POINT LOMA NAZARENE UNIVERSITY

Teacher Preparedness to Teach Evolution

A thesis submitted in partial satisfaction of the

requirements for the degree of

Master of Science

in General Biology

by

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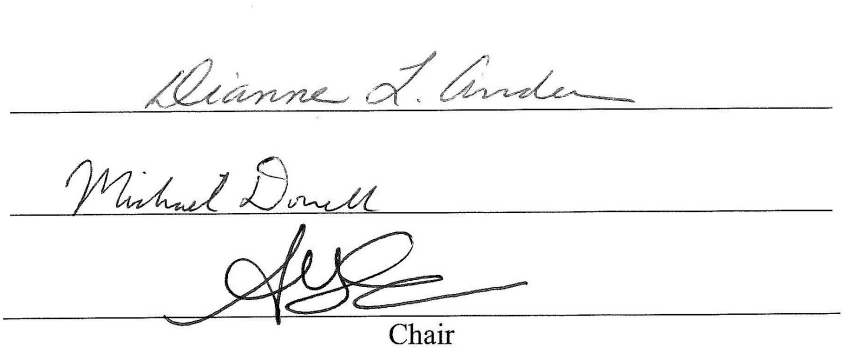
The thesis of Rebecca Diane Christian is approved, and it is acceptable in quality and form for publication:



Chair

Point Loma Nazarene University

2020

I dedicate and anoint this thesis for God's kingdom and His glory.

I declare this work to transform the science and education communities.

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Abstract of the Dissertation

Teacher Preparedness to Teach Evolution

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Point Loma Nazarene University, 2020

April Maskiewicz Cordero, Ph.D., Chair

The idea for this study came from the shortage of research that has been done to understand the evolution instruction provided by new secondary education teachers. A lack of training in teachers can potentially impact student understanding and acceptance. This study used a mixed-methods approach with a quantitative questionnaire modeled after Sickel and Friedrichsen's (2013) research to measure teacher preparedness in evolutionary content knowledge, acceptance, and pedagogy. On a scale of one to five, new teachers scored an average of three in evolutionary content knowledge, a four in acceptance of evolution, and a three in pedagogy. A strong negative correlation was found between acceptance of evolution and religion. Qualitative interviews were conducted with eight participants to find out their thoughts on the interaction of evolution and religion, and if they had any personal worldview conflicts between the two because conflicts have been found to negatively impact evolution instruction (Barnes & Brownell, 2016). Most

interviewees did not have a personal internal conflict between evolution and religion even though their average religiosity score was 3.01 (out of five). The primary external conflict teachers have is that their evolution instruction will have negative effects on students' perception of evolution because they may offend students. This study is important for science education research and for credential programs because it shows that new teachers are not well prepared to teach evolution which is a problem since evolution is the cornerstone of biology. Furthermore, this study reveals that evolutionary content knowledge and pedagogy are not improved by the completion of a course on evolution or a scientific methods course in a teacher credentialing program.

Introduction

Geneticist and evolutionary biologist, Theodosius Dobzhansky said, “Nothing in biology makes sense except in the light of evolution” (Dobzhansky, 1973). Evolution is a cornerstone in biology and is therefore imperative for students to understand in order to make sense of the natural world (Rice, Clough, Olson, Adams, & Colbert, 2015). Evolution instruction for secondary school students should include the evolution of species, emergence of new species, evolution from a common ancestor, evolution occurring gradually, and natural selection (NGSS Lead States, 2013; NABT, 2019; NSTA Position Statement, 2019). Much research has gone into studying students’ acceptance of evolution (Peterson, 2019). Little, in comparison, has been done to understand the evolution instruction provided by secondary education teachers and its potential impact on student understanding and acceptance.

One noteworthy study on public secondary education teachers is Griffith and Brem’s (2004) research on the relationship between the stress incurred by teachers when teaching evolution and the type of evolution instruction delivered by these teachers. They found that teachers’ negative attitudes toward evolution led toward less time on the evolution unit, restrictions on class discussion, avoiding the word “evolution” altogether, or bypassing the unit completely. Griffith and Brem named teachers that followed this type of behavior as “selective”. Teachers who were “selective” about the teaching of evolution were found to have a religious reason. Personally, as a Christian biology teacher, I faced some of the same struggles as the teachers in Griffith and Brem’s research. In the first year that I was required to teach evolution, I did not know how I could reconcile my faith and evolution. I had a Christian upbringing and was taught that evolution conflicted with Christianity and must therefore be rejected. However, my job as a middle school life science teacher, required me to teach evolution as mandated by Next

Generation Science Standards. My conflict between evolution and religion resulted in a lesson plan where students read the textbook and drew conclusions on their own. This was the only unit in my life science curriculum that I did not do any direct instruction because I had not reconciled my faith and evolution, and I did not want to feel personally condemned for teaching students incorrectly. My experience as well as studies like that of Griffith and Brem (2004) were the motivating factors for my pilot study.

In my pilot research, I studied the internal and external conflicts of secondary school biology teachers, and the impact of those conflicts on their instruction. The main internal conflict for instructors involved personal religious convictions with some going so far as to believe that accepting evolution results in eternal damnation, something that (Smith, 2009) also found. Griffith and Brem (2004) uncovered external pressures being primarily from the parents, the community, and the law. In my pilot study, the participants were given a list of internal and external conflicts and asked if they resonated with any of those conflicts (Appendix H). Four of the six teachers interviewed had been teaching for more than 10 years, and had long since resolved their initial conflicts with evolution. Two of the six participants had taught evolution for less than two years, and no longer resonated with the internal conflicts, but had still had external conflicts with administration and students when teaching evolution. I found that the way in which the participants resolved their conflicts determined how they implemented their evolution unit. Participants were given five statements on the compatibility of God and evolution and asked to rank the statements that best described their personal belief (Appendix H). Five out of six participants that chose statements about religion and evolution being compatible directly addressed religion in their evolution unit in hopes of lowering the resistance some of the students might have toward the topic. From my pilot study, I concluded that participants' evolution

instruction was impacted by how they resolved their personal conflicts between evolution and religion.

The findings from my pilot research motivated this thesis research study. First, my pilot study showed that teachers who had taught more than two years had already resolved their conflicts. In this study, I wanted to examine only secondary science teachers who had taught two years or less. Second, my pilot study showed that how teachers resolved their personal conflict with evolution impacted their evolution instruction. Now I wanted to test that finding on a larger group of teachers. I also wanted to find out if the teachers' credential program had helped them to resolve conflicts or prepared them to lesson plan for an evolution unit. Lastly, I found that teachers who viewed religion and evolution as compatible addressed religion in their evolution unit, which studies have shown to impact the acceptance of evolution by religious students. I wanted to test this finding on a larger group of teachers as well, and to see if credential programs had helped teachers find compatibility of evolution and religion.

Theoretical Framework

Research in constructivism focuses on interviewing the individual on their ideas and conceptions and the process in which they arrived at these conclusions (Julyan & Duckworth, 2005). By conducting research from this perspective, the goal is to further understand how new secondary science teachers think about their evolutionary pedagogy. In this current study, I looked at new secondary science teachers' level of preparedness to teach evolution. I also studied their personal conflicts with evolution and religion and their view of compatibility with God and evolution. Furthermore, the teachers' religiosity was measured which for the purpose of this study will be defined by an individual's involvement and allegiance to a religion. The findings may contribute to research in evolution teacher education.

Literature Review

Acceptance of evolution in America

31% of Americans reject human evolution (PEW, 2014) and 50% of students in introductory college biology classes reject all evolution (Rice, Olson, & Colbert, 2010). The primary reason for rejection of evolution is religiosity (Barnes & Brownell, 2018; Pew, 2013; Sickel & Friedrichsen, 2013; Smith, 2009; Wilbur & Withers, 2015). White evangelical protestants have the highest rejection rate of evolution (64%) among all religious groups (Pew, 2013). A 2014 Gallup poll showed that 42% of Americans accept creationism as the explanation for the origin of life on earth (Wilbur & Withers, 2015). Not surprisingly, most scientists are less religious than the American public: only 33% claim to believe in God vs. 83% of the American public (Pew, 2009). One of the contributing factors underlying the divide between the rejection of evolution among Christians and the rejection of God among scientists is the perceived incompatibility between evolution and religion (Barnes & Brownell, 2016; Barnes & Brownell, 2018; Pobiner, 2016; Smith, 2009). Acceptance in the U.S. is low and one variable linked to acceptance is understanding evolution.

Acceptance and understanding

The relationship between acceptance of evolution and understanding of evolution is still disputed in evolution education research (Peterson, 2019; Smith, 2009). Smith (2009) says a clear distinction between the two must be made. He defines understanding of evolution as connectedness, sense-making, application, and justification. To further define understanding, he quotes Nieswandt and Bellomo (2009), “Understanding of evolution is comprised of [not only] factual, [but also] procedural (rules, algorithms), schematic (‘knowing why’) and strategic knowledge (when, where, and how to apply knowledge)”. Some see acceptance coming before

understanding, others see understanding as a step toward acceptance, and still others see neither as a prerequisite (Peterson, 2019; Pobiner, 2016; Smith, 2009). Pobiner (2016) points out that it is possible to accept and not understand evolution and he found other research that showed participants that understand evolution and yet still reject it. Overall, research supports a correlation between acceptance and understanding although the two must still be kept separate (Peterson, 2017; Pobiner, 2016). Whether there is a correlation with acceptance and understanding or not, America's low acceptance rate shows that evolution instruction in the United States needs to be investigated.

Evolution instruction

Evolution instruction is mandated in high school biology courses in the U.S. The mandate comes from the National Association of Biology Teachers, the National Science Teachers Association, and Next Generation Science Standard HS-LS4 Biological Evolution: Unity and Diversity, which all state that evolution must be emphasized in science education and requires students to be able to apply evolutionary principles (NABT Position Statement on Teaching Evolution, 2019; NGSS Lead States, 2013; NSTA Position Statement, 2019). While the standards are uniform, the teaching strategies vary greatly. There appears to be a connection between the attitude of the instructor towards evolution and the resulting teaching strategy science teachers use (Barnes & Brownell, 2016; Mananghas, 2017; Smith, 2009).

An instructor's negative attitude toward evolution often comes from the fact that it can be difficult to teach. Instructors face both external pressures and the internal conflicts (Barnes & Brownell, 2018; Griffith & Brem, 2004; Groβschedl, Konneman, & Basel, 2014; Pobiner, 2016; Sickel & Friedrichsen, 2013). Griffith and Brem (2004) uncovered that external pressures stem from parents, community, and the law. Parents may object to evolution instruction and require

alternate assignments for their students. In conservative communities, many instructors face additional pressures to teach creationism. News reports of legal battles and protests about teaching evolution in the classroom are ubiquitous. When it comes to internal conflicts for instructors, the primary ones include personal religious convictions and beliefs that accepting evolution results in eternal damnation (Griffith & Brem, 2004; Smith, 2009). These external pressures and internal conflicts affect the teachers' attitudes toward teaching evolution.

An instructor's attitude toward evolution directly affects the quality of the teacher's evolution instruction (Barnes & Brownell, 2016; Mananghas, 2017; Smith, 2009; Tekkaya, Akyol, & Sungur, 2012). Griffith and Brem (2004) categorized three possible evolution teacher attitudes about evolurion 1) scientists 2) selective 3) conflicted. Those coded as "scientists" have the least amount of conflict because they accept evolutionary theory, have a love of science, and see evolution as essential content in the biology curriculum (Griffith & Brem, 2004). Their evolution instruction is based in the nature of science and does not fear controversy because science is clearly separate from religion. "Selective teachers" accept evolution, but strive for community and harmony. Their evolution unit usually omits the teaching of speciation and human evolution as these topics can be the most difficult to teach because of their controversial nature (Sickel & Friedrichsen, 2013; Smith, 2009). Lastly, "conflicted teachers" struggle because they are still exploring their own conflicts with evolution (Griffith & Brem, 2004). Their evolution instruction often consists of students writing a paragraph on how evolution makes them feel because the conflicted teacher is worried about the impact on a student. They may even go to such great lengths as to meet with students one-on-one during class to assure students that they are not trying to change their beliefs. While a teacher's attitude does affect instruction,

research has uncovered proven successful strategies for teaching evolution that can lead to greater acceptance.

Successful evolution teaching strategies

Research on successful teaching strategies conclude that there are three important components for promoting acceptance of evolution: 1) reconciliation of evolution and religion, 2) teaching the nature of science (NOS), and 3) providing a safe (non-judgmental) classroom environment (Barnes & Brownell, 2018; Griffith & Brem 2004; Groβschedl et al., 2014; Nadelson, 2009; Sickel & Friedrichsen, 2013; Smith, 2009; Smith & Eve, 2009). Each of these strategies will be discussed in detail in this section.

First, Barnes and Brownell's (2018) study found that many religious and non-religious college science instructors avoid the topic of religion when teaching evolution because of their belief that evolution is incompatible with religion. However, when instructors include information about how to reconcile religion and evolution, and can demonstrate their compatibility, or that they answer different questions, students may be more likely to accept evolution (Barnes & Brownell, 2018; Lindsay, Arok, Bybee, Cho, Cordero, Ferguson, & Jensen 2019; Smith & Eve, 2009).

Second, to show the compatibility of science and religion, some researchers argue that instructors must teach the NOS (Groβschedl et al., 2014; Nadelson, 2009; Sickel & Friedrichsen, 2013). The NOS explains the characteristics and the limitations of science. Smith (2009) in his summary of numerous papers on the NOS concluded that science is characterized by (a) being "tentative or subject to change, but reliable, (b) empirically based, (c) subjective or theory-laden, (d) a product of human creativity, (e) socio-culturally embedded within society, and (f) makes use of the distinction between observation and inference and between scientific theories and

laws" (p. 530). In addition, instruction must clarify the fact that science does not (or can not) answer questions about God (Barnes & Brownell, 2018; Smith, 2009). Teaching the NOS involves an explicit explanation of the questions science answers and the fact that science is based on empirical evidence and not personal belief. When the NOS is defined, creationism no longer fits in the evolution classroom because it is not based on empirical evidence and therefore not scientific (Barnes & Brownell, 2018; Smith, 2009).

