the factors that played a role in how these interviewees performed on the GAENE assessment. Table 14b displays a Pearson's correlation analysis of the 14 interviewees. There was no linear correlation between the GAENE Rasch scores and the Religiosity Index Average, R = .017, but there was a moderate positive correlation between the GAENE Rasch scores and the CINS scores, R = .51 (Table 14b). Other self-reported demographic information was considered and analyzed via a Spearman's correlative analysis to see if these factors affected the performance of the student-participants GAENE assessment scores. Spearman correlation was used because this data was categorical or "ordinal".

According to Table 15, the variables 'course enrollment' ($\rho = .13$, $p = .67$), 'K-12 schooling', ($\rho = .26$, $p = .37$), and 'position on the age of the universe' ($\rho = -.041$, $p = .89$), did not show a correlation with the student-participant scores on the GAENE. The variable 'origin

Table 12

Data from quantitative assessment, self-identified position, and in-person interview codes on authority, evolution acceptance, and compatibility of evolution & religion of the 14 student-participants that were interviewed

		Assessment Scores			Self-Identified Positions		Interview Codes		
Interviewee	Course	CINS	GAENE	Religiosity Index	Origin Position	Age of Universe	Authority	Evolution Acceptance	Compatibility of Evolution & Religion
P11	Human Biology and Bioethics	1	-2.65	3.25	Uncertain	I don't know/ never thought about it	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial Acceptance**	Incompatible
M9	Human Biology and Bioethics	5	-0.54	4.875	Old Earth Creation	Millions to billions of years old	I appeal to the authority of my parents/ family for my present evolution position	Rejection	Compatible
M4	Human Biology and Bioethics	10	0.67	4.25	Theistic Evolution	6,000 to 10,000 years old	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial Acceptance**	Compatible
H8	Human Biology and Bioethics	7	-1.04	5	Old Earth Creation	I don't know/ never thought about it	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial Acceptance*	No mention of compatibility
L10	Human Biology and Bioethics	9	0.67	3.75	Theistic Evolution	Millions to billions of years old	No mention of authority	Acceptance	Compatible
A5	Human Biology and Bioethics	2	-0.05	3.375	Young Earth Creation	6,000 to 10,000 years old	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Rejection	Compatible
G2	Human Biology and Bioethics	7	1.86	4.75	Uncertain	I don't know/ never thought about it	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial Acceptance*	Compatible
O12	Human Biology and Bioethics	9	1.15	4.875	Theistic Evolution	Millions to billions of years old	I appeal to the authority of the scientific community for my present evolution position	Partial Acceptance**	Compatible
N3	Human Biology and Bioethics	9	2.61	4.5	Theistic Evolution	Millions to billions of years old	I reject all authority	Acceptance	Compatible
S6	Human Biology and Bioethics	3	-1.3	4.75	Theistic Evolution	Millions to billions of years old	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial Acceptance*	No mention of compatibility
L15	Human Biology and Bioethics	9	1.38	4.375	Theistic Evolution	Millions to billions of years old	I reject all authority	Partial Acceptance**	No mention of compatibility
S13	Human Biology and Bioethics	5	0.43	3.625	Uncertain	Millions to billions of years old	No mention of authority	Acceptance	Compatible
A1	Ecological and Evolutionary Systems	8	-1.04	4.125	Uncertain	6,000 to 10,000 years old	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial Acceptance**	Compatible
D14	Ecological and Evolutionary Systems	8	7.22	3.875	Theistic Evolution	Millions to billions of years old	I appeal to the authority of the scientific community for my present evolution position	Partial Acceptance*	Compatible

* no issue with the theory of evolution except when it came to primate evolution and believed human beings were uniquely created

** accepted evolution as the best scientific explanation but still struggled with it on a personal level

Table 13

Coding Scheme applied to interviewed student-participants interview answers (n=14) and the percentages for each subcode that they were categorized in

Grouping Code		Subcode	Frequency	Student Quote
Identification with science	1	I'm a scientist	0.00%	(no evidence of this type of identification from the transcripts)
	2	I'm not a scientist	57.14%	"…yeah, I am business major…" (G3)
	3	I'm a rational/logical thinker	28.57%	"...I like observing things and I believe that what we see in observation is just the end product...I believe that everyone should have open resources to everything to make their own opinion about everything…" (L15)
	4	No mention	14.29%	(no evidence of this type of identification from the transcripts)
Reliability of NOS	1	Scientific findings are reliable	85.71%	"...I think they would not be putting it in text books unless they were completely certain…" G3
	2	Scientific findings are not reliable	14.29%	"With science I just don't know…I think [science] is affected by people's values and what they…choose to believe…" (A5)
Variability of NOS	1	Scientific findings are variable	100.00%	"...I think as long as evidence or facts come out that are undisputed then yeah you can change…" (G3)
	2	Scientific findings are not variable	0.00%	(no evidence of this type of identification from the transcripts)
Trustworthiness of NOS	1	Science is trustworthy	78.57%	"...I think the main goal of science is more to get to an answer and they do not care if that is combative at all towards people, they do not care if people agree, society agrees... because that is the truth…" (G3)
	2	Science is not trustworthy	21.43%	"…you don't have a solid yes to it…[its] being made up…" (P11)
Scientists within the NOS	1	Scientists are trustworthy	42.86%	"...they have a lot of facts that seem right…they are certain…they all believe in the same thing…" (S13)
	2	Scientists are not trustworthy	57.14%	"...[they] are making conclusions based off a person's personal bias and opinions...like when you are doing an experiment you can really want something to be the result and then fudge the data…sometimes people do that…that just scares me" (L15)
Authority	1	I appeal to the authority of my parents/ family for my present evolution position	7.14%	"…I think it's something that could have happened…but…my parents…they put evolution in a negative light…and [they say] this is wrong and God
	2	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	50%	"…My value is in my faith in God and in what the Bible said…" (P11)
	3	I appeal to the authority of my peers/ friends for my present evolution position	0.00%	(no evidence of this type of identification from the transcripts)
	4	I appeal to the authority of the scientific community for my present evolution position	14.29%	"…with the classes I have taken…there is enough evidence to support it…" (D14)
	5	I reject all authority	14.29%	"…the basic belief that I kinda of stand on is... he [God] created apes and we share characteristics...it doesn't really affect me… more knowedge is better..." (N3)
	6	No mention of authority	14.29%	(no evidence of this type of identification from the transcripts)
Evolution Acceptance	1	Accept	21.43%	"…science is a part of life…I've always thought…" (L10)
	2	Partial accept	64.29%	"...It makes sense with the fossils, and the transitional forms, and just showing how related we are with molecular homologies. But personally I…I do not accept that, but it makes sense…" (A1)
	3	Reject	14.29%	"…my religious background, I value that so much, my religion more than anything and that plays a part in what I believe in and I grew up believing that evolution was wrong…" (M9)
Compatibility of Evolution & Religion	1	Compatible	71.43%	"…but what we learned is that it's not denying the Bible…but these things [evolution] happened as well…" (N3)
	2	Incompatible	7.14%	"…it just doesn't make sense to me…it makes me question God…" (A5)
	3	No Mention	21.43%	(no evidence of this type of identification from the transcripts)
Tentative NOS & Evolution	1	All science has gaps – evolution is good science even with gaps	50.00%	"...I think it's really good science…it's backed by tons of evidence um it has fossil records homologies and it makes sense…" (A1)
	2	All science has gaps – evolution is good science even with gaps – but I don't believe it	50.00%	"...like if you are talking about micro evolution, I think that is like a good way of explaining something...but, I think that like parts of evolution, I just do not agree with that, I would not say like it is fully true, but I do think that it is a part of evolution, like is a good part of science..." (M4)
	3	Doesn't recognize uncertainty in science – evolution is bad science since it has gaps	0.00%	(no evidence of this type of identification from the transcripts)
	4	Doesn't recognize uncertainty in science – evolution is just good science	0.00%	(no evidence of this type of identification from the transcripts)

Table 14

Pearson's *correlation analysis of GAENE Rasch scores, CINS scores, and averaged religiosity index of total student-participants interviewed; A displays the correlation between the scores of the 85-total student-participants surveyed; B display the correlation between the scores of the 14 interviewed student-participants*

A	GAENE Rasch Score	CINS Score	Religiosity Index Average
GAENE Rasch Score	1.00		
CINS Score	0.35	1.00	
Religiosity Index Average	-0.034	0.0033	1.00

B	GAENE Rasch Score	CINS Score	Religiosity Index Average
GAENE Rasch Score	1.00		
CINS Score	0.51	1.00	
Religiosity Index Average	0.017	0.40	1.00

position' did have a moderate inverse correlation with the GAENE assessment score, $\rho = -.45$; the lower the GAENE score the more likely it was that the students-participants would have selected 'old-earth creation,' 'young-earth creation,' or 'uncertain' as their origin position. The origin positions were ranked as follows, 1. Intelligent Design, 2. Naturalistic Evolution, 3. Theistic Evolution, 4. Old-Earth Creation, 5. Young-Earth Creation, 6. Uncertain, however, it must be noted that while the p-value was much lower than the p-values of the other variables, it was still not significant.

Table 16 shows an analysis of the subcodes for each coding group of the interviewees to see if any of these variables correlated to the GAENE assessment score. The categorical ranking of the subcodes is identical to the way they are laid out in Table 13, with the first subcoded ranking as "1" and then each subsequent code increasing by one numeral. According to Table 16, the variables 'identification with science' ($\rho = .16$, $p = .58$), and 'variability of NOS,' (ρ = n/a, p = n/a), did not share linear relationships with the scores on the GAENE. The reason there is no ρ- and p-value for 'variability of NOS' is due to the fact that all the interviewed student-participants

were coded as understanding variability with the nature of science, therefore no correlative analysis could be determined. For the factors 'reliability of NOS' (ρ = -.41, p = .15), 'trustworthiness of NOS' (ρ = -.52, p = .057), 'evolution acceptance' (ρ = -30, p = .30), and 'compatibility of evolution & religion' (ρ = -.45, p = .11), they all possessed a moderate inverse correlation with the GAENE assessment score, however it must be noted that none of these factors were statistically significant. For the variable 'scientists within NOS' (ρ = .32, p = .26) there is a moderate positive correlation, but it is also not statistically significant. For the variable 'tentative NOS & evolution acceptance' (ρ = -.57, p = .033), there was a moderate inverse correlation with the performance on the GAENE assessment and it was statistically significant. Lastly, the variable of authority (ρ = .53, p = .049) has a moderate positive correlation with the performance on the GAENE assessment and showed statistical significance.