Third, the most current research on evolution instruction suggests that instructors must provide a safe place for students to process their attitudes toward evolution (Barnes & Brownell, 2018; Griffith & Brem, 2004). In order for students who hold religious beliefs to feel safe, religion needs to be addressed when learning about evolution. Undergraduate students with religious beliefs who have had bad experiences during evolution instruction at a secular university said their instructors mocked them, seemed angry toward religion, dismissed religious students as unintelligent, and did not provide an environment where they were safe to share their viewpoints (Barnes & Brownell, 2018). While the research did not show if the students became teachers themselves, their comments confirm that instructors' attitudes toward evolution and religion influence their evolution instruction and consequently students' response to evolution (Smith, 2009). In summary, successful evolution instruction strategies include teaching that reconciles evolution and religion showing compatibility between the two, teaching the NOS, and providing a safe learning environment (Barnes & Brownell, 2018; Griffith & Brem 2004; Groβschedl et al., 2014; Mananghas, 2017; Nadelson, 2009; Sickel & Friedrichsen, 2013; Smith, 2009; Smith & Eve, 2009; Wiles & Branch, 2008). As such, these strategies should be implemented in pre-service biology programs.

Preparation of pre-service biology teachers

If we are to increase the evolution acceptance rate of Americans, we must look at the way in which pre-service secondary science teachers are prepared to teach evolution. Groβschedl, Konnemann, and Basel (2014) conducted a study on 180 German pre-service biology teachers to show the relationship between acceptance of evolution and their preference for teaching evolution. They found that pre-service teachers' acceptance of creationism and their evolution content knowledge were the two determining factors of a pre-service teacher's preference. In addition to acceptance, Nadelson (2009) conducted a web-based intervention study to assess U.S. pre-service biology teachers' evolution understanding. He identified a wide range of accurate conceptions on evolution as well as many alternative conceptions held by the pre-service instructors. Both the Nadelson and Groβschedl et. al., studies reveal the need to further investigate the preparation of pre-service biology teachers on their evolution content knowledge and acceptance.

Sickel and Friedrichsen (2013) established four goals for preparing pre-service biology teachers to teach evolution: 1) knowledge of evolution, 2) acceptance of evolution, 3) understanding the NOS, and 4) pedagogical knowledge for teaching evolution including handling controversy in the evolution classroom. Each of these are discussed below.

First, to produce scientifically literate biology students, teachers must have an adequate understanding of evolutionary theory. Surprisingly, 69% of high school biology teachers have never had a course in evolution (Wilbur & Withers, 2015). Those instructors that have taken a biology course with a unit on evolution may still not be prepared for successful evolution instruction. A 2005 questionnaire revealed that 52% of Minnesota biology professors admitted that they do not equip their undergraduate students to teach evolution effectively (Wiles &

Branch, 2008). The evolution topics Sickel et al. (2013) recommends science teachers understand include the role of mutations in variation, mechanisms of evolution, microevolution, macroevolution, and evidence for evolution. Unfortunately many pre-service teachers have misunderstandings which need to be detected before they begin teaching because instructors will inevitably teach their alternative conceptions (Rice, Clough, Olson, Adams, & Colbert, 2015; Nadelson, 2009; Sickel & Friedrichsen, 2013; Smith, 2010). Alternative conceptions include the idea that a species chooses to evolve by natural selection, that biological evolution is a random process, that evolution is not observable, and that minimize the length of time for evolution to occur (Nadelson, 2009; Rice et al., 2015; Sickel & Friedrichsen, 2013; Smith, 2010; University of California Museum of Paleontology, 2019). Evolutionary biology must be taught to pre-service teachers because research shows that evolution knowledge and educational background leads to greater acceptance, preference for, and confidence in teaching evolution (Groβschedl et al., 2014; Mead & Branch, 2011; Rice et al., 2015; Sickel & Friedrichsen, 2013).

Second, promoting acceptance of evolution based on scientific evidence should be included in the preparation of pre-service teachers. Acceptance of evolution includes both macroevolution and microevolution. Nadelson and Southerland (2019) define "microevolution as the biological changes within a [species] population over the short term", and define macroevolution as "essentially the outcome of evolution over the long term that results in the development of new species or 'broader taxonomic grouping'" (p. 1640). Worldwide, one-third of K-12 teachers do not accept evolution or are undecided, and most who reject it, only reject macroevolution while they will accept microevolution (Sickel & Friedrichsen, 2013; Wilbur & Withers 2015). While it can be possible for a teacher who holds to a literal interpretation of the Bible to teach evolution well, research shows teacher's religious convictions and acceptance of

creationism can create obstacles when teaching evolution (Groβschedl et al., 2014; Rice et al., 2015; Sickel & Friedrichsen, 2013; Tekkaya et al., 2012). There is a large number of teachers who believe evolution should not be included in the curriculum or should be taught in conjunction with creationism, but it is important for instructors to differentiate between religious belief and scientific knowledge (Groβschedl et al., 2014; Sickel & Friedrichsen, 2013). Pre-service teachers should accept evolution before they enter the classroom.

Third, pre-service teachers need an accurate understanding of the nature of NOS. Like the lack of evolution courses for high school teachers, 67% of secondary science instructors have never had a course about the NOS (Wilbur & Withers, 2015). Yet teaching that evolution is a theory requires a sufficient understanding of NOS (Nadelson, 2009; Sickel, 2013; UCMP, 2019). The epistemological status of a theory according to the NOS, and in contrast to the daily use of the word "theory", must be internalized by pre-service teachers (Groβschedl et al., 2014; Nadelson, 2009). The term "theory" as used in science is a well-developed, scientifically accepted, evidenced-based explanation (Nadelson, 2009). Sickel et al. (2013) suggests that teachers should be taught proper scientific inquiries, verifiability and tentativeness of scientific knowledge, and the scientific definition of the word "theory". Many evolution education researchers suggest that NOS and evolution be taught together because some research shows a correlation between understanding the NOS and acceptance of evolution (Groβschedl et al., 2014; Sickel, 2013; Tekkaya et al., 2012).

Fourth, not only do pre-service teachers need to accept evolution, they need to understand both ineffective and effective pedagogy for evolution instruction including how to approach controversy with students (Oliveira, Cook, & Buck, 2011; Tekkaya et al., 2012). Pre-service teachers should develop strategies for how to talk to people with differing views on evolution,

and be aware of the relevant cases that have disputed evolution and creationism in the classroom (Sickel & Friedrichsen, 2013; Wiles & Branch, 2008). One way of handling controversy with religious students is providing examples of religious people who accept evolution to demonstrate that evolution and religion deal with different realms: a natural and supernatural world (Applegate & Stump 2016, UCMP, 2019). Showing the compatibility of evolution and religion can increase acceptance of evolution. In addition to handling controversy, they should know the content standards they are required to teach and be trained in the aspects of pedagogical content knowledge which includes curriculum, assessments, learners, instructional strategies, appropriate instructional time, classroom environment, and instructor partiality (Oliveira et al., 2011; Sickel & Friedrichsen, 2013; Tekkaya et al., 2012). Sickel and Friedrichsen (2013) explain further that a teacher's knowledge of the learner means that he or she anticipates difficulties and alternative conceptions students will have. The goal of neutral impartiality is for the teacher to have the choice not share their stance on evolution with their students. Committed paritiality also occurs when instructors freely share their stance (Oliveira et al., 2011). In conclusion, a successful pre-service biology program would teach evolutionary content knowledge, provide comprehensive curriculum on the NOS, help teachers accept evolution, and demonstrate pedagogical strategies including managing controversial topics in the evolution classroom.

High school science teachers have not been prepared or assessed properly on their ability to teach evolution, and some may have negative attitudes toward evolution that are contributing to the low acceptance rate of Americans. Successful evolution teaching strategies have been identified and pre-service biology requirements have been established but empirical data is needed to measure if pre-service biology teachers in 2019 are properly prepared to teach evolution. Nadelson (2009) recommends "further investigation into the multifaceted nature of

preparing preservice teachers to teach evolution" (Nadelson 2009). Nadelson's study showed that continued research is needed to find the most effective ways of increasing preservice teacher knowledge and the ability to integrate content into meaningful lessons on evolution.

As previously stated Sickel and Friedrichsen's (2013) study showed pre-service biology teachers need to develop pedagogical content knowledge (PCK). This study will define PCK as the teacher's "ability to integrate content into meaningful lessons on evolution". A meaningful lesson is defined as creating a lesson that meets national standards, addresses student alternative conceptions, and incorporates a plan to handle controversy the teacher may face when teaching evolution.

Research questions

1) To what extent are new secondary science teachers (from preservice up to two years of credential completion) prepared to teach evolution as measured by (a) content knowledge, (b) acceptance of evolution, and (c) pedagogical content knowledge?

2) What thoughts do new secondary science teachers have about the interaction of evolution and religion? Do they have any unresolved issues when teaching evolution?

Methods

Study site and participants

This research was intended to have 30 participants complete a 47 question survey on a google form that would take approximately 30-45 minutes. Eligible participants were either currently enrolled in a single subject credential program or have completed a credential program within the last two years. Participants were informed about the survey through the credential programs at two large public universities and one small Christian university in Southern California. In addition, over 600 teachers in public middle schools and high schools across Southern were emailed to participate. After two months of data collection only 28 teachers completed the questionnaire from all the participants that were invited to participate. Eight of the total participants were interviewed face-to-face.

Research design

The research design used a mixed-methods approach and study was conducted in accordance with Point Loma Nazarene University's Institutional Review Board's guidelines. The study began with a quantitative questionnaire for all of the participants, followed by scoring the questionnaire with the rubric (Table 2) which lead to selecting participants to be interviewed. The original intent was to interview teachers who showed a low preparedness per the

questionnaire. The interview would identify their thoughts about the interaction of evolution and religion, and identify possible unresolved issues when teaching evolution. Figure 1 was the original method for choosing participants to be interviewed and "low preparedness" was defined by less than a three average on the questionnaire rubric (Table 2). Those who scored the lowest on the questionnaire were asked to participate in the interview via email and were told "I found your questionnaire to be one of the most interesting and I am requesting to interview you to gather more information." The low response to interview request resulted in all participants being asked to be interviewed as seen in Figure 2.

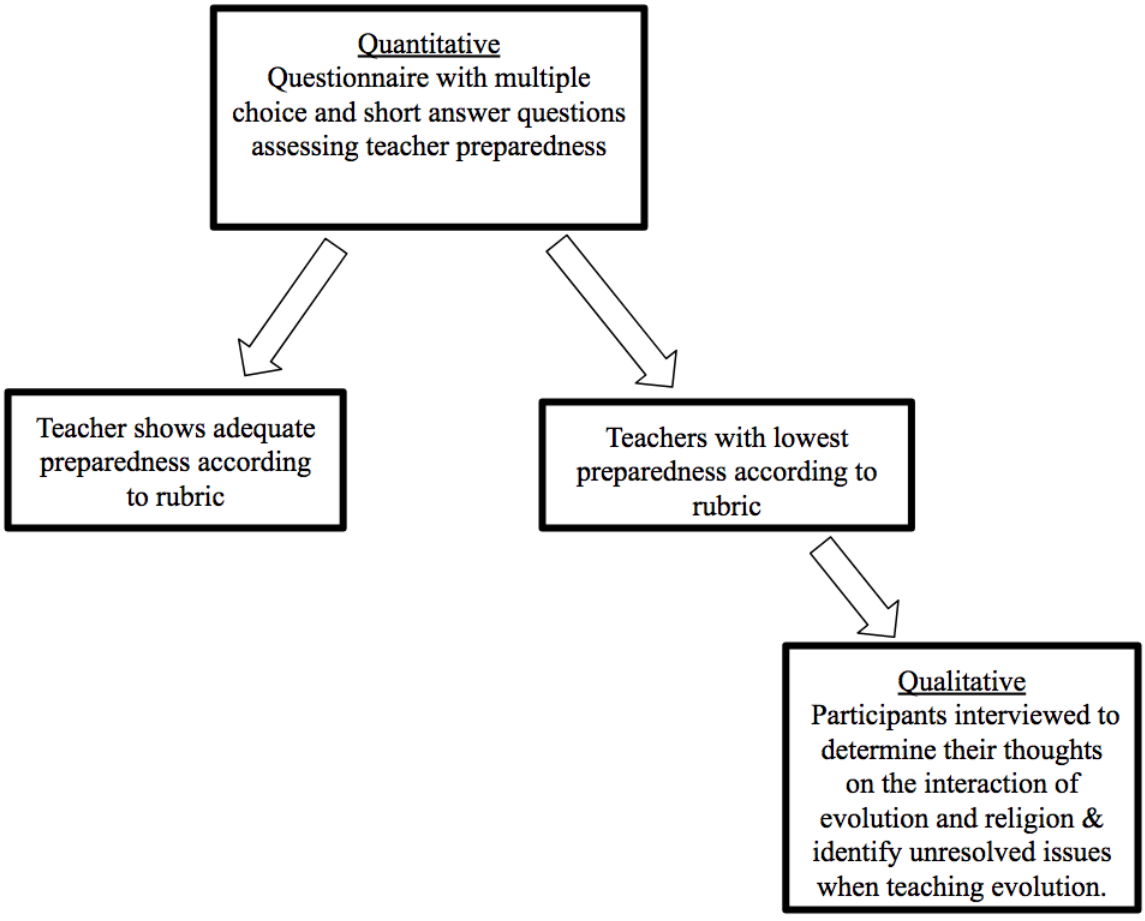


Figure 1. *Original Mixed Methods Research Design*

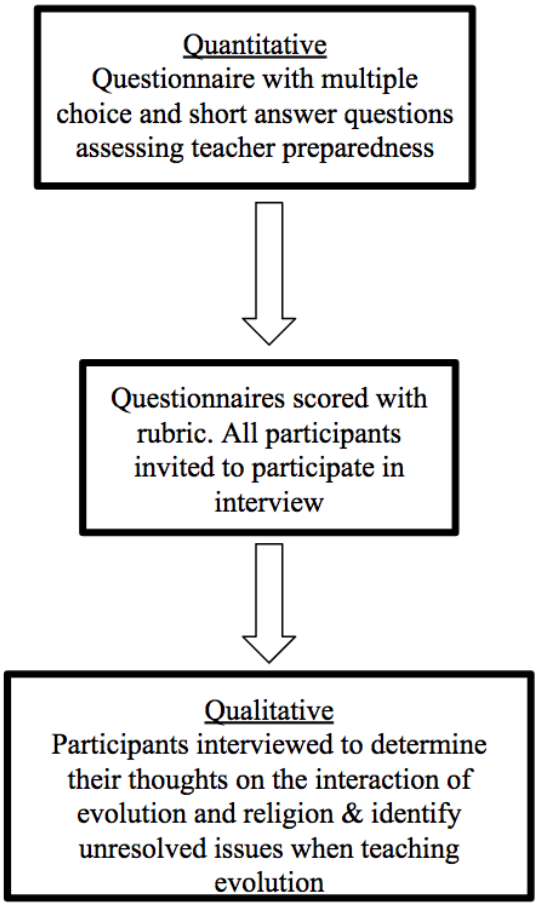


Figure 2. *Actual Mixed Methods Research Design*

Questionnaire data collection. Each participant received a $10 amazon gift card for their participation. The questionnaire was composed of demographic questions, multiple choice questions, and free response questions (Appendices A-E). Table 1 gives the rationale behind each part of the questionnaire. The questions assessed pre-service and new secondary science teachers on their knowledge of evolution (both micro- and macro-evolution), their knowledge of the NOS, acceptance of evolution, and pedagogical content knowledge relating to evolution instruction. Pedagogical content knowledge assessment was built from Sickel and Friedrichsen's (2013) research that considered pre-service teachers as being prepared in pedagogy by their knowledge of evolution curriculum, standards, assessment, knowledge of learners (and where

they may struggle), and instructional strategies. Data on their evolution knowledge and NOS understanding was used to answer question 1a of the research questions for this study. Data on acceptance of evolution was used to answer question 1b of the research question for this study. Data from their lesson plan was used to answer question 1c for this study.

Table 1

Questionnaire components and rationale

Questionnaire Component	**Description**	**Rationale**
Demographics	Age, gender, religion, name of credential program, progress in the credential program, level of education, completion of an evolution course and undergraduate major.	Obtain demographics of pre-service teacher
CINS (Concept Inventory of Natural Selection)	Ten question multiple choice questions	Measures microevolution content knowledge (Research Question 1a)
MUM (Measure of Understanding of Macroevolution)	Ten multiple choice questions	Measures macroevolution content knowledge and understanding of the nature of science (Research Question 1a)
I-SEA (Inventory of Student Acceptance of Evolution)	Twenty-four Likert scale questions	Measures the acceptance of microevolution, macroevolution, and human evolution (Research Question 1b)
Lesson Plan	Free response questions to create an evolution lesson plan	Measures the pedagogical content knowledge (Research Question 1c)

Demographic questions included age, gender, religion, name of credential program, progress in the credential program, level of education, undergraduate major, subject and grade level intending to teach, and three questions from a religiosity scale (Cohen et al., 2008). The Concept Inventory of Natural Selection (CINS), a twenty question multiple choice test, was used to assess understanding of natural selection (Evans & Anderson, 2013). Only ten of the questions were used on the questionnaire to minimize survey fatigue (See Appendix B for questions).

Knowledge of macroevolution was assessed by the Measure of Understanding of Macroevolution (MUM) (Nadelson & Southerland, 2010). MUM is a twenty-seven question multiple choice survey and one free response question that tests evolutionary understanding of deep time, phylogenetics, speciation, and fossils. Ten multiple choice questions from the MUM were chosen for this study to assess deep time, phylogenetics, speciation, and fossils (See Appendix C for questions). Teachers' NOS was assessed by MUM since it includes multiple choice questions that capture participant understanding of NOS (Mead et al., 2019). The Inventory of Student Acceptance of Evolution (I-SEA), a twenty-four question Likert scale, created by Nadelson & Southerland (2019) was used to measure the acceptance of microevolution, macroevolution, and human evolution (See Appendix D for questions). These three topics were chosen because Nadelson and Southerland (2019) found microevolution is generally accepted, whereas macroevolution and human evolution have low acceptance rates with human evolution having the lowest acceptance. The I-SEA seeks to identify the tipping point for individuals who oscillate between accepting microevolution and rejecting the other two categories. The last part of the questionnaire was created from both Nadelson (2009) and Sickel and Friedrichson (2013) and asked participants to create a lesson plan for teaching evolution (Appendix E) to assess their pedagogical knowledge. The CINS, MUM, I-SEA and lesson plan all seek to answer research question 1 to measure participants' content knowledge, evolution acceptance, and pedagogical understanding.

The rubric to score each component for preparedness can be found in Table 2, and the use of the rubric will be discussed in the Data Analysis section. I created this rubric in order to assess each category Sickel and Friedrichsen (2013) listed for which pre-service teachers should be prepared.

Table 2

Preparedness Rubric for Teachers

Assessment	**5**	**4**	**3**	**2**	**1**
CINS	90-100% correct on multiple choice	80-89% correct on multiple choice	70-79% correct on multiple choice	60-69% correct on multiple choice	Below 60% correct on multiple choice
MUM	90-100% correct on multiple choice	80-89% correct on multiple choice	70-79% correct on multiple choice	60-69% correct on multiple choice	Below 60% correct on multiple choice
I-SEA Microevolution	5 Average on Likert Scale	4 Average on Likert Scale	3 Average on Likert Scale	2 Average on Likert Scale	1 Average on Likert Scale
I-SEA Macroevolution	5 Average on Likert Scale	4 Average on Likert Scale	3 Average on Likert Scale	2 Average on Likert Scale	1 Average on Likert Scale
I-SEA Human Evolution	5 Average on Likert Scale	4 Average on Likert Scale	3 Average on Likert Scale	2 Average on Likert Scale	1 Average on Likert Scale
Lesson Plan	Exceptional understanding of evolution standards Exceptional understanding of knowledge of learners Exceptional understanding of evolutionary instructional strategies Includes an exceptional plan to handle controversy.	Understands evolution standards Understands knowledge of learners Understands evolutionary instructional strategies Includes plans to handle controversy.	Some understanding of evolution standards Some understanding of knowledge of learners Some understanding of evolutionary instructional strategies Includes a plan to handle controversy but is somewhat unclear.	Very little understanding of evolution standards Very little knowledge of learners Very little knowledge of evolutionary instructional strategies Includes a plan to handle controversy but it is very unclear.	No understanding of evolution standards No knowledge of learners No evolutionary instructional strategies listed Does not include a plan to handle controversy.

Interview data collection. The interview sought to answer research question 2, "What thoughts do new secondary science teachers have about the interaction of evolution and religion? Are there any unresolved issues when teaching evolution?" This qualitative data collection included interview questions and a quantitative religiosity scale. After analyzing data from Part I, eight participants agreed to be interviewed. All interviews were conducted via facetime and recorded. Each interviewee received a $20 amazon gift card for their participation in the 30 minute interview.

Interviewees introduced themselves by first name, credential program, progress in credential program, location of teaching assignment, grade level, and number of years teaching. Following their introduction, Task 1 asked participants four open-ended questions to discuss their evolution acceptance and the personal conflicts they may have experienced when first learning about evolution. These questions were adapted from Barnes and Brownell, (2016) and Griffith and Brem (2004), and I used them in my pilot study research (Appendix H). This task provided background information about the extent to which the teacher had resolved any personal conflicts with evolution.

Research has shown an association between content knowledge, acceptance, and religiosity (Barnes & Brownell, 2018; Pew, 2013; Sickel & Friedrichsen, 2013;Smith, 2009; Wilbur & Withers, 2015). Therefore, Task 2 of the interview began with the nine-item Religiosity Scale from Cohen, Shariff, and Hill (2008). Participants responded to questions on a five-point scale with one representing "strongly disagree" and five "strongly agree" (Appendix H). Religiosity is determined by a one reflecting the "least religious" and a five the "most religious".

Task 3 required participants to identify concerns they have when considering teaching evolution in the classroom. They read eight statements and commented on the statements they were concerned about that may cause a potential conflict (Appendix H). The statements related to external conflicts included fear of criticism from administration, students, religious authorities, community members, and past legal battles (Griffith & Brem, 2004). Internal conflicts were identified by having the participant read the following statements: "I am concerned about negative responses from a religious authority or parent that might occur when teaching students evolution" and "I have concerns about teaching evolution because of my religious beliefs", and then asked to explain what they thought about those statements.

Task 4 investigated participants' beliefs about the compatibility of God and evolution. Barnes and Brownell (2016) compiled five statements to determine compatibility, and the participants were asked to put them in order from "most represents their personal beliefs" to "least likely represents their personal belief" about human evolution and God (Table 4). This task explored the idea that incompatibility between evolution and religion contributes to rejection of human evolution (Barnes & Brownell, 2016; Barnes and Brownell, 2018; Pobiner, 2016; Smith, 2009).

Task 5 asked clarifying questions about how participants answered the questionnaire to further understand their conflict and potential effect on their evolution instruction.

Table 3

Interview components and rationale

Task	**Description**	**Rationale**
Task 1 - Open-Ended Questions	Four open-ended questions for participants to discuss their first experience with evolution evolution acceptance, personal conflicts they may have between religion and evolution, and an evolution lesson that would make them feel uncomfortable..	Explores the development of the participants' personal conflict with evolution. Begin to identify specific conflicts that would affect their evolution lesson.
Task 2 - Religiosity Scale	9 question Likert scale	Provides level of religiosity to compare with level of content knowledge and acceptance.
Task 3 - Internal and External Conflicts	Participants read statements and comment their thoughts and feelings behind on the potential conflict when teaching evolution.	Participants will identify conflicts that may affect their evolution instruction.
Task 4 - Compatibility of God and Evolution	Participants will put five statements in order from "most represents their personal beliefs" to "least likely represents their personal belief" about human evolution and God	Investigate participants' belief about compatibility of God and evolution to further understand their personal conflict with evolution
Task 5 - Clarification from Quantitative Assessment	Participants will be asked clarifying questions about questionnaire questions they scored low on	Investigate the reasoning behind answers from questionnaire to further understand personal conflict with evolution

The interview tasks are listed in Table 3. The score for each of the nine questions in Task 2 was averaged and participants were rated with a five as "most religious" and a one as "least religious" (Cohen et al., 2018). The rest of the responses for the interview were transcribed and coded (Table 4) by external and internal conflicts (Table 5), compatibility of God and evolution, and repeated terms used (Griffith & Brem, 2004; Mananghas, 2017).

Table 4

*Compatibility Statements of God and Evolution (*Barnes, M. E., & Brownell, S. E., 2016).

Task	Statement	Compatibility
1	Human beings have evolved over billions of years from older life-forms, and God guided this process.	Compatible
2	Human beings have evolved over billions of years from older life-forms, and God started this process but did not intervene after	Compatible
3	Human beings have evolved over billions of years from older life-forms, and God was not involved in this process.	Incompatible
4	Human beings have evolved over billions of years from older life-forms, and I do not know whether or not God had anything to do with this process.	Unsure of Compatibility
5	God created human beings more or less in their present form.	Incompatible

Quantitative Data Analysis

The rubric (Table 2) was applied to each questionnaire completed with each category receiving a score from one to five. The 10-question CINS was scored by finding the percent of correct answers. The 10-question multiple choice MUM is designed to score a one for a correct answer, a zero for an incorrect answer, and then calculate the percent correct (Nadelson & Southerland, 2010). The 24-question I-SEA measures acceptance of evolution with a Likert scale that determines a one as “strongly disagree” and five as “strongly agree”. The score on the Likert scale for the 27 questions was averaged, and aligned to the rubric. For example, if a participant averages a four on the Likert scale, a four was given to the participant on the preparedness rubric as well. If the average resulted in a decimal, the number was rounded to the nearest whole number. Also, as mentioned previously, they suggest a pre-service teacher should be equipped with strategies to handle difficult issues that come up when teaching a controversial topic like evolution. The lesson plan prompt (Appendix E) was scored according to the suggestions of

Sickel et al. (2013) with a five representing "exceptional understanding of the listed strategies" and a one as "no understanding of the strategies" (Table 2). The three categories on the lesson plan rubric were averaged to give each participant a score on "level of preparedness for teaching evolution".

Since I created the lesson plan assessment and rubric, further explanation of how the lesson plans were scored is needed. I scored each of the questionnaires according to the rubric (Table 2). In order to verify the rubric and scoring, another grader was provided with the questionnaires, rubric, and explanation of how to use the rubric. This grader coded 10 of the interviews. We then compared scores and changes were made to the rubric until each questionnaire score had a difference of less than 0.25.

Participants were asked to create a lesson plan for a sophomore college prep biology lesson that meets the Next Generation Science Standard, HS-LS4-1, which states, "Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence". The lesson plan was divided into three questions on the questionnaire and three sections on the rubric. The first question evaluated the participants' knowledge of the standard and the ability to plan an activity that meets the standard. The question stated: "Briefly describe an activity you would use to teach the HS-LS4-1 standard and explain your reasoning for choosing the activity". Exceptional understanding of evolution standards (five on the rubric) included at least one of the four evidences of evolution (embryology, comparative anatomy i.e. homologous or analogous structures, molecular biology, or fossils) and an activity that corresponds with that evidence. A clear explanation of the reasoning behind how the activity met the standards was required to receive a five. Understanding evolution standards (four on the rubric) was earned by providing one of the four

lines of evidence of evolution and choosing an activity that corresponds but does not give an explanation for how the activity meets the standard. Some understanding of evolution standards (three on the rubric) was earned with an activity such as the use of a cladogram (phylogenetic tree) which does show common ancestry but is no longer taught as part of the standards. Very little understanding of the evolutionary standards (two on the rubric) was earned if the activity taught about evolution, but not the common ancestry or evidence of evolution. For example, if participants taught only natural selection or survival of the fittest, this would be deemed "very little understanding" because their activity is not meeting the standard. In addition, if the participant gave no detail, they would also earn a two on the rubric. For example, a one word answer with no explanation would be "very little understanding of the evolutionary standards." No understanding of evolution standards (one on the rubric) was used if the activity had nothing to do with evolution or evolution is not mentioned. For example, if the participant had students dissecting frogs with no other explanation.

The second question addressed the participants' knowledge of learners in the lesson plan and stated "List possible misunderstandings you anticipate students may have about this topic and describe how you would address each possible student misunderstanding". The University of California Museum of Paleontology (2019) lists common misconceptions students may have. These include, evolution is 'just' a theory, evolution occurs in one lifetime, humans do not evolve, species are not related, evolution is not science because its not observable or testable, evolution is invalid, gaps in the fossil record disprove evolution, and evolution and religion are incompatible. Exceptional understanding of knowledge of learners (five on the rubric) was earned if at least two of these alternative conceptions were provided by the participant. Understanding of knowledge of learners (four on the rubric) was earned if one of these

conceptions was provided by the participant. Some understanding of knowledge of learners (three on the rubric) was earned if the participant did not give one of the listed conceptions but they did include at least two valid alternative conceptions based on their lesson that did not align with the standards. For example, if the participant's lesson focused on Darwin's birds beaks (that does not meet the standard) and the participant listed a misconception that the birds' chose to change their beaks, this would result in a three on the rubric. The reason is that while this is a common alternative conception for natural selection, it does not mention the alternative conceptions students have about common ancestry. Very little knowledge of learners (two on the rubric) would provide one valid misconception of evolution that does not align with common ancestry. No understanding of learners (one on the rubric) was earned if the participant did not provide a misconception or provided a misconception that does not have to do with evolution.