Table 15
Spearman's correlation analysis of various demographics that the interviewed student-participants self-reported to assess if these variables impacted their GAENE assessment score

	Dependent Variable	Independent Variable (s)	ρ	p-value (two-sided)
Interviewed Student's Survery Response (n=14)	GAENE Rasch Scores	Course Enrollment	0.13	0.67
		K-12 Schooling	0.26	0.37
		Origin Position	-0.45	0.11
		Age of Universe Position	-0.041	0.89

As seen in Table 16, there was a moderate inverse correlation between the GAENE Rasch scores and the sub coding of 'evolution acceptance' (ρ = -.30, p = .30). Therefore, there was a moderate trend of students having a higher GAENE Rasch score, but they were coded into either partial acceptance or rejection of evolution. Due to this incongruence (the GAENE

assessment is supposed to be a quantifiable measure of evolution acceptance), these same interview subcodes were compared against the students' subcode of evolution acceptance

Table 16
Spearman's correlation analysis of the various subcodes to assess if these group code categories impacted their GAENE assessment score

	Dependent Variable	Independent Variable (s)	ρ	p-value (two-sided)
Interviewed Student's Survery & Coded Response (s) (n=14)	GAENE Rasch Scores	Identification with science	0.16	0.58
		Reliability of NOS	-0.41	0.15
		Variability of NOS	n/a	n/a
		Trustworthiness of NOS	-0.52	0.057
		Scientists within the NOS	0.32	0.26
		Tentative NOS & Evolution	-0.57	0.033
		Authority	0.53	0.049
		Evolution Acceptance	-0.30	0.30
		Compatibility of Evolution & Religion	-0.45	0.11

to identify if authority plays a role in the rejection of macroevolution. To ensure that authority was the only variable that played a role in evolution acceptance, the subcodes for this category were compared against the same self-reported demographic variables as in Table15. As seen in Table 15, the variables 'course enrollment' ($\rho = .06$, $p = .84$), 'K-12 schooling' ($\rho = -.34$, $p = .22$), and 'positions on the origins' and 'age of the universe' ($\rho = .17$, $p = .55$; $\rho = -.17$, $p = .55$), did not share strong linear relationships with the subcoded measurement of evolution acceptance and none of these variables possessed a significance when compared against the students' subcode of evolution acceptance. (Table 17). The CINS scores of the interviewees was a compared against their coded evolution acceptance ($\rho = -.40$, $p = .15$) and there was a moderate inverse correlation of these two factors but no determined significance. Lastly, the Religiosity

Index scores were compared against the GAENE (Table 14b), and the subcoded measure of evolution acceptance (Table 19), to assess if this factor correlated with evolution acceptance or to assess if authority was the sole variable correlating with evolution acceptance. The Religiosity Index had a correlation of R = .017 with respect to the GAENE (Table 14b), and ρ = .19 and p = .52 with respect to the subcoded measure of evolution acceptance (Table 19), showing that there were no correlative relationships between these factors.

Table 17
Spearman's correlation analysis of various demographics that the interviewed student-participants self-reported to assess if these variables impacted their Evolution Acceptance subcode

	Dependent Variable	Independent Variable (s)	ρ	p-value (two-sided)
Interviewed Student's Survery & Coded Response (s) (n=14)	Evolution Acceptance	Course Enrollment	0.06	0.84
		K-12 Schooling	-0.34	0.22
		Origin Position	0.17	0.55
		Age of Universe Position	-0.17	0.55
		CINS	-0.40	0.15

It is observed in Table 18 that the only variable that had a significant relationship with evolution acceptance was authority (ρ = -.80, p = <.0001). Therefore, authority, or a lens of the warranting of authority in the lives of the student, is the only variable with a significant relationship with the GAENE and the subcode of evolution acceptance, as seen in Table 16 and Table 18. Evolution acceptance and authority have a strong inverse correlative relationship (Table 18). This means that the "higher" the level of evolution rejection (1. Accept, 2. Partial Accept, i.e. accept microevolution and reject macroevolution, and 3. Reject), the lower the coded for authority (Table 13). "Higher" authority codes were reflective of appealing to scientific authority, rejecting authority, or never mentioning authority; "lower" authority codes were reflective of appealing to the authority of family, religion, or friends (Table 13).

Table 18

Spearman's correlation analysis of the various subcodes of interviewed student-participants to assess if these group code categories impacted their Evolution Acceptance subcode

	Dependent Variable	Independent Variable (s)	ρ	p-value (two-sided)
Interviewed Student's Coded Response (s) (n=14)	Evolution Acceptance	Identification with science	0.096	0.74
		Reliability of NOS	0.39	0.17
		Variability of NOS	n/a	n/a
		Trustworthiness of NOS	0.35	0.21
		Scientists within the NOS	0.15	0.62
		Tentative NOS & Evolution	0.37	0.19
		Authority	-0.80	5.1 X 10^-4
		Compatibility of Evolution &	0.09	0.76

Response to Research Question 2

Question 2 asked: How does a student's measured religiosity index relate to their acceptance of the theory of evolution according to the GAENE? Is there a direct correlation between religiosity and rejection of macroevolution (i.e. the diversification of species and primate/human evolution) within the target demographic that was assessed in research question 1b? Table 14a displays a Pearson's correlation analysis between the scores that were gathered for the GAENE, Conceptual Inventory in Natural Selection (CINS), and the Religiosity Index that were gathered from the responses to of the *Evolution Research Participant Survey*. Of 85-total student-participants surveyed, there is no linear correlation between the GAENE Rasch scores and the Religiosity Index average, R = -.034 (Table 14a). As mentioned earlier, the same trend holds for those 14 student-participants selected for an in-person interview, with a correlation of the GAENE Rasch scores and Religiosity Index average at R = .017 (Table 14b). Table 19 shows

a Spearman correlation analysis of the Religiosity Index score and the interviewed students codes for evolution acceptance (($\rho = .19$, $p = .52$).

Table 19
Spearman's correlation analysis to assess if the subcode "Evolution Acceptance" was impacted their Religiosity Index Average of the interviewed student-participants

	Dependent Variable	Indepdent Variable (s)	ρ	p-value (two-sided)
Interviewed Student's Survery & Coded Response (s) (n=14)	Evolution Acceptance	Religiosity Index Average	0.19	0.52

Discussion

Reviewing the Purpose of this Study

The principle purpose of this study was to address two factors that Borderging et al. (2016) stated were the limiting factors in their research. One of these limiting factors was the lack of data on individual student's religiosity. The other limiting factor was that Borderging et al. (2016) used the Measure of Acceptance of the Theory of Evolution (MATE) survey by Rutledge and Warden (1999), even though they acknowledged critiques of how this assessment may blur the difference between belief and knowledge on the topic of evolution. They added that the GAENE solves this issue and encouraged that further research use this instrument. My study collected religiosity data via the use of the Religiosity Index by Cohen et al., (2008), and used of the GAENE by Smith, Snyder, and Devereaux (2016). While this study did not set out to replicate the Borderging et al. (2016) study, modifying these two different parameters, it did focus on (1a) the aspect of that study that looked into the epistemology of person's worldview and knowledge and how it related to their understanding of the 'Nature of Science', (1b) assessed if authority impacted evolution acceptance, particularly the acceptance or rejection of macroevolution, and (2) if religiosity impacted evolution acceptance.

Interpreting the Data in Response to Research Question 1

Reiterating the statement within research question 1, many students self-identify as having a creationist worldview of the origins of the universe, and/or as having misgivings about accepting all aspects of the theory of evolution. After evolution instruction, some students understand and accept the concepts of microevolution, but reject the concepts of macroevolution (i.e. the diversification of species and primate/human evolution). The average score for the

CINS, a measure of understanding natural selection and microevolution of the 85-total surveyed student-participants, was 7.9 out of 10, with a standard deviation of 2.1. The average GAENE Rasch score of the 85-total surveyed student-participants, was 2.1 on a scale from -7.30 to +7.22. A regression analysis was run between these two assessments which gave an $R^2 = .12$ ($p < 0.0001$), therefore showing that there is no linear relationship and a significant difference between the performances of these two assessments of the 85-total student-participants (Supplementary Table 1). I believe that this is because there is a distinction between acceptance of the overall theory of evolution, particularly when it comes to primate/ human evolution, and being able to understand and accept, natural selection and microevolution. As well, that this distinction exists due to socio-cultural factors that are shaping the epistemologies of the students evaluated. This in turn could be one of the reasons for the significant difference between the performance on the CINS and GAENE from my study. My findings suggest that the disparity in scores could be due to the epistemology of appealing to authority as a component of student's worldview and acquisition of knowledge. This will be addressed again in question 1b, below. The interviewees were students that understood and accepted the concepts of microevolution but rejected the concepts of macroevolution (i.e. The diversification of species and primate/ human evolution). The interviewees were selected after assessing the responses of the GAENE questions 3, 4, and 8, along with the answers provided in the evolution diagram questions (Appendices C, E-G)

Interpreting the Data in Response to Research Question 1a

Reiterating research questions 1a, how do these students, who after evolution instruction fully understand and accept the concepts of microevolution but reject the concepts of macroevolution (i.e. The diversification of species and primate/ human evolution), understand

the nature of science? Again, the 'Nature of Science' is a term used in science education literature as an umbrella term for what is believed to be the most important aspects of science that a student must learn to be able to have a strong understanding of what the study of science entails (Describing the nature of science, 2011). For the purpose of this study, it was determined that the ability to understand the reliability and variability of science is crucial, along with the ability to trust the findings of science and the work of scientists. My analysis included coding responses from 14 student-participants that understand and accept the concepts of microevolution but rejecting the concepts of macroevolution. I had initially hoped that the majority of the students interviewed would come from the biology major specific course, Ecological and Evolutionary Systems, however only two students of the 14 were from that course, with the other 12 coming from the Human Biology and Bioethics non-major specific course (Table 12). As a result, I then anticipated that many of the interviewed-student participants would not have a strong understanding of the 'Nature of Science'. Yet, as shown in Table 13, while none of the student-participants interviewed identified as a scientist, as many factors play a role in that sort of self-identification, they had an overwhelming understanding of the reliability and variability of science and had an overwhelming level of trust for science. This strong understanding of these aspects of the nature of science could be partially attributed to the quality of how the professors from this small private-Christian university biology department articulated the value of science to their students. Yet when it came to the tentative nature of science and the theory of evolution, all interviewed student-participants acknowledged that all science, in particular evolutionary science has gaps, but they were evenly split on whether these gaps in scientific knowledge meant that it is still "good science" or if those gaps are reasons to be skeptical and non-accepting of evolutionary science. This is an interesting and incongruent

finding when compared to the fact that 100% of the interviewed student-participants understand that there is variability and gaps in the scientific process and that things are subject to change. Therefore, I believe that these students treat evolutionary science as something separate from "regular" science; possibility because non-evolutionary science is not as intertwined with usage of the word "belief," as evolution has been inside the spaces of religion, and even the science classroom at times (Ha et al., 2011). Given that approximately 78% of the interviewed student-participants were coded as having a trustworthy view of science and scientific findings, it was unexpected finding that approximately 57% of these interviewees did not believe that scientists themselves were trustworthy and were skeptical of the intentions of them (Table 13). These findings align well with the works of Ecklund and Scheitle (2018), which found "religious people to be wary of scientists" because some may believe that "scientists are not morally reflective and have replaced religion with science." Therefore, many religious-identified people, from religious traditions that are more distrusting or hostile to science, are highly skeptical of the morality and biases of scientists because many believe them to be irreligious. This sentiment was perfectly captured by interviewee L15 who said, "...[scientists] are making conclusions based off a person's personal bias and opinions...like when you are doing an experiment you can really want something to be the result and then fudge the data…sometimes people do that…that just scares me". This idea was repeated over and over again across the interviewees and these statements were coded as 'not trusting scientists.' One interviewee, A1 said, "…again people are very stuck in their ways and want to believe what they have been taught, and holds true to those values, and like I feel like there is going to be bias in anything; whoever writes it is going to biased on what they see. It's very hard to be unbiased (sic)." When diving a bit deeper into these statements, I found that most of the students that were distrustful of scientists acknowledged

their own bias in rejecting primate/ human evolution, and felt that since they were making use of their own biases to construct their worldview, that scientists must do the same, thereby making them untrustworthy. It must also be noted, anecdotally, that the interviewed student-participants that were distrustful of scientists were not distrustful of their professors, even though many of their professors are "scientists" in the traditional sense and conduct research.