The third question sought to gain an understanding of participants' plan to handle controversy when teaching evolution. The prompt stated: "Briefly describe how you would handle a controversy that came up with administration, parents, students, or community members, that may occur from teaching this evolution lesson." In order for a participant to score an "exceptional plan" (five on the rubric), at least two of the following strategies was listed: explains the nature of science as it applies to evolution, refers to the state standard that is required to be taught, or refers to evolution as a scientific fact and not a religion. In order for a participant to score a four on the rubric, at least one strategy listed above would be provided. In order to score a three on the rubric, the participant would provide a strategy in detail, but not one of the listed strategies. In order to score a two on the rubric, the participant would provide a strategy, but not one of the listed strategies and the details of the plan are vague. In order to score a one on the rubric, the participant would not provide any strategies.

All participant questionnaires were scored and an average of their preparedness according to the rubric was calculated.

Qualitative data analysis

All interview coding is provided in Table 5. In Task 1, the four open ended questions were coded. In Task 2, the results for the religiosity scale were averaged. For Task 3, conflicts were categorized and the number of conflicts for each participant were totaled. Next, the compatibility of God and religion in Task 4 was coded by the statement participants chose as the one that best described their belief. Lastly, repeated words or ideas were compiled.

Table 5

Interview Coding Schemes

Grouping Code	Subcode
Level of Schooling when first learned about evolution	Elementary High School College Never learned about evolution in school
Learning environment of first exposure to evolution	Formal Setting Informal Setting Never Discussed
Religion discussed when you learned about evolution	Yes No
Worldview Conflicts with evolution and religion	Yes No
Uncomfortable evolution lesson	Any evolution topic Common ancestry lesson linking humans and primates One that would make religious students uncomfortable Other
Conflicts	Parents Admin Students Religious authority Community Legal battles Self- Condemning Religious Beliefs
Compatibility of God and Evolution	Compatibility of God and Evolution Incompatibility of God and Evolution Unsure of compatibility of God and Evolution

Results

Demographic data of participants

Demographic information for all participants who completed the survey including age range, gender, progress in credential program, completion of scientific method course in a credential program, completion of an evolution course, credentialed subject, highest level education level and undergraduate major is recorded in Table 6. While over 600 pre-service or in-service teachers who have been teaching for less than two years were invited to participate in the study, after one month of data collection, only 28 participants completed the questionnaire. Two participants, Participant 8 and Participant 16, could not be included in the data analysis because they did not meet the target demographic for this study, as they had taught more than two years or were not intending to teach science. Of the remaining 26 participants, (21 female and five male participants), eight were ages 18-24, 15 were 25-34, two were 35-44, and one was over 55. Eight were currently enrolled in a credential program, 11 have completed the program within the last year, and seven had completed the program within the last two years. The majority of participants had completed a scientific methods course (19 participants) in a credential program while seven had not. Sixteen had taken a course on evolution, five had not, and five answered that they were unsure. While all were secondary science teachers, 21 were credentialed in biology, three in chemistry, one in Earth Science, and one in STEM (Science, Technology, Engineering, Math). Nineteen participants currently teach or intend to teach high school and seven middle school. Fifteen of the participants' highest education level is a bachelor's degree and 11 had their Masters. Undergraduate majors were predominantly in the science field (17 biology and five non-biological science), followed by arts and humanities (three participants) and psychology (one participant). Table 6 also provides participants' religious

identification with five participants identified as agnostic, two as atheists, 12 as catholics, one as a muslim, two as protestant/evangelical, and four as protestant/other. Participants were asked to respond to the statement, "My religion or faith is an important part of my identity". Six participants strongly agreed, eight agreed, five were neutral, six disagreed, and one participant strongly disagreed. Participants were also asked to respond to the statement, "I attend religious services at least once per month". Ten participants strongly agreed, one agreed, one was neutral, four disagreed, and 10 strongly disagreed.

Table 6

Demographic Data

	Subcategory	Percent
Age Range	18-24	30%
	25-34	58%
	35-44	8%
	Over 55	4%
Gender	Female	81%
	Male	19%
Progress in Credential Program	In Progress	31%
	Completed within the last year	42%
	Completed within the last two years	27%
Completed a scientific method course	Yes	73%
	No	27%
Completed a college evolution	Yes	62%
	No	19%
	Unsure	19%
Credentialed Subject	Biology/Life Science	85%
	Chemistry	12%
	Earth	4%
	STEM	4%
Grade Level	Middle School	27%
	High School	73%
Highest Education Level	Bachelor's	58%
	Masters	42%
Undergraduate Major	Biology	65%
	Non-biological Science	19%
	Arts & Humanities	12%
	Psychology	4%

	Subcategory	Percent
Religion	Agnostic	19%
	Atheist	8%
	Catholic	46%
	Muslim	4%
	Protestant/Evangelical	8%
	Protestant/Other	15%
Religion is an important part of identity	Strongly Agree	23%
	Agree	31%
	Neutral	19%
	Disagree	23%
	Strongly Disagree	4%
Attends religious service at least once per month	Strongly Agree	39%
	Agree	4%
	Neutral	4%
	Disagree	15%
	Strongly Disagree	39%

Research question 1

Question 1 asked: To what extent are new secondary science teachers (from preservice up to two years of credential completion) prepared to teach evolution as measured by (a) content knowledge, (b) acceptance of evolution, and (c) pedagogical content knowledge?

Preparedness to teach evolution was determined by content knowledge, acceptance, and pedagogy. The CINS and MUM were used for content knowledge, I-SEA for acceptance of evolution, and pedagogy was determined via a lesson plan. The surveys (CINS, MUM, I-SEA) were scored based on the recommendations of the instrument authors, and a total score for each individual test was calculated. There are no 'norms' for these measures, therefore means, standard deviations, and maximum and minimum scores for each survey was calculated (see Table 7). Each data collection category score was then reduced to a five-point scale by the author for easier comparison between categories (Appendix F).

Quantitative results for question 1a

Question 1a focuses on the preparedness as measured by evolution content knowledge. As previously stated, the Conceptual Inventory of Natural Selection (CINS) used to measure content knowledge of microevolution and Measure of Understanding of Macroevolution (MUM) was used to measure macroevolution. An important factor that would affect content knowledge scores is if the participant's completion of a course included more than 25% evolution content. Sixty-two percent of the participants completed an evolution course, 19% had not, and another 19% were not sure (Table 6). The average CINS score was 3.03 (out of 5) with a standard deviation of 1.6. The average MUM score was 3.88 (out of 5) with a standard deviation of 1.4 (See Figure 3 for a histogram of the scores). In Table 8, a Spearman correlation coefficient

shows a weak and indirect association between the completion of an evolution course and both the CINS and MUM ($r_s(25) = -.34$

Table 7

Questionnaire results. Averages are listed with the standard deviations in parentheses.

		Content Knowledge		Acceptance of Evolution			Pedagody
Participant	Progress in Credential Program	CINS	MUM	ISEA Micro	ISEA Macro	ISEA Human	Lesson Plan
P1	In Progress	5	5	4.75	4.75	4.63	2.67
P2	Completed in the last year	2	5	4.38	3.5	3.5	3.17
P3	In Progress	5	4	4.25	4.63	3.25	4
P4	Completed within the last two years	3	5	5	5	5	4.67
P5	In Progress	1	4	2.63	2.88	3.38	3.67
P6	In Progress	1	2	4.25	4.5	4.13	4.33
P7	Completed within the last year	2	1	4	3.88	3.5	3.67
P9	In Progress	1	2	3.25	3.63	3.38	2.67
P10	Completed in the last year	3	5	5	5	5	3.33
P11	Completed within the last two years	1	1	4.38	3.75	3.63	2.33
P12	Completed within the last two years	1	2	4	2.5	3.13	2.33
P13	Completed in the last year	5	5	4.88	4	4	4
P14	Completed within the last two years	3	3	4.88	4.63	4.75	4
P15	Completed in the last year	4	4	4	3.63	4.5	3
P17	Completed in the last year	5	5	4.38	4.13	4.13	4.67
P18	Completed within the last two years	5	4	5	4.5	4.75	4
P19	In Progress	3	5	4.13	4.75	5	3.67
P20	Completed in the last year	2	5	5	5	5	3.33
P21	Completed in the last year	4	5	5	4.75	4.5	3.33
P22	Completed within the last two years	5	5	5	3.5	4.25	3
P23	Completed in the last year	2	5	4.63	3.88	4.75	2.67
P24	Completed within the last two years	3	3	5	4.75	5	3.33
P25	Completed in the last year	1	5	5	4.75	5	3.33
P26	In Progress	2	3	5	4.63	4.5	3.67
P27	Completed in the last year	5	5	4.5	3.75	3.63	4.33
P28	In Progress	5	3	4	3.88	3.5	3
	Average	3.04 (1.6)	3.88 (1.4)	4.47 (0.6)	4.18 (0.7)	4.22 (0.7)	3.47 (0.7)

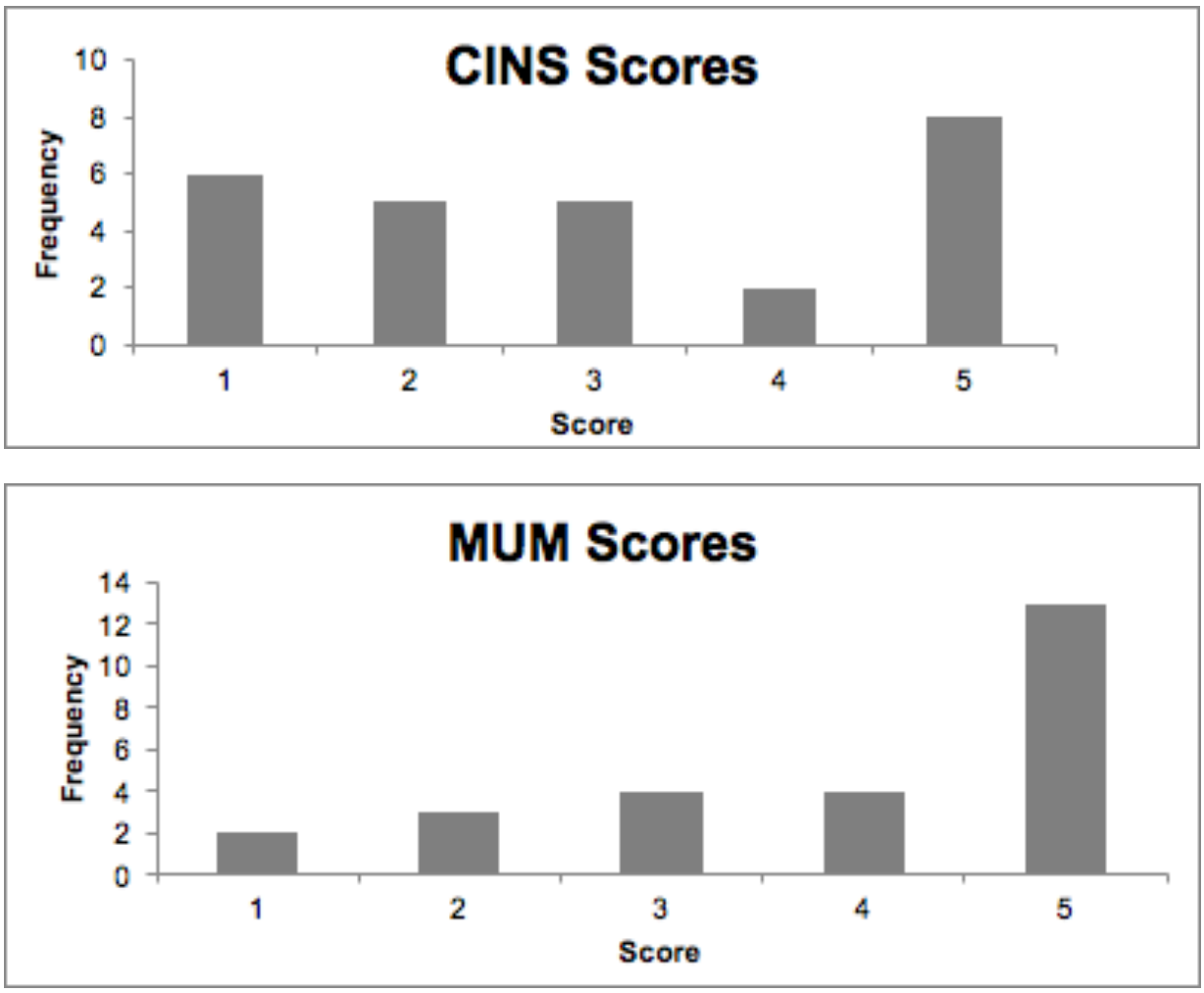


Figure 3. *Content knowledge scores*

Table 8

Participants' Evolution Background and Content Knowledge with Spearman Correlation

Participant	Evolution Course	Major	Content Knowledge	
			CINS	MUM
P1	Yes	Human Evolutionary Biology	5	5
P2	No	Social Psychology	2	5
P3	Yes	Biochemistry	5	4
P4	No	Microbiology	3	5
P5	I'm not sure	Chemistry	1	4
P6	I'm not sure	Human Biological Science	1	2
P7	Yes	Liberal Arts—bio/health	2	1
P9	Yes	Communication	1	2
P10	Yes	Biochemistry	3	5
P11	I'm not sure	Criminal Justice	1	1
P12	No	Biological Sciences	1	2
P13	Yes	Marine Biology	5	5
P14	Yes	Biology	3	3
P15	Yes	Biology	4	4
P17	Yes	Genetics	5	5
P18	No	Exercise Science	5	4
P19	Yes	Human Biology	3	5
P20	Yes	Chemistry	2	5
P21	Yes	Biology-Chemistry	4	5
P22	Yes	Biology-Chemistry	5	5
P23	Yes	Biology	2	5
P24	I'm not sure	Biochemistry	3	3
P25	Yes	Biology	1	5
P26	No	Agriculture Science	2	3
P27	I'm not sure	Biology	5	5
P28	Yes	Biology	5	3

Spearman correlation

Questionnaire Responses (n=26)	Dependent Variable	*Independent Variable(s)*	*r(s)*	*p-value*
	Evolution Course	CINS	-0.34	0.09
		MUM	-0.34	0.09

Quantitative Results for Question 1b

Question 1b focuses on preparedness as measured by acceptance of evolution. As previously stated, the I-SEA is broken up into three categories: microevolution, macroevolution, and human evolution. The lowest score, a 1, shows the least acceptance and the highest score, 5, shows full acceptance of evolution. The average score of the I-SEA microevolution was 4.47 with a standard deviation of 0.6. The average score of the I-SEA macroevolution was 4.18 with a standard deviation of 0.7. The average score of the I-SEA human evolution was 4.22 with a standard deviation of 0.7.