Interpreting the Data in Response to Research Question 1b

Research question 1b asked if the interviewees rejection of macroevolution related to their religiosity, or could it solely be correlated to an epistemology of appealing to authority, as defined in the work of Borderging et al. (2016)? This analysis was based on the coded responses of the 14 student-participants that were selected for an in-person interview. To ensure that the coded identification of appealing to authority, or a warranting of the lens of authority in the lives and worldview of the student-participants, was a sole factor in the interviewed student's levels of evolution acceptance, it was crucial to rule out all other measured and observed factors within this study (Table 3). I compared all surveyed and coded variables against the GAENE Rasch scores as seen in Table 14b, Table 15, and Table 16 via Pearson's and Spearman's correlative analyses where appropriate. Table 14b showed a moderate positive correlation between the GAENE Rasch scores and the CINS scores, R = .51, however this study assumes that if a student-participant has a higher score on the CINS, an assessment focused on understanding natural selection and microevolution, they would inherently have a higher score on the GAENE. Likewise, due to the fact the CINS does not deal with the concepts of macroevolution as explicitly as it does with microevolution, this assessment would not be a defining factor in evolution acceptance, particularly the rejection of macroevolution. Table 15 shows that there is no significant association between the self-reported demographic variables and the interviewed

student-participants GAENE Rasch scores, therefore showing that these variables did not have a relationship with student-participant performance on the GAENE. Table 16 shows that for the variable of the tentative NOS & evolution that there was a moderate inverse correlation with the performance on the GAENE assessment, with a significance between these two factors. Likewise, for the variable of authority there was a moderate positive correlation and significance between these two factors with the performance on the GAENE assessment (Table 16). Yet, it was surprising that the GAENE Rasch Scores and the coded evolution acceptance subcodes did not have a strong linear relationship. Due to this, and some unexpected findings regarding the GAENE that will be addressed later, I chose to continue evaluating these factors solely with the subcode of evolution acceptance because I believed that this subcoding better captured the interviewees true acceptance or rejection of evolution better than their GAENE Rasch score. Therefore, the same analysis was repeated with the Spearman correlation using the evolution acceptance code rather than the GAENE as the primary comparison, as seen in Table 17, Table 18, and Table 19. I observed across these three tables that the only variable that had a correlative relationship, with significance, was authority ($\rho = -.80$, $p = <.0001$). Therefore, based on this data, the rejection of macroevolution, particularly the diversification of species and primate/ human evolution, seems to come from an authority, or a warranting of authority, in the lives of the student-participants and thereby affects their worldview and acquisition of knowledge. No other factor observed in this study, including religiosity, played a role in students' rejection of evolution.

Interpreting the Data in Response to the Statement of Research Question 2

Research question 2 asked, how is a student's measured religiosity index related to their acceptance of the theory of evolution as measured by the GAENE? And, is there a direct

correlation between religiosity and rejection of macroevolution (i.e. the diversification of species and primate/ human evolution) within the target demographic? In Table 14a the Pearson's correlation analysis of the 85-total student-participants surveyed showed no linear correlation between the GAENE Rasch scores and the Religiosity Index average, R = -.034. The same trend held true for those 14 student-participants selected for an in-person interview, with the correlation of the GAENE Rasch scores and Religiosity Index average at R = .017 (Table 14b). Religiosity was also compared against the subcoded levels of evolution acceptance because I found this to be a better measure of evolution acceptance. Table 18 reveals that the Spearman correlation for the Religiosity Index score did not correlate with students' evolution acceptance. Therefore, based on this data, one's religiosity has no effect on their acceptance levels of evolution, whether measured through the GEANE or coded via qualitative in-person interview analysis. This is important because there have been instances in the science education literature where a student's religious affiliation and their acceptance of evolution have been believed to be linked in some capacity (Deniz et al., 2008; Colburn & Henriques, 2006; Goldston et al., 2009; Masci, 2017; Pobiner, 2016). Even in the work of Borderging et al. (2016) there is this notion that the conflicts of religion and science are the primary reason for student rejection of the theory of evolution. Yet, based on the data in this study, this hypothesis that religion is the primary reason for rejection of the theory of evolution might not be accurate.

Unexpected Findings

There were two unexpected findings in this study: the first was the lack of trust these students had in scientists, and the second was the lack of a relationship between the GAENE Rasch scores and the coded level of evolution acceptance of the interviewed student-participants. As stated earlier in this discussion, it was surprising that of the 11 interviewees who were coded

as having an understanding of the trustworthiness of science, five of them believed scientists to not be trustworthy, and of the three that believed science to not be trustworthy, they all believed scientists to not be trustworthy (Supplementary Table 2). While this study did not address this issue, nor does it make a definitive statement on why this may be the case, I conjecture that because these students acknowledged their own biases in what they have chosen to accept within science, and what factors they know to be causing bias within their worldview, the students believe that scientists to do same, which therefore makes scientists untrustworthy to them.

The other unexpected finding was the low-to-moderate correlation that the GAENE Rasch scores had with the interview subcoding for evolution acceptance ($\rho = -.30$). The negative rho score for the Spearman correlation shows that the higher the GAENE Rasch Score, i.e. more accepting of evolution, the lower the evolution acceptance code, i.e. lower means more accepting of evolution according to the subcoding categorical order as seen in Table 13. While I expected GAENE scores and evolution acceptance codes to correlate, the lack of a stronger linear relationship is disconcerting. At the time this study was conceived, and underwent data collection, the GAENE was considered to be a better examination of evolution acceptance when compared with the MATE, a measure of evolution acceptance that superseded the GAENE by Rutledge and Warden (1999). Borderging et al. (2016) acknowledged critiques of how the MATE blurred the difference between belief and knowledge on the topic of evolution and encouraged future works to use the GAENE as it solved this issue. I believe that the GAENE is still problematic primarily because of questions 1, 2, 5, and 10 (Supplementary Table 3).

Question 1 of the GAENE states, “Everyone should understand evolution.” Out of the two interviewed student-participants that were subcoded as “reject” for evolution acceptance, one of them “strongly agree[d]” with this statement. Out of the nine interviewed student-

participants that were subcoded as “partial acceptance,” meaning that they accepted the concepts of microevolution and rejected the concepts of macroevolution and/ or had general misgivings about the overall theory but accepted aspects of it as true, eight of them “strongly agree[d]” or “agree[d]” with this statement (Supplementary Table 3). As the science education literature tells us, understanding rests on two things: possessing knowledge on a topic that can lead to proper comprehension of said topic, and having a “feeling” of knowing caused by personal cognitive intuition, which can impact the student’s ability to readily accept the theory of evolution (Ha et al., 2011; Burton, 2009). Likewise, even the relationship between understanding and acceptance is debated within the science education literature, with some claiming that acceptance of the topic must come first before understanding can take place, while others claim that understanding must be handled first before someone can accept the topic (Sinatra et al., 2003). Intertwining the concept of understanding into a measure of acceptance potentially gives an overly optimistic measure of acceptance for the theory of evolution.

Question 2, of the GAENE states, “It is important to let people know about how strong the evidence that supports evolution is.” Out of the two interviewed student-participants that were subcoded as “reject” for evolution acceptance, both either “strongly agree[d]” or “agree[d]” with this statement (Supplementary Table 3). Out of the nine interviewed student-participants that were subcoded as “partial acceptance,” six of them “strongly agree[d]” or “agree[d]” with this statement (Supplementary Table 3). This shows that these interviewees understand how compelling the evidence for evolution at a scientific level is, however, they are still personally rejecting, or only partially accepting, the overall theory of evolution.

Question 5, of the GAENE states, “People who plan to become biologists need to understand evolution.” Out of the two interviewees that were subcoded as “reject” for evolution

acceptance, one of them "agree[d]" with this statement (Supplementary Table 3). Out of the nine interviewed student-participants that were subcoded as "partial acceptance," eight of them "strongly agree[d]" or "agree[d]" with this statement (Supplementary Table 3). This shows that these students know that those who want to pursue a career in the sciences need to understand evolution. However, again, this study suggests that this question conflates the issue of understanding and acceptance and maintains the same critique as for question 1. Likewise, the GAENE is a measure of personal evolution acceptance, therefore the structure of this question addressing an "unknown" person pursuing a career in the sciences does not lend itself to measuring personal acceptance.

Question 10, of the GAENE states, "I would be willing to argue in favor of evolution in a small group of friends." Of the two interviewed student-participants that were subcoded as "reject" for evolution acceptance, one of them "disagree[d]" with this statement, and the other had a neutral opinion of "I do not know/ No opinion" (Supplementary Table 3) Out of the nine interviewees that were subcoded as "partial acceptance," four of them "strongly agree[d]" or "agree[d]" with this statement, while the rest "strongly disagree[d]" or disagree[d]" (Supplementary Table 3). While those that were subcoded as having rejected evolution, acceptance did not agree with this statement, and only four out of the nine that were subcoded as having a partial acceptance of evolution, agreed with this statement, these findings suggest that this question could be leading to an incorrect measure of acceptance. In each interview that was conducted, there was a question asking if the student had ever had difficult conversations about evolution. While this data was not coded, and therefore anecdotal to the study, many, if not all of those four students had mentioned that either in their course, in their dorm, or just with friends they had discussed the theory of evolution and had argued both sides of the evolution debate in

an effort to better understand it and to see what the people around them understood and accepted at a scientific level, and what they personally believed in accordance with their respective religion. So, while being willing to argue in favor of evolution can be an indicator of acceptance, it needs to be taken into account that the interviewed student-participants in this study had had "debate team" style conversations about the theory of evolution, regardless of their own personal acceptance on the topic.