A valid religiosity measurement was not used on the questionnaire, however the survey asked for a response to this statement, "I attend religious services at least once per month". In Table 9, the "practice religion" column shows those results with answers ranging from strongly agree to strongly disagree. This particular category was chosen as a measure of one's religiosity because when examining the results, those with minimal or no faith (atheist and agnostic) were represented by disagree or strongly disagree, and those who do profess a faith agreed or strongly agreed. For the purpose of determining variables that lead to acceptance of evolution, correlations were run practice of religion and evolution content knowledge. Table 10 shows the Spearman correlation coefficients between the I-SEA Macroevolution and Practice Religion, the completion of an evolution course and I-SEA Macroevolution, MUM and I-SEA Macroevolution, and the CINS and I-SEA Microevolution. The only associations were strong negative correlations between the I-SEA Macroevolution and the Practice of Religion ($r_s(25)=-0.69$, $p<0.001$) and I-SEA Human evolution and the practice of religion ($r_s(25)=-.75$, $p<0.001$) showing both associations to be statistically significant.

Table 9

Participants' Religion and Acceptance of Evolution

Participant	Religion	Faith is identity	Practice religion	ISEA Macro	ISEA Micro	ISEA Human
P1	Atheist	Strongly	Strongly disagree	4.75	4.75	4.63
P2	Protestant/Other	Agree	Strongly agree	3.5	4.38	3.5
P3	Protestant/Other	Agree	Strongly agree	4.63	4.25	3.25
P4	Atheist	Agree	Strongly disagree	5	5	5
P5	Catholic	Strongly agree	Strongly agree	2.88	2.63	3.38
P6	Catholic	Agree	Disagree	4.5	4.25	4.13
P7	Protestant/Other	Agree	Strongly agree	3.88	4	3.5
P9	Catholic	Strongly agree	Strongly agree	3.63	3.25	3.38
P10	Agnostic	Neutral	Strongly disagree	5	5	5
P11	Catholic	Disagree	Disagree	3.75	4.38	3.63
P12	Protestant/Evangelical	Strongly agree	Strongly agree	2.5	4	3.13
P13	Catholic	Strongly agree	Strongly agree	4	4.88	4
P14	Agnostic	Disagree	Strongly disagree	4.63	4.88	4.75
P15	Catholic	Neutral	Strongly disagree	3.63	4	4.5
P17	Agnostic	Neutral	Strongly disagree	4.13	4.38	4.13
P18	Agnostic	Neutral	Strongly disagree	4.5	5	4.75
P19	Muslim	Disagree	Strongly disagree	4.75	4.13	5
P20	Agnostic	Disagree	Strongly disagree	5	5	5
P21	Protestant/Other	Agree	Strongly disagree	4.75	5	4.5
P22	Protestant/ Evangelical	Strongly agree	Strongly agree	3.5	5	4.25
P23	Catholic	Agree	Agree	3.88	4.63	4.75
P24	Catholic	Disagree	Disagree	4.75	5	5
P25	Catholic	Disagree	Neutral	4.75	5	5
P26	Catholic	Neutral	Disagree	4.63	5	4.5
P27	Catholic	Agree	Strongly agree	3.75	4.5	3.63
P28	Catholic	Strongly agree	Strongly agree	3.88	4	3.5

Table 10

I-SEA Spearman Correlation Coefficients. Significant associations (p<.05) are noted with an asterisk (*).

	I-SEA Micro	*I-SEA Macro*	*I-SEA Human*
CINS	0.25		
Practice Religion		-0.69*	-0.75*
Evolution Course		0.24	
MUM		0.35	

Quantitative results for question 1c

Question 1c focuses on preparedness as measured by pedagogical content knowledge. As previously stated, pedagogical content knowledge was determined by the participant's ability to create a lesson that is aligned with state science standards, addresses students' alternative conceptions of evolution, and includes strategies to address a potential controversy that may occur when teaching evolution. The Next Generation Science Standard HS-LS4-1 was provided for the participant in the lesson plan prompt: "Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence". The lesson plan average for all participants was 3.47 (out of 5) with a standard deviation of 0.66. See Figure 4 for the frequency of lesson plan scores for all participants. Of the three lesson plan categories scored, meeting the standard had an average score of 3.37 with a standard deviation of 1.09, addressing alternative conceptions had an average of 3.42 with a standard deviation of 0.90, and addressing potential controversy had an average of 3.53 with a standard deviation of 1.02.

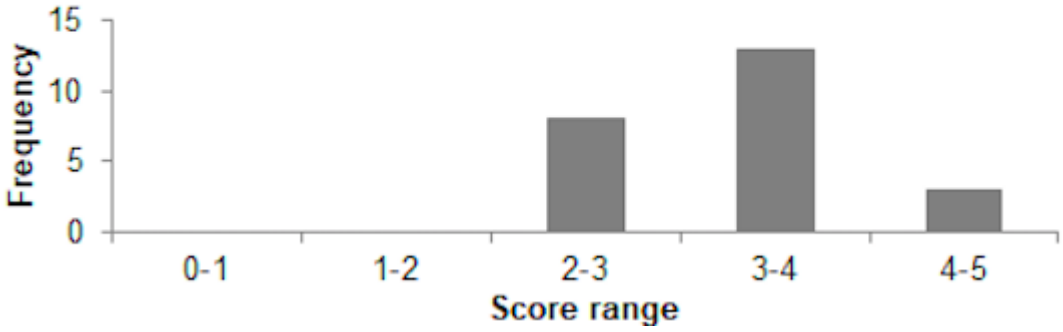


Figure 4. *Pedagogy scores*

Lesson plan scores were graded by the rubric for the three categories listed above and averaged. According to Table 11, the highest lesson plan score was 4.67 achieved by Participant 4 and Participant 17. Participant 4's lesson plan, for example, scored a 5 on meeting standards, 5 on addressing student's alternative conceptions, and a 4 on strategies for controversy for an average score of 4.67. In the science standards category, the lesson written by Participant 4 received a five because it demonstrated an exceptional understanding of evolution standards, evidenced by providing at least one of the four evidences of evolution (embryology, comparative anatomy, molecular biology, or fossils) and provided the reasoning behind the lesson. Participant 4 stated,

> "I would have the students look at hand x-rays of various animals and try to identify the various functions. This would address the homologous structures line of evidence for evolution. I would have them analyze DNA sequences and map animals with similar DNA as another line of evidence. To engage in the fossil record students can sort fish bones based on their strata layer. Lastly I would play guess the embryo to show students how most life begins as a similar form then differentiates. This would be a week and a half-2 week sequence to address this NGSS standard. I would give a performance task asking the students to use these lines of evidence to communicate their understanding of evolution." (sic)

Notice in the quote above the mention of examining homologous structures with hand x-rays satisfies the comparative anatomy line of evidence, analyzing DNA sequences satisfies the molecular biology line of evidence, the sorting fish bones activity satisfies fossils as a line of evidence, and the "Guess the Embryo" game satisfies embryology.

Second, in the alternative conceptions category, Participant 4's lesson received a 5 because it showed exceptional understanding of knowledge of learners by providing two common naive conceptions and a strategy to address those. Participant 4 stated,

> "Students sometimes think each animal was individually created. They also find it hard to grasp that we are evolving over many generations. I let my students know they can believe whatever they want to believe, but in our science class we aren't looking through a belief lens, we are looking at the world through a scientific lens. Where we only talk about and teach things that are proven facts that have been researched and extensively proven to be true by scientists. I stress the difference between change (how we grow from a baby to adult) from evolution which happens over millions of years. I provide lots of visuals and examples." (sic)

Two common alternative conceptions were included in the lesson explanation above. The first common alternative conception was that humans do not evolve evidenced by "students sometimes think each animal was individually created". The second is evolution occurs in one lifetime evidenced by "they also find it hard to grasp that we are evolving over many generations". The mention of two alternative conceptions resulted in this lesson receiving a score of 5 in the alternative conception category.

Lastly, if a participant gives two examples of common research-based strategies for teaching evolution, this was coded as a 5, showing an exceptional understanding of addressing

controversy. Participant 4's lesson scored a 4 for controversy because only one common research-based strategy was listed. Participant 4 stated, "Just like I tell my students, I would reiterate to the family that we only teach scientifically accepted content and their belief is valid but it is a separate topic from science." Research has shown that one successful strategy dealing with controversy is to refer to evolution as a scientific fact and not a religion (Barnes & Brownell, 2018).

Participants 4 and 17 scored the highest score on the lesson plan, while Participant 11 and 12 scored the lowest with a 2.33 (Table 11). Participant 11's lesson plan scored a 1 on meeting standards and a 2 on student's alternative conceptions. The lesson plan scored a 1 on meeting standards because understanding of the evolution standard was not shown through the four lines of evidence of evolution. Participant 11 stated, "I would introduce different scientists and their different theories." The lesson plan received a 2 on student's alternative conceptions because a valid naive conception of evolution was provided but was not associated with common ancestry--the topic aligned with the Next Generation Science Standard listed. Participant 11 said, "The information I am presenting [on evolution] is based on my (personal) opinion and beliefs." This statement does not provide specific evidence that the participant is aware of alternative conceptions that would deter students from learning the state standard dealing with common ancestry. Participant 11 scored a high score of 4 on controversy so Participant 12's low score of a 2 will be explained. Participant 12 stated,

> "You are teaching Science, just like a parent has the right to not have there child exposed to sex education; they too can choose to not have their child exposed to the lesson of what true evolution is. In both cases the parents are doing their children an injustice in today's society. for it seems to keep our children naïve or ignorant is what the educational

systems wants; theirs is a political agenda, not a true educational one." (sic)

Participant 12 does list a strategy of giving parents the option of opting their student out of the evolution lesson, but it is not one of the research-based strategies.

Table 11

Participants' credential information, evolution background, and lesson plan score

Participant	Progress in Credential Program	Scientific Method Course	Evolution Course	Lesson Plan
P1	In Progress	Yes	Yes	2.67
P2	Completed within the last year	Yes	No	3.17
P3	In Progress	Yes	Yes	4
P4	Completed within the last two years	Yes	No	4.67
P5	In Progress	Yes	I'm not sure	3.67
P6	In Progress	No	I'm not sure	4.33
P7	Completed within the last year	Yes	Yes	3.67
P9	In Progress	No	Yes	2.67
P10	Completed in the last year	Yes	Yes	3.33
P11	Completed within the last two years	No	I'm not sure	2.33
P12	Completed within the last two years	Yes	No	2.33
P13	Completed in the last year	Yes	Yes	4
P14	Completed within the last two years	Yes	Yes	4
P15	Completed in the last year	No	Yes	3
P17	Completed in the last year	Yes	Yes	4.67
P18	Completed within the last two years	No	No	4
P19	In Progress	No	Yes	3.67
P20	Completed in the last year	Yes	Yes	3.33
P21	Completed in the last year	Yes	Yes	3.33
P22	Completed within the last two years	Yes	Yes	3
P23	Completed in the last year	Yes	Yes	2.67
P24	Completed within the last two years	Yes	I'm not sure	3.33
P25	Completed in the last year	Yes	Yes	3.33
P26	In Progress	Yes	No	3.67
P27	Completed in the last year	Yes	I'm not sure	4.33
P28	In Progress	No	Yes	3

A multiple regression was performed to see if taking an evolution course or science methods course can predict how well one would perform on the lesson plan ($\hat{y}$ = -0.27326X1(evo course) + 0.12612X2(methods course) + 3.61602). A backward stepwise method was used to produce an initial screening of the predictors. The R square for the regression equals 0.029, meaning that evolution course and a science methods course only explain 2.9% of the variance of Y. The coefficient of multiple correlation (R) equals 0.170079. This shows there is a weak direct relationship between the lesson plan score and either course. In addition, a Spearman correlation was run to assess the association between content knowledge scores and lesson plan scores as well as evolution acceptance scores and lesson plan scores. All associations were weak and insignificant (Table 12).

Table 12

Spearman correlation with lesson plan scores, content knowledge, and evolution acceptance

	Dependent Variable	*Independent Variable(s)*	*r(s)*	*p-value*
Questionnaire Responses (n=26)	Lesson Plan Score	CINS	0.3	0.13
		MUM	0.18	0.39
		I-SEA MICRO	0.19	0.36
		I-SEA MACRO	0.34	0.09
		I-SEA HUMAN	0.15	0.47

Response to research question 2

Of the 26 participants, the 12 that scored the lowest on overall preparedness across the categories were invited to be interviewed. As was the problem with the questionnaire, teachers were not responding to the invitation. After two weeks with a very low response rate, all 26 participants were then invited to be interviewed. Pertinent demographics of the eight interviewees as well as their questionnaire scores are provided in Table 13.

Table 13

Interview participants' demographics and scores

					Content Knowledge		Acceptance of Evolution			Pedagody
Interviewee	Progress in Credential Program	Number of Years Teaching	Religion	Religiosity	CINS	MUM	ISEA Macro	ISEA Micro	ISEA Human	Lesson Plan
P2	Completed in the last year	2	Protestant/ Other	3.44	2	5	3.5	4.38	3.5	2.5
P6	In Progress	0	Catholic	3.11	1	2	4.5	4.25	4.13	3.75
P7	Completed in the last year	2	Protestant/ Other	4.44	2	1	3.88	4	3.5	4
P15	Completed in the last year	3	Catholic	3.22	4	4	3.63	4	4.5	3
P18	Completed within the last two years	2	Agnostic	1.44	5	4	4.5	5	4.75	3.75
P20	Completed in the last year	3	Agnostic	1.67	2	5	5	5	5	3.5
P26	In Progress	2	Catholic	2.88	2	3	4.63	5	4.5	3.75
P27	Completed in the last year	3	Catholic	3.89	5	5	3.75	4.5	3.63	4.25

Qualitative results for research question 2a

Question 2a asked: What thoughts do new secondary science teachers have about the interaction of evolution and religion? Upon completion of the interview, the participants' answers were coded as described in the methods section. Surprisingly, 87.5% of the interviewed participants stated that they currently did not have a worldview conflict between evolution and religion. Many participants did not view evolution and religion (E&R) to be in opposition. Participant 20 stated, "It is possible for the two [E&R] to reconcile". While most stated that they did not have a conflict, their rationale behind their views varied. For example, some saw E&R working together. Participant 27, a Catholic with a 3.89 religiosity score, reconciled E&R because, "He (God) started it and then science took over after that." Some other participants did not see a conflict between E&R because they doubt the existence of God. Participant 18 who scored a 1.44 on the religiosity index said, "There's just lacking any kind of evidence with God." Only one participant viewed E&R in contention, but argued that both topics have valid

arguments. Participant 6 said, “You can’t really disprove religion altogether, but you can't really disprove biology altogether either…. I like to believe my religion, but at the same time, a lot of what science and evolution and biology say ‘well that's not how it went down’. But at the same time, it's hard to like lose faith in something you believe most of your life.” While Participant 6 is the exception, most of those interviewed were not conflicted about the interaction of evolution and religion, even though the average religiosity score of all participants was 3.01 with a standard deviation of 1.07.

To further investigate if any prior worldview conflict between E&R had been resolved through a formal or informal educational setting, participants were asked: “Was religion discussed when you learned about evolution?” (Table 14). Seventy-five percent of the participants agreed that religion was discussed when studying evolution in a formal classroom setting.One participant, Participant 15, has never discussed E&R in a formal classroom (Figure 5A). The other participant, Participant 20, had heard evolution discussed at length at the informal setting of her church. “Guest speakers [were invited] to come [to my church] and do evolution debates and [my church’s] stance is that evolution is not sound doctrine. And so I grew up hearing that evolution was not an acceptable theory.” Of the participants who did experience evolution and religion in a formal classroom setting, 33% experienced it in high school class while 67% did not experience the E&R interacting until the collegiate classroom (Figure 5B).

Three participants stated that they saw a conflict between their religious beliefs and evolution during their biology course in high school. Participant 27 said,

> “I’ve been religious my whole life and in high school doing my catechism studies with my church, I remember going to biology, and there being this topic of evolution and me just questioning so bad because obviously there’s like scientific evidence to back up what

[evolution] is saying. I didn't know how to handle that. It did not necessarily question my faith, but it made me question this whole science background and question evolution". Participant 20 also had a personal conflict with E&R in high school. She was part of a Christian club and the club discussed how "it made us uncomfortable to cover evolution in school". She felt "disingenuous and lacking integrity" when she would answer open-ended questions on evolution exams because she would give right answers, but she did not personally agree with the expected answers. Participants gave examples of classroom situations when evolution and religion were discussed together that were initiated by students and instructor. For example, Participant 18 took a science teaching course at a conservative university and said "[E&R] was a topic we discussed and how students are able to take their religious beliefs, and, you know, allow them to work within their scientific paradigm." On the other hand, Participant 20, in response to the question, "Was religion ever discussed in your formal education classroom?" responded "Definitely by students, definitely by me [when I was a student]." Whether initiated by students or by instructors, 88% of participants had a learning experience where evolution and religion were discussed even though only 25% experienced these two topics during their *first* exposure to evolution (Table 14). Participant 6 stands out because she was the only interviewee to currently have a worldview conflict and she first learned about evolution in middle school. While she did discuss E&R in college, this never occurred in any of her science classes. It was not until she took a college philosophy course that E&R were brought up. She stated, "We talked about how people would view [evolution] with points of view from both ends, like believing in God and from science backgrounds." (sic). Like Participant 6, three other participants have only discussed evolution and religion in a non-science classroom in college.

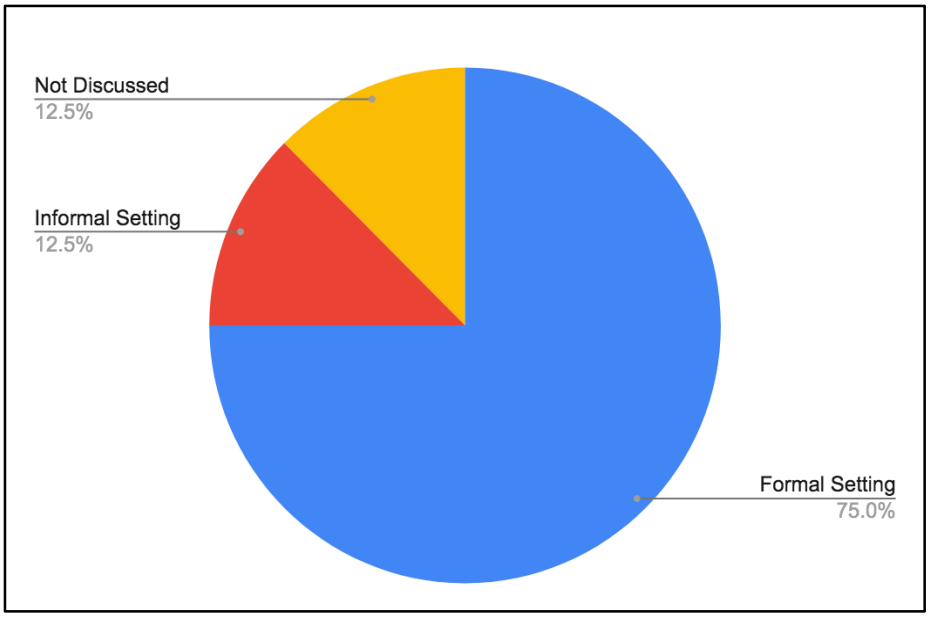


Figure 5A. *Type of learning environment for first exposure to evolution*

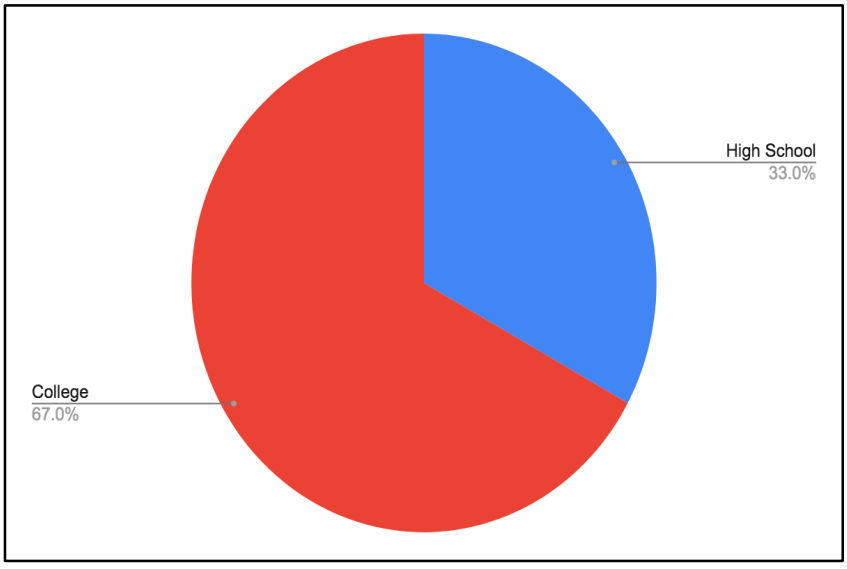


Figure 5B. Grade level of first exposure to evolution

Table 14

Exposure to evolution and religion

Participant	Worldview Conflict	When did you first learn about evolution?	Was religion discussed when you first learned about it?	Type of setting when participant first discussed evolution and religion	Quotes
P2	No	High School	No	Formal - College Science Methods Course	"I had a professor that taught science courses for education, like how we teach education. This topic [of evolution and religion] came up and then we had this discussion."
P6	Yes	Middle School	No	Formal - College Philosophy Course	"It was a philosophy class and we talked about how people would view [evolution] with points of view from both ends, like believing in God and from science backgrounds."
P7	No	High School	No	Formal - College Theology Course	"I had to write a paper on [evolution and religion] in one of my theology classes at a Christian college. I wrote the paper about God's creating and evolution and how they work together."
P15	No	College	No	Never Discussed	"When they talked about evolution, religion was never discussed that I remember."
P18	No	Elementary	No	Formal - College Science Methods Course	"In my scientific teaching course [evolution and religion] was a topic we discussed and how students can take their religious beliefs and, you know, allow them to work within their scientific paradigm."
P20	No	High School	Yes	Informal - Church Conferences	"Guest speakers [were invited] to come [to my church] and do evolution debates and [my church's] stance is that evolution is not sound doctrine. And so I grew up hearing that evolution was not an acceptable theory."
P26	No	High School	Yes	Formal - High School Biology	"Students brought it up...the teacher said 'this isnt necessarily trying to disprove religion'...and I think thats what kind of made students kind of be able to see it was acceptable to be both religious and believe in science."
P27	No	High School	No	Formal - College Science Course	"In college, in a discussion, a peer said "yes these are things thaty may have happened and these are possible answers to this but I think God created those answers for that."

Next, participants were asked to rank statements that best describe their beliefs about the compatibility of God and evolution to further understand their thoughts (Appendix F). Figure 6 shows that 50% of the interviewees were unsure about the role of God in evolution because they chose the statement, "Humans have evolved over billions of years and I do not know if God had anything to do with this process" as the statement that best represented their personal belief. Twenty-five percent of interviewees believed that evolution involved God by choosing the statement, "God created humans more or less in their present form" as the statement that best describes their belief. And 25% of interviewees believed that evolution and God are integrated because they chose the statement, "Humans have evolved over billions of years and God started this process but did not intervene after."

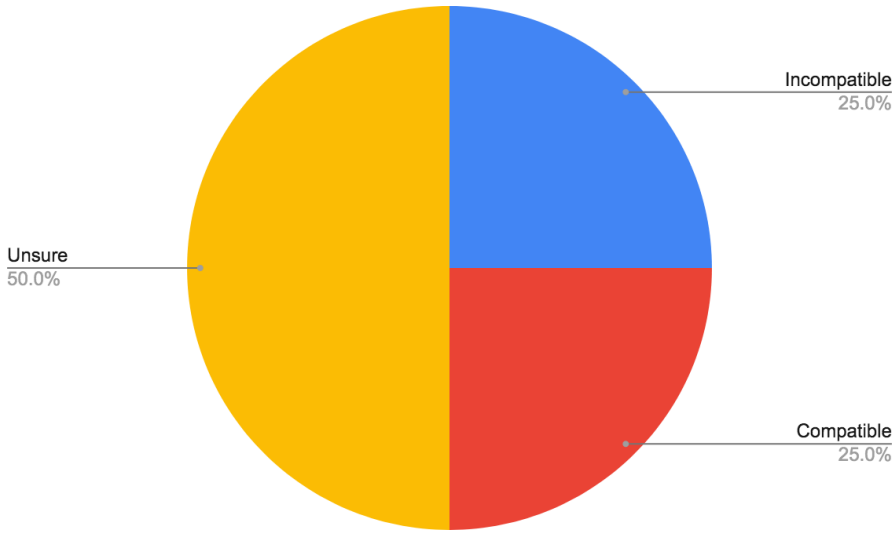


Figure 6. *Participants' perceived compatibility of God and evolution*

Finally, to determine science teachers' thoughts on the interaction of acceptance of evolution and religion, a Spearman correlation analysis was performed between participants' scores for the I-SEA human evolution and the Compatibility between God and Evolution score (Table 15). The Spearman correlation shows a strong, significant positive association between

the interviewees' acceptance of human evolution (I-SEA Human) and compatibility of God and evolution ($r_s(7)=0.74$, $p < .05$). Another Spearman correlation indicated a strong significant negative association between acceptance of human evolution (I-SEA Human) and religiosity ($r_s(7)= -.89$, $p < 0.005$). Finally, the result of a Spearman correlation showed a strong significant negative correlation between the compatibility of God and Evolution and the participants' religiosity ($r_s(7)=-0.93$, $p<.001$).

Table 15

Spearman correlation of I-SEA Human, Compatibility of God and Evolution, and Religiosity

	ISEA Human	*Compatibility of God and Evolution*	*Religiosity*
ISEA Human	1		
Compatibility of God and Evolution	0.74*	1	
Religiosity	-0.89*	-0.93*	1

Significant associations are noted with an asterisk (*).

Qualitative results for research question 2b

Question 2b asked: Are there any unresolved issues when teaching evolution? Participants were given seven statements showing common teacher conflicts when teaching evolution (Appendix F). They were asked to read each statement and comment on which statement they felt was true. Results are displayed in Table 16.

Table 16

Conflicts and questionnaire scores

		Questionnaire Scores					
Interviewee	Number of Conflicts	CINS	MUM	ISEA Macro	ISEA Micro	ISEA Human	Lesson Plan
P2	3	2	5	3.5	4.38	3.5	2.5
P6	2	1	2	4.5	4.25	4.13	3.75
P7	2	2	1	3.88	4	3.5	4
P15	1	4	4	3.63	4	4.5	3
P18	1	5	4	4.5	5	4.75	3.75
P20	7	2	5	5	5	5	3.5
P26	3	2	3	4.63	5	4.5	3.75
P27	2	5	5	3.75	4.5	3.63	4.25

Table 17 shows each conflict with the percentage of interview participants that currently had that conflict. Twenty five percent of interviewees selected only one conflict when teaching evolution, 38% chose two conflicts, 25% chose three conflicts, and one participant chose seven conflicts. The most commonly chosen statement (87.5% of participants) was, “I think about negative effects from students during class when teaching students evolution”. The conflicts chosen the least were internal conflicts pertaining to personal religious convictions, possible legal ramifications, and fear of potential conflicts with community members.

Table 17

Types of conflicts

Conflict	Percent of Participants
Students	87.50%
Parents	62.50%
Religious Authority	25%
Admin	25%
Legal	12.50%
Internal Conflict	12.50%
Community	12.50%

In order to determine if numbers of conflicts were associated with evolution understanding, evolution acceptance, or preparedness to teach evolution as measured by their lesson plan design, a Spearman's correlation was performed (Table 18). Results showed that the number of conflicts were weak to moderately correlated, but none showed statistical significance.