Considering these critiques, it must not be lost what the GAENE does right. It is only four out of the 13 questions that this study is raising a concern over as to why there was not a strong linear relationship between the GAENE and the coded evolution acceptance. The rest of the questions range from microevolution and natural selection to macroevolution, address speciation, and how evolution relates to other facets of biology. However, like the MATE before it, I believe that an update to this assessment is needed to further enhance quantitative measures of evolution acceptance. Another assessment that has been discovered since the start of this study is the "Inventory of Student Evolution Acceptance – I-SEA" that parses out evolution acceptance by microevolution, macroevolution, and human evolution (Nadelson & Southerland, 2012). Studies have also emerged since the beginning of this study that have assessed how different evolution acceptance measurements can affect research findings and to determine if standardization can be applied to evolution assessments going forward within this field (Mead, Kohn, Warwick, & Schwartz, 2019; Barnes, Dunlop, Holt, Zheng, & Brownell, 2019).

Significance of Findings

The significant findings based off of the data collected and analyzed for this study, and as stated above, are that the rejection of macroevolution, particularly the diversification of species and primate/ human evolution, stems solely from some sort of authority, or a warranting of

authority, in the lives of the student-participants and thereby affects their worldview and acquisition of knowledge. Likewise, no other factor observed in this study, including religiosity, played a role in the student participants rejection of aspects of the theory of evolution, particularly primate/human evolution. In the work of Borgerding et al. (2016), it addresses that there is no way to a fully assess a person's personal epistemology due to the overall multidimensional of socio-cultural influences that make it complex to assess; however, subsets of one's epistemology can be assessed to see how it affects "their views about the development and justification of knowledge in general (pp. 497)." From the outset of this study, authority was one of the primary focuses to see if it played any role in evolution acceptance. As observed in Table 16, it was one of two statistically significant variables, with a moderately-strong linear relationship, when compared against the GAENE Rasch scores of the interviewed student-participants using Spearman correlative analysis. Likewise, in Table 18, it was the only statistically significant variable, with a strong linear relationship, when compared against the subcoded evolution acceptance levels of the interviewees using Spearman's correlation analysis. As the literature stands, there has been an interest in why students create alternative conceptions about the theory of evolution that only further propagate their lack of understanding and/or acceptance of micro-and/or macroevolution (Anderson et al., 2002; Demastes, Good, & Peebles, 1996; Evans & Anderson, 2013). The work of To, Tenenbaum, and Hogh (2016) also addresses how alternative conceptions relate to how a student makes use of multiple lens of warrant (i.e. scientific knowledge they know, their own intuition, etc..) to create an "answer" to something presented to them that they believe to be correct, when in fact it is incorrect. Therefore, examining how students' epistemologies are impacting how they perceive the compatibility of

science and religion, understanding and acceptance of evolution, and micro-and macroevolution, is crucial for evolution education research.

Religion and evolution understanding and acceptance have been very intertwined, whether purposefully or not, within the field of science education until more recently. When conducting research, there has been a growing desire to be aware of how distrust between researcher and participants can emerge by viewing or treating those whom reject evolution, as merely irrational or uneducated (Pobiner, 2016). This has been addressed in the literature on the use of the term "belief" in the context of evolution research, and how it should not be used or conflated with understanding and/or acceptance (Deniz et al., 2008; Sinatra et al., 2003). Religion and evolution acceptance were also addressed in Borgerding et al. (2016) when it came to what types of authority may be a part of the dynamic epistemological make-up of an individual student. In my study, religiosity had a weak linear correlation with the 85-total student-participants that took part in the *Evolution Research Participant Survey* when compared with their GAENE Rasch scores (Table 14). This same trend held true, as seen in Table 19, when the religiosity index was compared against the subcoded evolution acceptance levels of the interviewees. The findings of this study show that, of the student-participant populations that were analyzed, the personal religiosity of a student has little to no effect on their evolution acceptance. This may show that the religion or religiosity of a student is not something that may be a principle factor in evolution rejection, which could encourage research in other areas that may causes evolution rejection, such as a student's epistemologies and how they construct their knowledge and worldview.

Limitations of Finding

The primary limitation of this study is the sample size of 14 interviewed student participants. To make the significant findings mentioned above more conclusive, further research that is similar to what this study observed on how an appeal to authority correlates to the rejection of macroevolution and how religiosity may or may not effect evolution acceptance is crucial to see if these are worthy avenues within the field of evolution education to take into consideration.

One limitation was that 12 of the 14 interviewed student-participants came from the Human Biology and Bioethics course, with only 2 from the Ecological and Evolutionary Systems course, and none from the Introduction to Biology course (Table 12). Having most of the interviewed students come from a general education biology course definitely gives a different perspective than students from a biology major specific course. Although, it is interesting to note that of the two interviewed student-participants from the major specific biology course, both rejected macroevolution and had issues with the theory of evolution as a whole.

As well, at the time of this study I could not find quantifiable measures of macroevolution understanding and macroevolution acceptance in the literature. These sorts of quantifiable measures can be used in tandem with the qualitative measures that I used in my study to better assess the student's surveyed and interviewed levels of understanding and acceptance of the concepts of macroevolution. This study solely focused on acceptance of the concepts of macroevolution due to this limitation.

One potential limitation exists within the findings for research question 2, due to the highly religious-affiliated homogeneous nature of the student population of the small-private Christian university where this study was conducted. This could skew the results to show that

religiosity does not have a linear relationship with evolution acceptance because the students observed in this study make up a very small portion of the "religiosity spectrum," averaging rather high levels of religiosity across the 85-total surveyed.

Lastly, another limitation of this study was how the interviewed student-participants were not selected randomly but rather, were a convenience sample. They were chosen by their response "I don't know," "disagree," or "strongly disagree," for questions 3, 4 and 8 of the GAENE (Appendix C), and how they responded to open-ended cladogram diagram task assessing if they accepted microevolution and rejected macroevolution (Appendices E-G). If this study was to be conducted again, a maximum GAENE Rasch score of 3.44 (i.e. an average of 3.5 out of 4 of the collapsed summated score), a Religiosity Index average of at least 2.5 out of 5, and a CINS score of 7 would be cut off points for the target demographic to be interviewed, in addition to the responses on the open-ended questions that assessed if they accepted microevolution and rejected macroevolution.

Future Studies

I encourage future studies to further the development of quantitative and qualitative assessments on the epistemology of appealing to authority, the continued development of quantitative measures of evolution acceptance, and to address the limitations within this study. The interview protocol used by Borgerding et al. (2016), and this study, was based on the works by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) and King and Kitchener (1994) to identify students' views of evolution within the context of science. The interview protocol does a great job of addressing the many aspects of a student's view on evolution, along with their appeal to authority as an epistemology that shapes their worldview and knowledge acquisition, without leading a student-participant in any specific direction. However, this protocol could also

be a good starting point for a revision that targets the subset of epistemology that deals with appealing to authority and expanding it further. I am not aware of any quantitative analyses that can measure the impact of appealing to authority in how someone constructs knowledge and their worldview, and thus it would be a worthy endeavor for future research. Finally, quantitative and qualitative methods complement each other by capturing aspects that the other does not, and future evolutionary acceptance research needs to make use of the mixed-methods approach.

Revisions to the GAENE, or new measures of evolution acceptance are always needed. Each measurement builds on the next and only makes future assessments stronger in their ability to quantify evolution acceptance. Possessing a better understanding of how different evolution acceptance measurements can affect research findings, and the potential for standardizations across assessments is a growing and worthwhile area of research in the field of scientific education (Mead et al., 2019; Barnes et al., 2019).

Lastly, addressing the limitations within this study is crucial, as it is only when through the replication, or near replication, of this study that the significance found within this studies sample size can be validated and expanded upon.

Conclusion

This purpose of this study arose from anecdotal evidence as I witnessed people who identified as a creationist, and accepted microevolution, but still completely rejected macroevolution, particularly when it came to primate/ human evolution. For many students who fit that dynamic in evolution acceptance, they are grappling with difficult concepts that challenge their worldview, or what the authority figures in their lives say is "true" or "correct." Due to this, it is imperative for science educators to gain a better understanding of how these factors can affect students, and how each student carries with them a very different lived experience, that in turn impacts how they come to acquire knowledge. Therefore, if through future research methods and new or revised assessments, an educator can be able to better understand their students, and be able to provide their students with alternate, but scientifically accurate ways to identify what they understand and accept, then, this at times controversial and painful topic, may be able to be a little easier to understand, accept, and manage for both the student(s) and the educator(s).

References

Anderson, D. L., Fisher, K. M., & Norman, G. J. (2002). Development and evaluation of the conceptual inventory of natural selection. *Journal of Research in Science Teaching*, *39*(10), 952-978.

Barnes, M. E., Dunlop, H. M., Holt, E. A., Zheng, Y., & Brownell, S. E. (2019). Different evolution acceptance instruments lead to different research findings. *Evolution: Education and Outreach*, *12*(1), 4.

Barnes, M. E., Elser, J., & Brownell, S. E. (2017, February 01). Impact of a Short Evolution Module on Students' Perceived Conflict between Religion and Evolution. Retrieved April 28, 2017, from http://abt.ucpress.edu/content/79/2/104

Barnes, M. E., Dunlop, H. M., Holt, E. A., Zheng, Y., & Brownell, S. E. (2019). Different evolution acceptance instruments lead to different research findings. *Evolution: Education and Outreach*, *12*(1), 4.

Borgerding, L. A., Deniz, H., & Anderson, E. S. (2016). Evolution acceptance and epistemological beliefs of college biology students. *Journal of Research in Science Teaching*, *54*(4), 493-519.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(1), 32-42.

Brumby, M. N. (1984). Misconceptions about the concept of natural selection by medical biology students. *Science Education*, *68*(4), 493-503.

Burton, R. A. (2009). *On being certain: Believing you are right even when you're not*. New York, New York: Macmillan.

Catley, K. M. (2006). Darwin's missing link—a novel paradigm for evolution education. *Science Education*, *90*(5), 767-783.

Catley, K. M., & Novick, L. R. (2009). Digging deep: Exploring college students' knowledge of macroevolutionary time. *Journal of Research in Science Teaching*, *46*(3), 311-332.

Catley, K. M., Novick, L. R., & Shade, C. K. (2010). Interpreting evolutionary diagrams: When topology and process conflict. *Journal of Research in Science Teaching*, *47*(7), 861-882.

Cohen, A. B., Shariff, A. F., & Hill, P. C. (2008). The accessibility of religious beliefs. *Journal of Research in Personality*, *42*(6), 1408-1417.

Colburn, A., & Henriques, L. (2006). Clergy views on evolution, creationism, science, and religion. *Journal of Research in Science Teaching, 43*(4), 419-442.

Cox, S. D. (2014). *American Christianity: The Continuing Revolution*. Austin: Univ. of Texas Press.

Creswell, J. W., Plano Clark, V. L., Gutmann, M. L. & Hanson, W. E. (2003). Advanced mixed methods research designs. In A. Tashakkori and C. Teddlie (Eds), *Handbook on mixed methods in the behavioral and social sciences* (pp. 209-240). Thousand Oaks, CA: Sage Publications.

Demastes, S. S., Good, R. G., & Peebles, P. (1996). Patterns of conceptual change in evolution. *Journal of Research in Science Teaching*, *33*(4), 407-431.