Table 18

Spearman correlation analysis effect of number of conflicts on questionnaire scores

	Dependent Variable	Independent Variable(s)	r(s)	p value
Interviewed Participants' Response (n=8)	Number of Conflicts	CINS	-0.54	0.17
		MUM	0.32	0.44
		ISEA Macro	0.38	0.35
		ISEA Micro	0.41	0.31
		ISEA Human	0.01	0.99
		Lesson Plan	-0.22	0.61

To further assess conflicts while teaching evolution, participants were asked, "Can you give me an example of an evolution lesson that could make you feel uncomfortable?" (Figure 7). Unexpectedly, 37.5% said that any evolution lesson makes them uncomfortable because of their

lack of knowledge in the topic, yet the majority (67%) who answered in that way had taken an evolution course. Participant 7 stated, “It would be hard for me to tell them and try to convince them and get them to understand something I don’t fully understand.” Participant 15 added, “It is hard for kids to grasp that certain animals have certain traits in common that makes them all related...and I’m definitely not an expert in it.” Twenty-five percent of the interviewees agreed that they would be uncomfortable with a lesson that teaches common ancestry between humans and primates. Participant 27 said, “A lesson that would make me uncomfortable is one that teaches kids we came from monkeys” because of the difficult questions students would ask. Participant 26 stated, “I’d get some students asking a question ‘are we related to them [monkeys] or not’...and if i took a stand on that, that we are genetically related to primates...I think I’d probably get some [phone] calls.” Since this was not an intervention study, corrections were not provided to the participants, they were simply asked to explain their rationale behind their answer. Twenty-five percent said that any evolution lesson would make them feel uncomfortable because they don’t want to make religious students uncomfortable. Participant 20 said, “I would hate to like, misspeak on something and then have them feel like it’s an attack on their belief system.” (sic) Only one teacher, Participant 18, stated that other issues would make him uncomfortable:

> “Something that would make me feel uncomfortable is probably something about sexual orientation. You know, kids like to think that there's some kind of genetic connection there that’ll explain [sexual orientation] evolutionarily. And that would make me uncomfortable. I also, racial stereotypes would also make me uncomfortable. For evolution being a foundation for that. I mean, I guess if you look at some, you know, racial groups, very racist groups, you know, I just think about like, you know, white

supremacy groups. Oh, the top of my head thinking certain people act certain ways and that's in their genes". (sic)

While Participant 18's response may be extreme, all participants said they could think of a lesson that would make them uncomfortable.

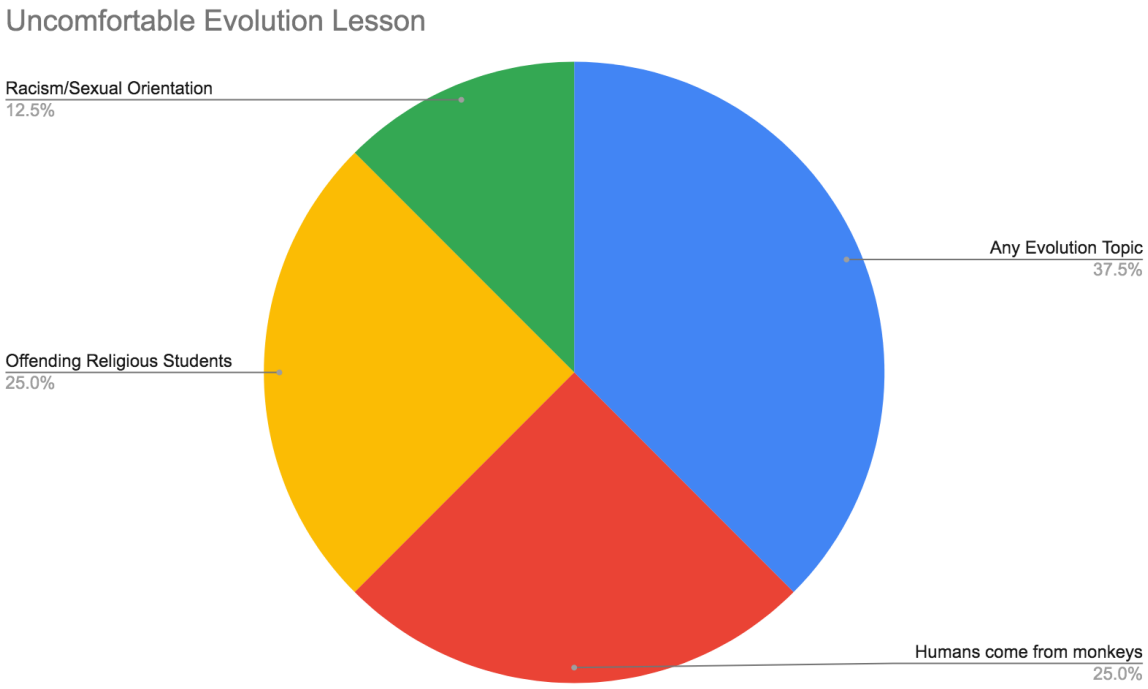


Figure 7. *Uncomfortable evolution lessons*

As mentioned previously, the first question asked of the interviewees was, "Do you personally experience any worldview conflict with evolution and religion." Table 19 compares their initial answer with the final question of the interview where they stated their personal belief about evolution and religion. This data is complicated by the fact that their responses to various questions about compatibility are inconsistent. Participants 2 and 15 initially stated that they did not have a worldview conflict between evolution and religion, but later in the interview stated they believed that God and evolution were incompatible. Both participants chose "God created human beings more or less their present form". Contrasting with the theory of evolution,

Participant 2 said, “I don't think that human beings evolved over billions of years from older life forms at all.” Participant 2 had an I-SEA Human score of 3.5 which means she is neutral toward her acceptance of human evolution, but her quote shows that she disagrees with human evolution. Additionally, her statement that she does not have a worldview conflict with evolution and religion is negated by the fact that she does not believe humans evolved but she does believe God created humans in their present form. Similar to Participant 2, Participant 15 stated, “I believe God created everything...it reminds me of Adam and Eve. Adam and I are kind of like in the same mold I want to say.” This is inconsistent because Participant 15 had a 4.5 I-SEA Human score which means she agrees with human evolution, yet her quote shows that she does not believe humans have evolved. Participant 6 stated that she had a worldview conflict and is unsure of the compatibility of God and evolution. She chose the statement, “Human beings have evolved over billions of years from older life-forms, and I do not know if God has anything to do with this process.” Participant 7 and Participant 27 said they did not have a worldview conflict and chose a statement with God and evolution compatible: “Human beings have evolved over billions of years from older life-forms, and God started this process but did not intervene after.” Participant 7 added, "God was involved in the process at the beginning...but then he gave Adam and Eve freedom...and from then on He was like 'figure it out.’" Likewise, Participant 27 said, "He started it and then science took over after that." Participants 18, 20, and 26 do not currently have a worldview conflict and chose the statement that is unsure if God and evolution are compatible. Participant 18 said, “They are lacking any kind of evidence with God. [Being] brought up Jewish...I do question how it all started...it's just kind of overwhelming so that's why I say I'm not sure." Participant 20 said, "I don't feel like I have a strong opinion one way or the other about the existence of God. I don't think God was necessarily an essential component [in

evolution]". Participant 26 took a neutral stance: "I feel like not knowing if God has anything to do with this gives me a platform to stand on. If I were to admit that [God was not involved in the process] then I'm going to upset the religious folks." In summary, 25% had initially stated that they did not have a worldview conflict with E&R, but later chose a statement of belief that reflected God and evolution are not compatible. One participant stated she had a conflict and answered that she was unsure about the compatibility of God and evolution. The remaining participants said they did not have a conflict and chose a compatible or unsure statement.

Table 19

Participants' initial answers to "Do you personally experience any worldview conflicts between evolution and religion?" to their belief of their compatibility between God and Evolution.

Participant	Worldview Conflict	Compatibility of God and Evolution	Compatibility of God and Evolution Statement Chosen	Quote
P2	No	Incompatible	God created human beings more or less in their present form.	"I don't thnk that human beings evolved over billions of years from older life forms at all."
P6	Yes	Unsure	Human beings have evolved over billions of years from older life-forms, and I do not know if God had anything to do with this process	"I do not know if God had anything to do with this process because you cant really disprove religion altogether, but you cant really disprove biology all together either."
P7	No	Compatible	Human beings have evolved over billions of years from older life-forms, and God started this process but did not intervene after	"God was involved in the process at the beginning...but then he gave Adam and Eve freedom...and from then on He was like 'figure it out.'"
P15	No	Incompatible	God created human beings more or less in their present form.	"I believe God created everything...it reminds me of Adam and Eve. Adam and I are kind of like in the same mold I want to say."
P18	No	Unsure	Human beings have evolved over billions of years from older life-forms, and I do not know if God had anything to do with this process	"They are lacking any kind of evidence with God. [Being] brought up Jewish...I do question how it all started...it's just kind of overwhelming so that's why I say I'm not sure."
P20	No	Unsure	Human beings have evolved over billions of years from older life-forms, and I do not know if God had anything to do with this process	"I don't feel like I have a strong opinion one way or the other about the existence of God. I don't think God was necesarily an essential component [in evolution]"
P26	No	Unsure	Human beings have evolved over billions of years from older life-forms, and I do not know if God had anything to do with this process	"I feel like not knowing if God has anything to do with this givees me a platform to stand on. If I were to admit that [God was not involved in the process] then i'm going to upset the religious folks."
P27	No	Compatible	Human beings have evolved over billions of years from older life-forms, and God started this process but did not intervene after	"He started it and then science took over after that."

Unexpected Results

Interviewees were asked questions about religion, but never directly asked about creation. Unexpectedly, six of the eight interviewees brought up "creation" or referenced Adam and Eve during the interview. Coding the responses about creationism, three referred to personal beliefs,

two referred to potential conflicts with students, and one referred to when she learned about evolution and religion in college (Table 20). Personal beliefs surfaced when participants were asked if they had worldview conflicts between E&R and when they were asked to explain their rationale for choosing the statement of compatibility that best described their belief about God and evolution.

Table 20

Participants who mentioned creation in the interview.

Grouping Code	Subcode	Percent	Participant Quote
Creation	Personal Beliefs	37.50%	"I believe at one point there were bacteria, that God created it, but I don't believe that God's all the organisms of creation came from the bacteria." (P7)
	Potential Conflicts with Students	25%	"Some students might be like, 'well what about like Adam and Eve?' and i dont even know how I would explain" (P6)
	Learning about Evolution and Religion	12.50%	"[The paper] was on knowledge and belief and then we had to back it up with evidence. We used evolution and creationism as like a big umbrella because that was just a perfect example." (P2)
	No mention of creation	25%	(no evidence of this from the transcripts)

Conclusion

Research question 1

The first purpose of this study was to measure preparedness of new secondary science teachers (from preservice up to two years of credential completion) in content knowledge, acceptance of evolution, and pedagogical content knowledge based on the goals established by Sickel and Friedrichsen (2013) for preparing pre-service biology teachers. For preparedness in content knowledge, the findings show that the 26 participants had greater content knowledge in macroevolution than microevolution. This is surprising because for one to understand macroevolution, they would need to understand microevolution. These findings lead me to question the accuracy of either the CINS or MUM as a measure of content knowledge. Sixty-two percent of participants had completed an evolution course which is 31% higher completion rate than Wilbur and Withers (2015) had found in their study of post-secondary evolution instructors. Interestingly, completion of an evolution course did not have a significant effect on content knowledge for either microevolution or macroevolution.

Second, when acceptance of evolution was measured, unsurprisingly most participants accepted microevolution. Acceptance of human evolution, however, exceeded macroevolution, which was not expected. While this finding agrees with research showing acceptance of microevolution to be greater than that of macroevolution (Sickel & Friedrichsen, 2013; Wilbur & Withers 2015), it is nevertheless quite surprising that the teachers would have a higher acceptance rate of human evolution than macroevolution. This is surprising because one cannot accept human evolution if he or she does not also accept macroevolution which includes the evolution of one species from another. In fact, the 2013 PEW study showed that 31% of Americans rejected human evolution. Therefore, once again, I am suspicious of the effectiveness

of the I-SEA at measuring macroevolution versus human evolution acceptance. The small sample size may have also contributed to the data showing a higher rate of acceptance of human evolution than macroevolution.

Much of the literature discusses the strong positive relationship between knowledge and acceptance (Groβschedl et al., 2014; Mead & Branch, 2011; Rice et al., 2015; Sickel & Friedrichsen, 2013). My study, however, shows there were weak correlations between content knowledge and acceptance. The CINS showed an average code of three meaning participants scored an average of 70% according to my five point rubric conversion (see Appendix F). The I-SEA microevolution showed an average score of 4.5 on the rubric meaning participants strongly agreed with microevolution. Therefore, a high acceptance of microevolution is not correlated with content knowledge based on the instruments used in this study. Alternatively, the MUM showed an average score of 3.9, meaning participants scored an average of 79% on understanding of macroevolution, but the I-SEA macroevolution showed a lower acceptance with a score of 4.2. This suggests that simply increasing content knowledge will not increase acceptance, as some other studies have shown (Pobiner, 2016). These results suggest that there may be limitations to the effectiveness of the CINS, MUM, and I-SEA, and that acceptance of evolution is a complicated and nuanced topic.

Although there was a weak correlation between knowledge and acceptance, the practice of religion did show a strong negative relationship with both acceptance of macroevolution and human evolution. This confirms the claim that there is a relationship between religion and acceptance as claimed in the 2013 PEW study; religiosity was the primary reason for rejection of evolution in that study.

In regards to pedagogical content knowledge, the intent was to identify any weaknesses in new teachers preparedness to teach evolution, and then to make recommendations for teacher training programs. Three categories were evaluated--science standards, alternative conceptions, and handling controversy--and interestingly, the average score for all categories was similar (approximately 3.4). I will address each category separately. First, a 3.4 in the science standards category denotes the teacher has *some* understanding of evolution standards (See Appendix F for rubric). In the evolution lesson task, participants were asked to briefly describe an activity you would use to teach the HS-LS4-1 standard on evolution and explain their reasoning for choosing the activity. A participant having 'some understanding' would list an activity that met the old California Science Standards but is no longer taught as part of the recently adopted Next Generation Science Standards. An example of this would be a cladogram activity because it does not meet the Next Generation Science Standard, HS-LS4-1, which states, "Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence". I recommend teacher training programs help pre-service teachers clarify and provide activities that are aligned with this standard. NGSS already helps teachers create lessons by providing the disciplinary core idea (DCI) to align activities and these could be used as examples:

> "LS4.A: Evidence of Common Ancestry and Diversity: Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence." (NGSS Lead States, 2013).

For example, teacher training programs could help teacher candidates interpret the standard, find the corresponding DCI, and provide activities that correspond with fossil records, DNA sequences, and amino acid sequences.