Deniz, H., Donnelly, L. A., & Yilmaz, I. (2008). Exploring the factors related to acceptance of evolutionary theory among Turkish preservice biology teachers: Toward a more informative conceptual ecology for biological evolution. *Journal of Research in Science Teaching, 45*(4), 420-443.

Describing the nature of science. (2011, October 7). *Science Learning Hub.* Retrieved April 1, 2019, from https://www.sciencelearn.org.nz/resources/412-describing-the-nature-of-science

Dobzhansky, T. (2013). Nothing in biology makes sense except in the light of evolution. *The American Biology Teacher, 75*(2), 87-92.

Ecklund, E. H., & Scheitle, C. P. (2018). Religious People Do Not Like Scientists, *Religion vs. science what religious people really think (pp. 34)*. New York: Oxford University Press

Evans, P. L., & Anderson, D. L. (2013). The Conceptual Inventory of Natural Selection a decade later: Development and pilot testing of a middle school version leads to revised college/high school version. In *Annual International Conference of the National Association for Research in Science Teaching. Rio Grande, Puerto Rico*.

Finke, R., & Stark, R. (1997). *The Churching of America: 1776 – 1990; Winners and losers in our religious economy*. New Brunswick, NJ: Rutgers Univ. Press.

PLNU. (2018). 2018-2019 Course Catalog Retrieved from https://catalog.pointloma.edu

Goldston, M. J., & Kyzer, P. (2009). Teaching evolution: Narratives with a view from three southern biology teachers in the USA. *Journal of Research in Science Teaching*, 46(7), 762-790.

Ha, M., Haury, D. L., & Nehm, R. H. (2011). Feeling of certainty: Uncovering a missing link between knowledge and acceptance of evolution. *Journal of Research in Science Teaching, 49*(1), 95-121.

Ingram, E. L., & Nelson, C. E. (2005). Relationship between achievement and students' acceptance of evolution or creation in an upper-level evolution course. *Journal of Research in Science Teaching*, 43(1), 7-24.

Institutional Research (2017). About PLNU. Retrieved April 28, 2017, from http://www.pointloma.edu/discover/about-plnu

Kelton, J., & Griffith, J. V. (1986). The learning context questionnaire for assessing intellectual development. *Davidson, NC: Davidson College*.

Martinich, A., & Stroll, A. (2019). Epistemology. *Encyclopædia Britannica, Inc*. Retrieved April 5, 2019, from https://www.britannica.com/topic/epistemology

Masci, D. (2017). For Darwin Day, 6 facts about the evolution debate. *Pew Research Center.* Retrieved April 28, 2017, from http://www.pewresearch.org/fact-tank/2017/02/10/darwin-day/

Mead, L. S., Kohn, C., Warwick, A., & Schwartz, K. (2019). Applying measurement standards to evolution education assessment instruments. *Evolution: Education and Outreach*, *12*(1), 5.

Nadelson, L. S., & Southerland, S. (2012). A more fine-grained measure of students' acceptance of evolution: development of the Inventory of Student Evolution Acceptance—I-SEA. *International Journal of Science Education*, *34*(11), 1637-1666.

Novick, L. R., & Catley, K. M. (2006). Interpreting hierarchical structure: Evidence from cladograms in biology. *Diagrammatic Representation and Inference Lecture Notes in Computer Science,* 176-180.

Novick, L. R., Schreiber, E. G., & Catley, K. M. (2014). Deconstructing evolution education: The relationship between micro- and macroevolution. *Journal of Research in Science Teaching, 51*(6), 759-788.

O'Loughlin, M. (2007). Rethinking science education: beyond Piagetian constructivism toward a sociocultural model of teaching and learning. *Journal of Research in Science Teaching, 29*(8), 791-820.

Perry Jr, W. G. (1999). Forms of Intellectual and Ethical Development in the College Years: A Scheme. Jossey-Bass Higher and Adult Education Series. Jossey-Bass Publishers, 350 Sansome St., San Francisco, CA 94104.

Pobiner, B. (2016). Accepting, understanding, teaching, and learning (human) evolution:

Obstacles and opportunities. *American Journal of Physical Anthropology, 159*, 232-274.

Rutledge, M. L., & Warden, M. A. (1999). The development and validation of the Measure of Acceptance of the Theory of Evolution instrument. *School Science and Mathematics*, *99*(1), 13-18.

Salkind, N. J. (2010). *Statistics for people who (think they) hate statistics: Excel 2007 edition*. Thousand Oaks, CA: SAGE Publications.

She, H. (2004). Fostering radical conceptual change through dual-situated learning model. *Journal of Research in Science Teaching*,*41*(2), 142-164.

Sinatra, G. M., Southerland, S. A., Mcconaughy, F., & Demastes, J. W. (2003). Intentions and beliefs in students' understanding and acceptance of biological evolution. *Journal of Research in Science Teaching*, 40(5), 510-528.

Smith, M. U. (1992). Expertise and the organization of knowledge: Unexpected differences among genetic counselors, faculty, and students on problem categorization tasks. *Journal of Research in Science Teaching*, *29*(2), 179-205.

Smith, M. U., Snyder, S. W., & Devereaux, R. S. (2016). The GAENE—Generalized Acceptance of Evolution Evaluation: Development of a new measure of evolution acceptance. *Journal of Research in Science Teaching*, *53*(9), 1289-1315.

To, C., Tenenbaum, H. R. & Hogh, H. (2017), Secondary school students' reasoning about evolution. *Journal of Research in Science Teaching*, 54: 247–273.

Appendix A: Participant Demographic Information

Participant Demographic Survey
This survey is being used to collect demographic data for potential participants in a thesis study project being conducted by Richard Peterson, principal investigator and graduate student at Point Loma Nazarene University (PLNU)

You can contact R. Peterson at rtpeterson127@pointloma.edu

Thesis Study Purpose: To assess student levels of acceptance and rejection of micro- and macro-evolution based off of religiosity and epistemology.

I have read the above study information, understand it in its entirety, and have had an opportunity to have all of my questions at this time answered (please put an "X" on the diamond next to your selection).

- ◊ Yes
- ◊ No

Thank you for agreeing to be part of this project! Please answer each question as honestly and accurately as possible and remember that there are no right or wrong answers; we are interested in better understanding you, including your beliefs, thoughts, and opinions. Often, the first answer that comes to mind is the best one for you. Your participation today is totally voluntary but completing the survey in its entirety will provide the researcher with the necessary information to continue through their thesis project. Upon completion of this survey, the researcher may reach out to you to conduct an in-person interview for further information. Thank You for your participation

1. **Age: _____**

2. **Gender Identity**

   - ◊ Male
   - ◊ Female
   - ◊ Decline to say
   - ◊ Other: _____

3. **How would you describe your ethnic background/race? (Please check all that apply)**
   - ◊ African American / Black
   - ◊ American Indian / Alaska Native
   - ◊ Asian
   - ◊ Caucasian / White, not of Hispanic Origin
   - ◊ Caucasian / White, including Hispanic Origin
   - ◊ Hispanic or Latino
   - ◊ Native Hawaiian or other Pacific Islander
   - ◊ Other: _____

4. **Education – Undergraduate Level**
   - ◊ Freshman/First Year
   - ◊ Sophomore/Second Year
   - ◊ Junior/Third Year/First Year Transfer
   - ◊ Senior//Fourth Year/Second Year Transfer

◊ Fifth Year/Third Year Transfer

5. **Major or intended major for highest level of education sought or earned?**

---

6. **Religion – How would you describe your CURRENT religious identity? (Please check all that apply)**
   - ◊ Agnostic
   - ◊ Atheist
   - ◊ Baha'i
   - ◊ Buddhist
   - ◊ Catholic
     - ◊ Eastern Catholic (Byzantine, Ruthenian, Coptic, Maronite, Chaldean, etc…)
     - ◊ Roman Catholic
     - ◊ Independent (Old Catholic, Polish National Catholic etc…)
   - ◊ Christian
   - ◊ Daoism
   - ◊ Eastern Orthodox (Greek, Russian, Orthodox Church in America, etc…)
   - ◊ Oriental Orthodox (Armenian, Coptic, Ethiopian, etc…)
   - ◊ Protestant
     - ◊ Anglican/Episcopal
     - ◊ Baptist
       - ◊ American Baptist
       - ◊ Southern Baptist
     - ◊ Christian Scientist
     - ◊ Church of Christ
     - ◊ Church of God
     - ◊ Church of the Nazarene
     - ◊ Disciple of Christ
     - ◊ Evangelical
     - ◊ Fundamentalist
     - ◊ Historically Black Protestant
       - ◊ African Methodist Episcopal Church
       - ◊ Church of Christ in God
       - ◊ National Baptist Convention
     - ◊ Lutheran
       - ◊ Evangelical Lutheran Church in American
       - ◊ Lutheran Church – Missouri Synod
       - ◊ Lutheran – Other
     - ◊ Methodist
       - ◊ United Methodist Church
       - ◊ Methodist – Other
     - ◊ Non-denominational
     - ◊ Pentecostal
     - ◊ Presbyterian
       - ◊ Presbyterian Church, U.S.A.
       - ◊ Presbyterian Church in America
   - ◊ Jainism

- ◊ Jehovah's Witness
- ◊ Jewish
  - ◊ Reform Judaism
  - ◊ Conservative Judaism
  - ◊ Orthodox Judaism
- ◊ Mormon/ Church of Jesus Christ of Latter-Day Saints
- ◊ Muslim
- ◊ Native American Religion
- ◊ Scientology
- ◊ Unitarian – Universalist
- ◊ Unity Church
- ◊ Wiccan
- ◊ None
- ◊ Other: _____

7. How would you describe your familial religious upbringing? (Please check all that apply)

- ◊ Agnostic
- ◊ Atheist
- ◊ Baha'i
- ◊ Buddhist
- ◊ Catholic
  - ◊ Eastern Catholic (Byzantine, Ruthenian, Coptic, Maronite, Chaldean, etc…)
  - ◊ Roman Catholic
  - ◊ Independent (Old Catholic, Polish National Catholic etc…)
- ◊ Christian
- ◊ Daoism
- ◊ Eastern Orthodox (Greek, Russian, Orthodox Church in America, etc…)
- ◊ Oriental Orthodox (Armenian, Coptic, Ethiopian, etc…)
- ◊ Protestant
  - ◊ Anglican/Episcopal
  - ◊ Baptist
    - ◊ American Baptist
    - ◊ Southern Baptist
  - ◊ Christian Scientist
  - ◊ Church of Christ
  - ◊ Church of God
  - ◊ Church of the Nazarene
  - ◊ Disciple of Christ
  - ◊ Evangelical
  - ◊ Fundamentalist
  - ◊ Historically Black Protestant
    - ◊ African Methodist Episcopal Church
    - ◊ Church of Christ in God
    - ◊ National Baptist Convention
  - ◊ Lutheran
    - ◊ Evangelical Lutheran Church in American
    - ◊ Lutheran Church – Missouri Synod
    - ◊ Lutheran – Other

- ◊ Methodist
  - ◊ United Methodist Church
  - ◊ Methodist – Other
- ◊ Non-denominational
- ◊ Pentecostal
- ◊ Presbyterian
  - ◊ Presbyterian Church, U.S.A.
  - ◊ Presbyterian Church in America

◊ Jainism
◊ Jehovah's Witness
◊ Jewish
- ◊ Reform Judaism
- ◊ Conservative Judaism
- ◊ Orthodox Judaism

◊ Mormon/ Church of Jesus Christ of Latter-Day Saints
◊ Muslim
◊ Native American Religion
◊ Scientology
◊ Unitarian – Universalist
◊ Unity Church
◊ Wiccan
◊ None
◊ Other: _____

8. Where have you received the majority of your knowledge regarding the diversity of animal species on Earth?

◊ Public schooling
◊ Private schooling – nonreligious
◊ Private schooling – religious
◊ Personal investigation
◊ Biblical studies
◊ Other: _____

9. Where have you received the majority of your knowledge regarding the appearance of human life on Earth?

◊ Public schooling
◊ Private schooling – nonreligious
◊ Private schooling – religious
◊ Personal investigation
◊ Biblical studies
◊ Other: _____

Origins Position

Now we'd like to know a little bit more about your opinions about the origin of life on Earth. Please remember that your responses will remain confidential and that often the first response that comes to mind is the best one for you. Although there is not universal agreement on how to define these positions, below is one way to define a variety of positions about evolution.

a. Naturalistic evolution: Evolution proposes that the life on Earth, including humans, arose through strictly undirected natural processes acting on random modifications in the genes of various life forms without any supernatural intervention. Often referred to as atheistic evolution.
b. Intelligent Design: Intelligent Design proposes that some aspects of the natural world are explained better by an Intelligent Designer than by natural selection. This position accepts that natural selection does work on living creatures, but that some features of living creatures are so complex that ***they could not be explained by natural processes alone*** and therefore have been acted on by an intelligent source outside of supernatural revelation or sacred texts. While some Christians hold this view, this view is not associated with Christianity and is absent of God but instead allows for an alternate higher power.
c. Theistic evolution: Theistic evolution, also called Evolutionary Creation, proposes that life on Earth, including humans, arose through natural processes that were initiated, maintained, and guided by God. Christians that hold this position accept that natural selection can explain the rise of new species and accept scientific evidence for evolution, but believe that natural laws and processes (like natural selection) are governed by God.
d. Old-Earth creation: Old-Earth creation proposes that the world and life on it was created over a long period of time. Species were specially created in their current form and remain generally unchanged today on an Earth that may be billions of years old. Biblical accounts of universe creation in Genesis 1 & 2 are not viewed as literal. Evolutionary processes for humans are rejected in this view.
e. Young-Earth creation: Young-Earth creation proposes that the world and the life on it was created in six, 24-hour days that align with the Biblical accounts in Genesis 1 & 2. Species remain generally unchanged today on an Earth that is between 6,000 and 10,000 years old. Evolutionary processes are rejected in this view.
f. Uncertain: Believe that God created life, but uncertain how.

10. Using the definitions above, which most closely matches your own view?

- ◊ Naturalistic evolution
- ◊ Intelligent Design
- ◊ Theistic evolution
- ◊ Old-Earth creation
- ◊ Young-Earth creation
- ◊ Uncertain (because this was a choice above so seems like it should be an option.
- ◊ Other: _____

11. How old do you think the Earth is?

- ◊ 6,000 to 10,000 years old
- ◊ Millions to billions of years old
- ◊ I don't know / never thought about it.
- ◊ Other: _____

Please feel free to add any additional information regarding your opinion in terms of the origins of human life and diversity of species on Earth if you feel that the options above do not fully represent your personal beliefs. (e.g. I'm a Theistic Evolutionist but I also think the Earth is over a billion years old.)

12. I have at some point in my life changed my beliefs regarding the appearance of human life and/or diversity of animal species on Earth.

◊ Yes

◊ No

If yes, how have your thoughts regarding origins changed?

13. Does your family, home church, and/ or members a part of your upbringing, share the same views that you do?

◊ Yes

◊ No

If no, please describe

14. Have you ever had any formal education regarding the following topics? (Please put an "X" in the appropriate square)

	Yes	No
Appearance of human existence on Earth		
Origins of animal species diversity on Earth		
Theory of biological evolution		

If yes to any of the above please describe what institution and what class it was (ie. UCSD – BIEB 150, PLNU BIO-211, etc...)

15. Open Response

Now is the time for you to add anything that was not covered in this survey that you think would be important for its researcher to know or consider in terms of your thoughts and feelings regarding the origins of humans and the biodiversity of animal species on Earth. Please provide some form of contact so that the researcher may contact you for further questions to assist with this study in legible handwriting (ie. name, e-mail, phone number, etc...). **Thank You!**

Appendix B: CINS

Conceptual Inventory of Natural Selection 2013 High School/College Version

Evans, P. L., & Anderson, D. L. (2013). The Conceptual Inventory of Natural Selection a decade later: Development and pilot testing of a middle school version leads to revised college/high school version. In *Annual International Conference of the National Association for Research in Science Teaching. Rio Grande, Puerto Rico*.

Your answers will test your understanding of the Theory of Natural Selection. Please choose the answer that best shows how a biologist would answer each question.

Introduction to Galapagos finches

- Finches have been studied on the Galapagos Islands by many scientists.
- The original finches most likely came to the islands one to five million years ago.
- Scientists have evidence that 14 species of finches on the Islands evolved from a single species.
- Species found on the islands have different beak sizes and shapes.

---

1. **What will probably happen if a breeding pair of finches is placed on an island with no predators and plenty of food so that all the birds live?**
    a. The population of finches would stay small because finches only have enough offspring to replace themselves when they die.
    b. The population of finches would double and then stay about the same.
    c. The population of finches would grow to a large number and would keep growing.
    d. The population of finches would grow slowly and then stay the same.
2. **A population of finches lives on an island for many years where there are predators and limited food. What will probably happen to the population if conditions on the island are stable?**
    a. The population will grow rapidly each year.
    b. The population will remain stable, with few changes each year.
    c. The population will get larger, then smaller each year.
    d. The population will get smaller, then larger each year.
3. **Finches on the Galapagos Islands require food to eat and water to drink. Which statement is true about the finches and the available resources?**
    a. Sometimes there is enough food and water, but at other times there is not enough food for all of the finches.
    b. When food and water are limited, the finches will find other kinds of food so there is always enough.
    c. When food and water are limited, the finches all eat and drink less so there is always enough.
    d. There is always plenty of food and water to meet the finches' needs.
4. **Depending on the size and shape of the beak, some finches get nectar from flowers, some eat insects in the bark, some eat small seeds, and some eat large nuts. Which sentence best describes how the finches will interact with each other?**
    a. Many of the finches on an island cooperate to find food and share what they find so that they all live.

b. Many of the finches on an island fight with one another, and the physically strongest ones win.
c. There is more than enough food to meet all the finches' needs, so they don't need to compete for food.
d. Finches compete with other finches that eat the same kinds of food, and some die because they do not get enough to live.

5. A population of finches has hundreds of birds of a single species. Which sentence best describes the group of finches?

a. The finches share all the same traits and are identical to each other.
b. The finches share all of the most important traits, and the small differences between them do not affect how well they reproduce or how long they live.
c. The finches are all identical on the inside, but have many differences in appearance.
d. The finches share all of the most important traits, but also have differences that may affect how well they reproduce or how long they live.

6. How did the different types of beaks first appear in the finches?

a. Changes in the finches' beak size and shape happened because of their need to be able to eat different kinds of food to survive.
b. Changes in the size and shape of the beaks of the finches because of random changes in the DNA.
c. Changes in the beaks of the birds happened because the environment caused beneficial changes in the DNA.
d. The beaks of the finches changed a little bit in size and shape during each bird's life, with some getting larger and some getting smaller.

Introduction to South American guppies

- These are small, colorful fish found in streams in Venezuela.
- Scientists have studied guppies in both natural streams and in lab experiments.
- Males have black, red, blue and reflective spots.
- Brightly colored males are easily seen and eaten by predators, however females tend to choose more brightly colored males.
- In a stream with no predators, the number of males that is bright and flashy increases in the population.
- If predators are added, the number of brightly-colored males gets smaller within about five months (3-4 generations).

---

7. What kind of variation in the traits of the guppies is passed on to their offspring?

a. Only behaviors that were learned during a guppy's life.
b. Only traits that were beneficial during a guppy's life.
c. Only traits that were coded for by a guppy's DNA.
d. Only traits that were affected by the environment in a beneficial way during a guppy's life.

8. Fitness is a term often used by biologists to explain the evolutionary success of certain organisms. Which trait would someone who studies these fish think is the most important in deciding which fish are the "most fit"?

a. Large body size and able to swim quickly away from predators.
b. High number of offspring that live to reproductive age.
c. Excellent at being able to compete for food.
d. High number of matings with many different females.

9. What is the best way to describe the evolutionary changes that happen in the guppy population over time?

a. The traits of each guppy in the population change slowly.
b. Guppies with certain traits reproduce and become more common.
c. Behaviors learned by certain guppies are passed on to their offspring and become more common.
d. Mutations happen in the guppy population to meet the needs of the fish as the environment changes.

10. What could cause populations of guppies in different streams to become different species?

a. Groups of guppies could accumulate so many differences that they would not be able to breed with each other, and this would make them different species.
b. All guppies are alike and there are not really different species.
c. Guppies that need to attract mates could change their spots in many ways, and this would make them different species.
d. Guppies that want to avoid predators in the different streams could change their patterns so they are not so bright, and this would make them different species.

Appendix C: GAENE

Generalized Acceptance of EvolutioN Evaluation (GAENE)

Smith, MU, Snyder SW, & Devereaux, RS. (2016). The GAENE—Generalized Acceptance of EvolutionN Evaluation: Development of a New Measure of Evolution Acceptance. *Journal of Research in Science Teaching, 53*(9), 1289-1315.

The online accessible version of this assessment can be found at, http://www.psytoolkit.org/survey-library/evolution-gaene.html

Please answer the following statements using the scale below:
1=Strongly disagree, 2=disagree, 3=I don't know/no opinion, 4=Agree, 5=Strongly agree

1. Everyone should understand evolution.
2. It is important to let people know about how strong the evidence that supports evolution is.
3. Some parts of evolution theory could be true.
4. Evolutionary theory applies to all plants and animals, including humans.
5. People who plan to become biologists need to understand evolution.
6. I would be willing to argue in favor of evolution in a public forum such as a school club, church group, or meeting of public school parents.
7. Simple organisms such as bacteria change over time.
8. Nothing in biology makes sense without evolution.
9. Understanding evolution helps me understand the other parts of biology.
10. I would be willing to argue in favor of evolution in a small group of friends.
11. Evolution is a good explanation of how humans first emerged on the earth.
12. Evolution is a scientific fact.
13. Evolution is a good explanation of how new species arise.

Appendix D: Religiosity Index Assessment

Religiosity Index Assessment

Cohen, A. B., Shariff, A. F., & Hill, P. C. (2008). The accessibility of religious beliefs. *Journal of Research in Personality*, *42*(6), 1408-1417.

1. **In a few sentences, briefly describe your views on the relationship between religion and evolutionary theory.**

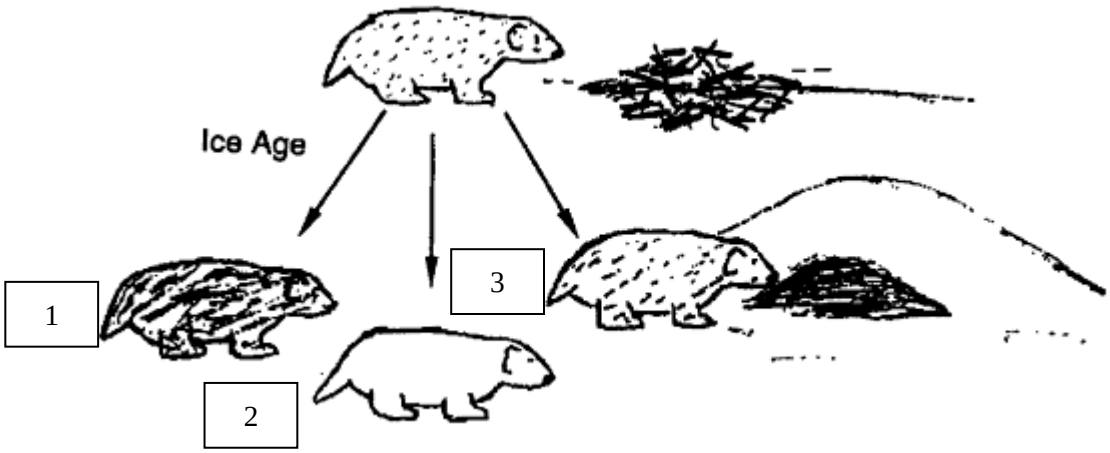
2. **Looking back at the evolution section in your class, did anything in the lectures, readings, or discussions, make you uncomfortable in regards to the religion and evolutionary theory? If yes, please explain.**

3. **Looking back at the evolution section in your class, was there anything that was presented about religion and evolution that you appreciated (discussion, instructor's presentation on the issues, etc…)? If yes, please explain.**

4. **Rate each of the following eight questions on a 5-point scale from strongly disagree (1) to strongly agree (5):**

My personal religious beliefs are very important to me	
My religion or faith is an important part of my identity	
If someone wanted to understand who I am as a person, my religion or faith would be very important in that	
I attend religious services regularly	
I practice the requirements of my religion or faith	
I believe in God	
I consider myself a religious person	
I consider myself a spiritual person	

Appendix E: Evolution Diagram Questions (Part 1)



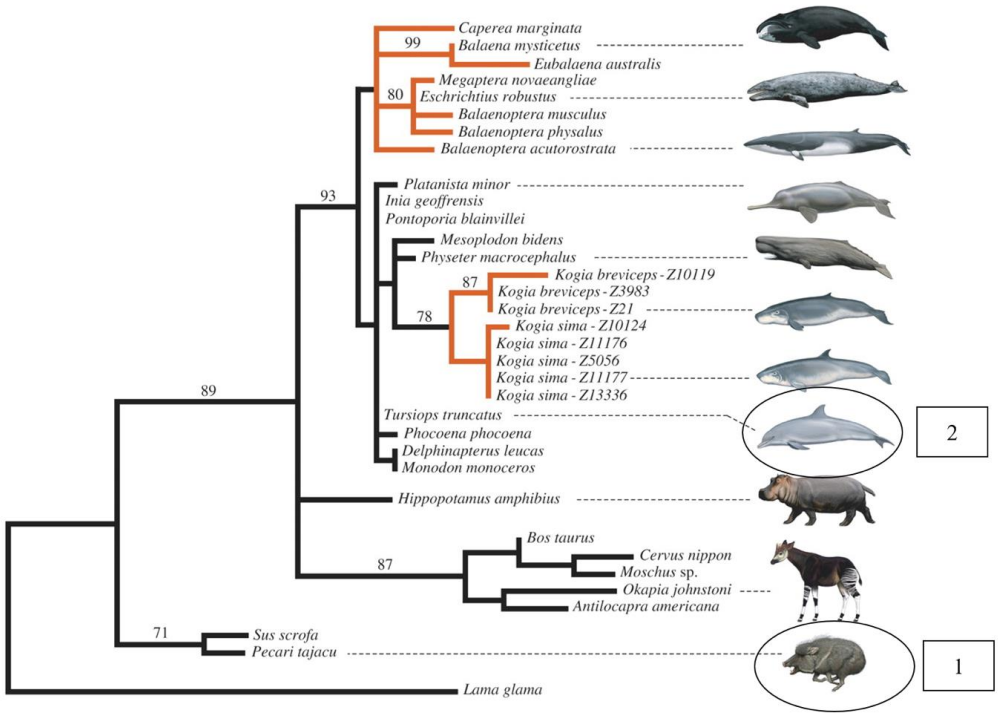
The animal on the top of this diagram is our ancestral mammal. It's kind of fat. It has kind of short hair. And it makes a nest on the ground in sticks; that's how it nests. Then the ice age comes, and it gets really cold.
Then there is a mutation. Something happens to produce new variation. Number 1 has the bear developing long hair. Number 2 has the bear losing its hair. Number 3 shows the bear learning how to burrow into the ground.

Which one, if any, of these mutations be more likely? Why?

What kind of evolution, micro-evolution or macro-evolution, do you think this example would be? Please define your choice and explain why you chose it?

Do you think that the type of evolution that you selected for the above answer is a good way to explain this example? Why or why not?

Appendix F: Evolution Diagram Questions (Part 2)



This is a diagram of whale evolution over a period of millions of years. Please use the following image while answering the following questions.

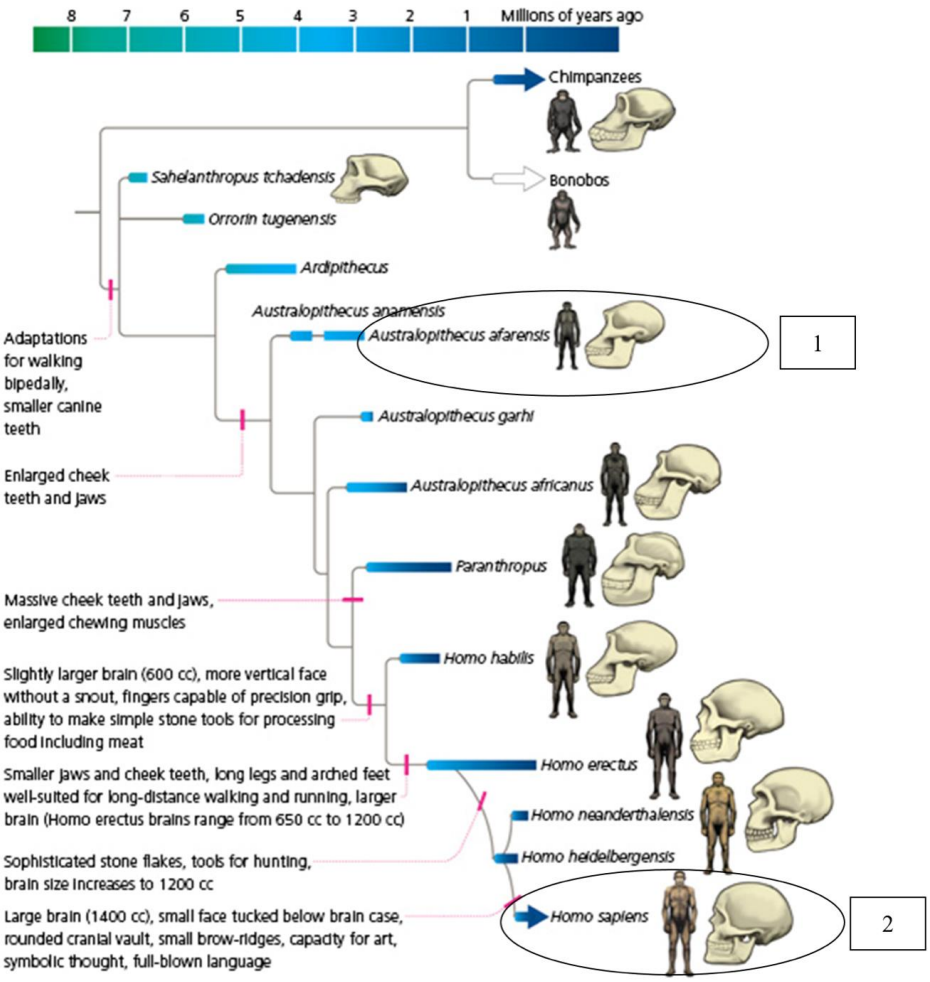
Explain the relationship between the ancestral species Number 1, and the current species listed as Number 2.

What kind of evolution, micro-evolution or macro-evolution, do you think this example would be? Please define your choice and explain why you chose it?

Do you think that the type of evolution that you selected for the above answer is a good way to explain this example? Why or why not?

Appendix G: Evolution Diagram Questions (Part 3)

This is a diagram of Primate evolution over a period of millions of years. Please use the following image while answering the following questions.



Explain the relationship between the ancestral species listed as Number 1, and the *Homo sapiens* species listed as Number 2

What kind of evolution, micro-evolution or macro-evolution, do you think this example would be? Please define your choice and explain why you chose it?

Do you think that the type of evolution that you selected for the above answer is a good way to explain this example? Why or why not?

Appendix H: Interview Protocol

Interview Protocol

Borgerding, L. A., Deniz, H., & Anderson, E. S. (2016). Evolution acceptance and epistemological beliefs of college biology students. *Journal of Research in Science Teaching, 54*(4), 493-519.

1. What would you define biological evolution? What does this definition mean for you?
2. How did you come to define biological evolution it in that way?
3. I'm going to present 2 scenarios, and ask some follow up questions to get a picture of how you think about these sorts of issues.
    - Many religions of the world have creation stories. These stories suggest that a divine being created the earth and its people. Scientists claim, however, that humans evolved from lower animal forms (some of which are like apes) into the human forms known today.
        a. What do you think about these statements, particularly the notion of humans evolving from lower animal forms and having similarities with apes?
        b. How did you come to hold that point of view?
        c. On what do you base that point of view?
        d. Is it possible that experts in the field disagree about this subject?
        e. In the context of your own beliefs, does this statement have any effect on your religion or views of science?
    - Some people think that evolution is too controversial and can potentially conflicts with students' religious views. Therefore, it should NOT be taught in U.S. high schools. Other people think that evolution is well substantiated science that all students should learn and therefore SHOULD be taught in U.S. high schools.
        a. What do you think about these statements?
        b. How did you come to hold that point of view?
        c. On what do you base that point of view?
        d. When two people differ about matters such as this, is it the case that one opinion is right and one is wrong? If yes, what do you mean by "right"? If no, can you say that one opinion is in some way better than the other? What do you mean by "better"?
        e. How is it possible that people have such different views about this subject? How is it possible that experts in the field disagree about this subject?
4. How would you define micro-evolution? Do you understand this concept? Do you accept this concept as the best possible scientific explanation? Why or why not?
5. How would you define macro-evolution? Do you understand this concept? Do you accept this concept as the best possible scientific explanation? Why or why not?
6. Can you ever know for sure if your ideas about evolution are correct? How or why not?
7. When two people differ about matters such as this, is it the case that one opinion is right and one is wrong? If yes, what do you mean by "right"? If no, can you say that one opinion is in some way better than the other? What do you mean by "better"?
8. How is it possible that people have such different views about this subject?
9. Do you think that evolution is an example of "good" or "bad" science? Why?
10. What do you consider good science to be? Bad science?
11. Can you describe for me what you think a scientific account for the diversity of life on earth today is? Can you describe for me what an unscientific account would be?
12. Can experiments be conducted in evolutionary biology? Explain.
13. After scientists have developed a scientific theory like evolution theory, does the theory ever change?
    1. If you believe that scientific theories do not change, explain why. Defend your answer with examples.

2. If you believe that scientific theories do change, (a) Explain why theories change? (b) Explain why we bother to learn scientific theories? Defend your answer with examples.

14. Is there a difference between a scientific theory and a scientific law? Could evolutionary theory ever become a law? Why or why not? Have your ideas about this been impacted by this class at all?
15. Science textbooks often define evolution as changes in gene frequencies in populations over time. How certain do you think scientists are about what evolution is and how it works? Why or why not?
16. Scientists think the dinosaurs went extinct about 65 million years ago. Some scientists think that a huge meteorite hit the earth and caused the extinction, and other scientists think that massive volcanic eruptions caused the extinctions. How are these *different conclusions* possible if scientists in both groups are using the same data? Do you think they'll ever agree?
17. Some people think that science IS affected by people's *values*, and other people say that science IS NOT affected by *values*. *What do you think* – would you say science IS or IS NOT impacted by social and cultural values? Why or why not?
18. Do you think values play a role in evolutionary biology or not? Why or why not?
19. Scientists perform investigations to find answers to questions. Do you think evolutionary scientists use their *creativity and imagination* during their investigations? Why or why not?
20. Have you ever had a conversation when you disagreed with a person about your views on evolution? How did it go?
21. Do you think it's possible for adults to change their ideas about evolution very much, or is that something that probably doesn't happen? Why? Has this happened to you?
22. Have your ideas about biological evolution been impacted by the class you are currently in?
23. Can you remember when you first learned about evolution? With whom did you have your earliest conversations about evolution? What did you think about evolution then?
24. How do you feel in class when learning about evolution? What would make learning about evolution better for you?

Appendix I: Supplementary Tables

Supplementary Table 1

Linear regression analysis of the GAENE and CINS of the 85-total surveyed student-participants

	Dependent Variable	Indepdent Variable (s)	R^2	p-value (two-sided)
Total Student's Surveryed (n=85)	GAENE	CINS	0.12	.92 X 10^-4

Supplementary Table 2

Group Coding & Subcoding for the 14 interviewed student-participants

	Group Coding Catergories								
Interviewee	Identification with science	Reliability of NOS	Variability of NOS	Trustworthiness of NOS	Scientists within the NOS	Authority	Evolution Acceptance	Compatibility of Evolution & Religion	Tentative NOS & Evolution
P11	I'm not a scientist	Scientific findings are not reliable	Scientific findings are variable	Science is not trustworthy	Scientists are not trustworthy	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial accept	Incompatible	All science has gaps – evolution is good science even with gaps – but I don't believe it
M9	I'm not a scientist	Scientific findings are reliable	Scientific findings are variable	Science is trustworthy	Scientists are trustworthy	I appeal to the authority of my parents/ family for my present evolution position	Reject	Compatible	All science has gaps – evolution is good science even with gaps
M4	I'm not a scientist	Scientific findings are reliable	Scientific findings are variable	Science is trustworthy	Scientists are not trustworthy	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial accept	Compatible	All science has gaps – evolution is good science even with gaps – but I don't believe it
H8	I'm not a scientist	Scientific findings are reliable	Scientific findings are variable	Science is not trustworthy	Scientists are not trustworthy	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial accept	No Mention	All science has gaps – evolution is good science even with gaps – but I don't believe it
L10	I'm not a scientist	Scientific findings are reliable	Scientific findings are variable	Science is trustworthy	Scientists are trustworthy	No mention of authority	Accept	Compatible	All science has gaps – evolution is good science even with gaps
A5	No mention	Scientific findings are not reliable	Scientific findings are variable	Science is not trustworthy	Scientists are not trustworthy	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Reject	Compatible	All science has gaps – evolution is good science even with gaps – but I don't believe it
G2	I'm not a scientist	Scientific findings are reliable	Scientific findings are variable	Science is trustworthy	Scientists are not trustworthy	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial accept	Compatible	All science has gaps – evolution is good science even with gaps – but I don't believe it
O12	I'm a rational/logical thinker	Scientific findings are reliable	Scientific findings are variable	Science is trustworthy	Scientists are trustworthy	I appeal to the authority of the scientific community for my present evolution position	Partial accept	Compatible	All science has gaps – evolution is good science even with gaps
N3	I'm not a scientist	Scientific findings are reliable	Scientific findings are variable	Science is trustworthy	Scientists are not trustworthy	I reject all authority	Accept	Compatible	All science has gaps – evolution is good science even with gaps
S6	I'm not a scientist	Scientific findings are reliable	Scientific findings are variable	Science is trustworthy	Scientists are trustworthy	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial accept	No Mention	All science has gaps – evolution is good science even with gaps – but I don't believe it
L15	I'm a rational/logical thinker	Scientific findings are reliable	Scientific findings are variable	Science is trustworthy	Scientists are not trustworthy	I reject all authority	Partial accept	No Mention	All science has gaps – evolution is good science even with gaps
S13	No mention	Scientific findings are reliable	Scientific findings are variable	Science is trustworthy	Scientists are trustworthy	No mention of authority	Accept	Compatible	All science has gaps – evolution is good science even with gaps
A1	I'm a rational/logical thinker	Scientific findings are reliable	Scientific findings are variable	Science is trustworthy	Scientists are trustworthy	I appeal to the authority of my religion/ church/ sacred texts for my present evolution position	Partial accept	Compatible	All science has gaps – evolution is good science even with gaps – but I don't believe it
D14	I'm a rational/logical thinker	Scientific findings are reliable	Scientific findings are variable	Science is trustworthy	Scientists are not trustworthy	I appeal to the authority of the scientific community for my present evolution position	Partial accept	Compatible	All science has gaps – evolution is good science even with gaps

Supplementary Table 3

Individual GAENE responses of the 14 interviewed student-participants

	Individual GAENE Questions													GAENE Average	Subcoding
Interviewee	Everyone should understand evolution	It is important to let people know about how strong the evidence that supports evolution is	Some parts of evolution theory could be true	Evolutionary theory applies to all plants and animals, including humans	People who plan to become biologists need to understand evolution	I would be willing to argue in favor of evolution in a public forum such as a school club, church group, or meeting of public school parents	Simple organisms such as bacteria change over time	Nothing in biology makes sense without evolution	Understanding evolution helps me understand the other parts of biology	I would be willing to argue in favor of evolution in a small group of friends	Evolution is a good explanation of how humans first emerged on the earth	Evolution is a scientific fact	Evolution is a good explanation of how new species arise	Rasch Score	Evolution Acceptance
P11	I Do Not Know/No Opinion	I Do Not Know/No Opinion	I Do Not Know/No Opinion	I Do Not Know/No Opinion	I Do Not Know/No Opinion	I Do Not Know/No Opinion	I Do Not Know/No Opinion	I Do Not Know/No Opinion	I Do Not Know/No Opinion	Strongly disagree	Strongly disagree	Strongly disagree	Strongly disagree	-2.65	Partial Acceptance
M9	Strongly agree	Strongly agree	Agree	Agree	Strongly agree	Disagree	Agree	I Do Not Know/No Opinion	I Do Not Know/No Opinion	Disagree	Disagree	Disagree	Disagree	-0.54	Rejection
M4	Agree	I Do Not Know/No Opinion	Agree	Agree	Strongly agree	I Do Not Know/No Opinion	Agree	I Do Not Know/No Opinion	Agree	Agree	Strongly disagree	Agree	Agree	0.67	Partial Acceptance
H8	Agree	I Do Not Know/No Opinion	Agree	Disagree	Strongly agree	Strongly disagree	Agree	I Do Not Know/No Opinion	Agree	Strongly disagree	Strongly disagree	Agree	Strongly disagree	-1.04	Partial Acceptance
L10	Agree	Agree	Agree	Agree	Strongly agree	Disagree	Agree	Agree	I Do Not Know/No Opinion	I Do Not Know/No Opinion	I Do Not Know/No Opinion	Agree	Agree	0.67	Acceptance
A5	I Do Not Know/No Opinion	Agree	Agree	I Do Not Know/No Opinion	Strongly agree	I Do Not Know/No Opinion	Agree	Agree	Agree	I Do Not Know/No Opinion	Disagree	I Do Not Know/No Opinion	I Do Not Know/No Opinion	-0.05	Rejection
G2	Strongly agree	Strongly agree	Strongly agree	Agree	Strongly agree	I Do Not Know/No Opinion	Agree	Agree	Agree	Agree	Disagree	I Do Not Know/No Opinion	Strongly agree	1.86	Partial Acceptance
O12	Strongly agree	Strongly agree	Strongly agree	I Do Not Know/No Opinion	Strongly agree	I Do Not Know/No Opinion	Agree	Agree	Agree	Agree	Disagree	I Do Not Know/No Opinion	I Do Not Know/No Opinion	1.15	Partial Acceptance
N3	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	I Do Not Know/No Opinion	Agree	Strongly agree	Disagree	Disagree	Strongly agree	2.61	Acceptance
S6	Agree	Agree	Agree	I Do Not Know/No Opinion	Agree	Disagree	Agree	I Do Not Know/No Opinion	I Do Not Know/No Opinion	Disagree	Strongly disagree	I Do Not Know/No Opinion	Disagree	-1.3	Partial Acceptance
L15	Agree	Agree	Agree	Agree	Strongly agree	Agree	Strongly agree	I Do Not Know/No Opinion	Agree	Strongly agree	I Do Not Know/No Opinion	Strongly disagree	Agree	1.38	Partial Acceptance
S13	Agree	Agree	Agree	Agree	Agree	Disagree	Agree	I Do Not Know/No Opinion	I Do Not Know/No Opinion	Agree	I Do Not Know/No Opinion	Agree	Agree	0.43	Acceptance
A1	Agree	Agree	Strongly agree	Disagree	Strongly agree	Strongly disagree	Agree	Disagree	Strongly agree	Strongly disagree	Disagree	Strongly disagree	Disagree	-1.04	Partial Acceptance
D14	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	7.22	Partial Acceptance