In the second category, addressing alternative conceptions, a 3.4 represents that the teacher has some understanding of the knowledge of learners. Having 'some understanding' of what learners know means that the participant did not give one of the listed misconceptions (their term) from University of California Museum of Paleontology (2019). I would recommend teacher credentialing programs include the University of California Museum of Paleontology's (UCMP) misconceptions and corrections of misconceptions in a scientific methods course. A 3 is earned in the category of knowledge of learners if the participant did not give one of the listed misconceptions, but they did include at least two other misconceptions. An example of other misconceptions would be misconceptions about natural selection instead of common ancestry because HS-LS4-1 is about common ancestry. If the participant listed the misconception that students think that Darwin's birds' *chose* to change their beaks, this would result in a 3 on the rubric because it is a valid misconception that students may have, but is not one that students have when learning about common ancestry.

For the last category, handling controversy, a 3.4 represents 'some understanding' meaning that participants did not provide one of the strategies from teaching and learning research such as 1) explaining the nature of science as it applies to evolution, 2) referring to the state standard that is required to be taught, or 3) referring to evolution as a scientific fact and not a religion. I recommend that teacher credential programs have teacher candidates read the literature on suggested ways to handle controversy when teaching evolution and come up with

practical responses they would feel comfortable using with students, parents, and administration (Barnes & Brownell, 2018).

One would expect that taking a methods course would improve pedagogical content knowledge, but the data from the instruments used in this study do not support that. When looking at the correlations for taking an evolution course or methods course, neither were predictive of one's pedagogical content knowledge suggesting that just taking a course is not sufficient to properly prepare someone to teach evolution. In fact, 73% of the 26 participants had completed a scientific methods course and 75% of the eight interviewees had completed a scientific methods course. Yet only one of the interviewees said that their scientific methods course included a discussion about teaching evolution, and "students were able to take their religious beliefs and allow them to work within their scientific paradigm." The other participants who had completed a scientific methods course did not remember the topic of evolution being discussed. It is also interesting to note that the eight interviewees represented six different credential programs, so this appears to be a systemic problem and not an issue with one particular institution.

A study conducted by Groβschedl et al. (2014) found relationships between both content knowledge and pedagogy as well as acceptance of evolution and their preference of teaching evolution. However, this study found only weak relationships between content knowledge and lesson plan scores, and between acceptance of evolution and lesson plan scores (Table 12). Other studies showed a connection between the instructor's acceptance of evolution and their evolutionary pedagogy (Barnes & Brownell, 2016; Mananghas, 2017; Smith, 2009), but my research did not show that relationship.

Research question 2

The second purpose of this study was to conduct interviews to understand the thoughts of secondary science teachers concerning the interaction of E&R, and to uncover any unresolved issues when teaching evolution. All but one of the interviewees stated that they did not have a personal worldview conflict between E&R. Only two of those interviewed said that religion was discussed the first time they learned about evolution, although seven of the eight have discussed E&R in a formal classroom to date. Research shows that students who are religious feel safe if religion is addressed when learning evolution (Barnes & Brownell, 2018). This is relevant to this study because since seven of the eight interviewees had an opportunity to talk about religion when learning about evolution; and this could be the reason why worldview conflicts did not exist for them. There were two outliers in the study that added to the complexity and nuance of understanding the E&R perspectives. All but one participant had experienced evolution and religion in the classroom as a learner, but surprisingly this was not the same person that currently has a conflict between evolution and religion. These two people are anomalies in the sense that one did discuss E&R in the classroom and still had a conflict, while the other had never discussed E&R in the classroom but does not have a conflict.

Research has shown perceived incompatibility between E&R causes Christians to reject evolution (Barnes & Brownell, 2016; Barnes & Brownell, 2018; Lindsay et al., 2019; Pobiner, 2016; Smith, 2009). To assess compatibility, the eight interviewees were given five statements about the compatibility of God and evolution and asked to sort them from “best describes your personal beliefs” to “least describes your personal beliefs” (see Appendix H). The interviewees responses showed a strong positive association between the compatibility of God and evolution,

and the acceptance of human evolution. This supports the claim that acceptance of human evolution increases when the people have a higher belief of the compatibility of God and evolution. The high acceptance rate of the interviewees may be linked to the fact that they discussed E&R in a class and had an opportunity to come to the understanding that the E&R can be compatible. When instructors help students reconcile religion and evolution, demonstrate possible compatibilities, and answer students' questions, students may be more likely to accept evolution (Barnes & Brownell, 2018; Lindsay et al., 2019; Smith & Eve, 2009). Alternatively, this study showed strong negative correlations between religiosity and acceptance of human evolution among those interviewed which is also consistent with the findings from the questionnaire in this study. This means the more religious a person, the lower the acceptance of human evolution and vice versa.

All of this E&R data suggests that a goal for science teacher instruction should include helping religious students come to realize the compatibility of God and evolution which would potentially increase acceptance. The challenge, however, is that this study found that the compatibility between 'God and evolution' and religiosity had a strong negative relationship which means the more religious a person is, the less likely they are to believe E&R are compatible. According to research, one strategy known to help religious students find compatibility is to teach the nature of science, explaining that science is not intended to answer questions about God and that science is based on observed data not personal belief (Barnes & Brownell, 2018; Groβschedl et al., 2014; Nadelson, 2009; Sickel & Friedrichsen, 2013; Smith, 2009). One religious interviewee gave a great example of what this looked like in a classroom and could be duplicated to increase the rate of compatibility.

"[I took an] evolution class and uh, I remember going into the class being very like, no,

> she's not going to convince me, I'm not going to accept evolution. This is ridiculous. [The instructor] had us start out the semester and by discussing like philosophically like why do these two ideas (evolution and religion) have to be at odds with each other. And she had us read a book and they just asked a lot of big questions like, 'Do you think it's possible that God could use evolution as a means of like establishing the world that we, you know, read about the Bible?' and um, things like that. And so she just kind of softened the blow a little bit. Like just because you accept evolution does not mean you have to deny your religious upbringing. Like they can actually reconcile. And so then eventually it just became a lot easier for me to wrap my head around it". (sic)

Demonstrating reconciliation helped this student to "wrap her head around" E&R the two reconciling and could be a strategy to increase compatibility among religious students. Instructors could make statements such as "do you think it's possible God could use evolution?" and "just because you accept evolution does not mean you have to reject your religious upbringing".

Research has shown that personal conflicts instructors have toward evolution can affect their evolution instruction (Griffith & Brem, 2004). My interviewees were given seven conflicts that teachers have had in the past when teaching evolution and asked which conflicts they currently have when teaching evolution. The majority of participants selected no more than three conflicts that they currently have when teaching evolution, with students, parents, and religious authority being ranked as the top three. My study showed that the number of conflicts surprisingly did not affect the lesson plan scores. The source of uncomfortable topics for interviewees were lack of evolutionary content knowledge, common ancestry between humans

and primates, offending religious students, and racism caused by evolution. As stated previously, teacher training programs should include information from UCMP in their curriculum to equip science teachers to be prepared for conflicts that may occur when teaching evolution. For example, the UCMP website addresses the misconception (their wording) that evolution "leads to immoral behavior" such as racism. Their correction to this alternative conception is, "Evolution does not make ethical statements about right and wrong. Some people misinterpret the fact that evolution has shaped animal behavior (including human behavior) as supporting the idea that whatever behaviors are 'natural' are the 'right' ones. This is not the case." (University of California Museum of Paleontology, 2019). This type of information can be helpful for new teachers.

The most interesting finding was discovering inconsistencies when comparing the results of interviewees' initial responses to "Do you have a conflict with religion and evolution?" and the compatibility of God and evolution statements chosen at the end of the interview. Eighty seven percent of interviewees' answered at the beginning of the interview that they did not have a worldview conflict between evolution and religion, but only 25% chose the statement that God and evolution are compatible. This validates the importance of a mixed method approach in asking the same question in different ways and with varying depths. The initial question, "Do you have a worldview conflict between evolution and religion?" was mostly answered by a simple yes or no. Interviewees were asked follow up questions such as "have you ever had a conflict?" or simply asked to explain how they came to that answer. Then, at the end of the interview, participants read five statements about the compatibility of God and evolution, put them in order from "best describes your personal beliefs" to "least describes your personal beliefs", and explained the rationale for why they put the statements in that order. That activity

better revealed participants' worldview. This is an important point because teacher credential programs need to recognize the limitations of using only a survey at the end of the program to determine if teacher candidates have resolved conflicts between evolution and their personal beliefs.

In conclusion, the new teachers in this study were not well prepared to teach evolution in regards to content knowledge and pedagogy. The average evolution content knowledge score was a C which is not adequate because evolution is the foundation of biology. Interviewees even admitted they were insecure about their content knowledge of evolution and admitted that they were "nowhere near" experts on the topic. For pedagogy, participants scored a three average which meant they have *some* understanding of how to teach evolution, but it is limited. Again, if evolution is a cornerstone of biology, then teachers are not serving biology students well if they are only somewhat prepared to teach such a complicated and controversial topic as evolution. These new teachers seemed to be accepting of evolution with a four (out of five) average for the I-SEA in microevolution, macroevolution, and human evolution. A four is interpreted as being in agreement with evolution. This high acceptance rate could potentially be attributed to discussions and assignments in classrooms that include both evolution and religion, as most of them had this opportunity in their past. Therefore, I recommend that teacher training programs include E&R topics in their scientific methods course. As was seen, simply having a scientific methods course is not sufficient unless evolution is one of the foci of the course.

As stated previously, the CINS, MUM, and I-SEA might not have been good measurements but are still the best we have at this time, and I would recommend those instruments to teacher credential programs. It was also very insightful for participants to choose a statement of the compatibility of God and evolution, and identify conflicts as determinants for

acceptance of evolution. The lesson plan instrument showed the participants' weaknesses in preparedness for teaching evolution, so I would recommend having teacher candidates unpack NGSS standards, and use curriculum provided by UCMP to prepare for potential learners alternate conceptions and dealing with controversy.

Limitations

The primary limitation of this study was the small sample size. Conducting the questionnaire at the beginning of the school year limited the number of teachers that were available to conduct the survey.

Contribution to science education and implications for teacher credential programs

The results from this study suggest that teacher credential programs should have a scientific methods course with a unit dedicated to evolution. In this unit, teacher candidates should write lesson plans that are aligned with NGSS HS-LS4-1. The unit should also teach the UCMP's common misconceptions and corrections to those misconceptions. The unit should include the research from Barnes and Brownell (2018) on handling controversy when teaching evolution. Lastly, the compatibility of evolution and religion should be discussed in the evolution unit to aid religious participants in the teacher credential program as well as informing all of the teachers how to teach a lesson on the compatibility of religion and evolution in a biology classroom. Upon completion of the scientific methods course, an evaluation should be conducted in a mixed methods format to ascertain the pre-service teacher's preparedness to teach evolution.

Future studies

An unexpected result from this study was the topic of creation being mentioned by the interviewees during the interviews, although it was not directly asked. Thirty seven percent of participants brought up creation in their interview when they explained their personal beliefs

about evolution. Groβschedl et al. (2014) found that pre-service teachers' acceptance of creationism and content knowledge of evolution determined their pedagogy. My study showed content knowledge did not affect pedagogy. Future studies could survey pre-service teachers on their acceptance of creationism and determine if or how it affects evolution instruction.

References

Applegate, K., & Stump, J. (2016). *How I changed my mind about evolution: Evangelicals reflect on faith and science*. Monarch Books.

Barnes, M. E. & Brownell, S. E. (2018). Experiences and practices of evolution instructors at Christian universities that can inform culturally competent evolution education. *Science Education. 102,* 36–59.

Barnes, M. E. & Brownell, S. E. (2016). Practices and perspectives of college instructors on addressing religious beliefs when teaching evolution. *CBE-Life Sciences Education*, *15*(2), 1–19. doi: 10.1187/cbe.15-11-0243.

Dobzhansky, T. (1973). Nothing in biology makes sense except in the light of evolution. *The American Biology Teacher, 35*(3), 125-129.

Evans, P. & Anderson, D.L. (April 2013). The Conceptual Inventory of Natural Selection a decade later: Development and pilot testing of a middle school version leads to a revised college/high school version. Paper presented at annual meeting of the National Association for Research in Science Teaching (NARST) 2013, Rio Grande, Puerto Rico, April 6-9, 2013.

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.

Griffith, J. A. & Brem, S. K. (2004). Teaching evolutionary biology: Pressures, stress, and coping. *Journal of Research in Science Teaching*, *41,* 791-809. doi:10.1002/tea.20027.

Großschedl, J., Konnemann, C., & Basel, N. (2014). Pre-service biology teachers' acceptance of evolutionary theory and their preference for its teaching. *Evolution: Education and Outreach,7*(1).

Julyan, C. & Duckworth, E. (2005). A Constructivist Perspective on Teaching and Learning Science. *Constructivism: Theory, Perspectives, and Practice*, pp. 61-79. New York: Teachers College Press.

Lindsay, J., Arok, A., Bybee, S. M., Cho, W., Cordero, A. M., Ferguson, D. G., Jensen, J. L. (2019). Using a reconciliation module leads to large gains in evolution acceptance. *CBE—Life Sciences Education*, *18*(4).

Mangahas, A. E. (2017). Perceptions of high school biology teachers in Christian schools on relationships between religious beliefs and teaching evolution, *Journal of Research on Christian Education*, *26*(1), 24-43. doi: 10.1080/10656219.2017.1282902.

Mead, L. S. & Branch, G. (2011). Overcoming obstacles to evolution education: Why bother teaching evolution in high school? *Evolution: Education and Outreach, 4*(1), 114-116.

Nadelson, L. S. (2009). Preservice teacher understanding and vision of how to teach biological evolution. *Evolution: Education and Outreach, 2*(3), 490-504.

NABT Position Statement on Teaching Evolution. Retrieved from https://nabt.org/files/galleries/NABT_Statement-_Evolution.pdf.

NGSS Lead States (2013). *Next Generation Science Standards: For states, by state*s. Washington, DC: The National Academies Press.

NSTA Position Statement. Retrieved from https://www.nsta.org/about/positions/evolution.aspx

Oliveira, A.W., Cook, K. & Buck, G.A. (2011). Framing evolution discussion intellectually. *Journal of Research in Science Teaching, 48,* 257-280.

Peterson, R. (2019). Creationist-believing students' scientific knowledge and reasoning about evolution (Unpublished thesis). Point Loma Nazarene University, San Diego, California.

Pew Research Center Public's Views on Human Evolution. (2013). Retrieved from http://www.pewforum.org/2013/12/30/publics-views-on-human-evolution/Pew Research Center. Attitudes and beliefs on science and technology topics. (2014). Retrieved from https://www.pewresearch.org/science/2015/01/29/chapter-3-attitudes-and-beliefs-on-science-and-technology-topics

Pew Research Center. Scientists and belief. (2009). Retrieved from https://www.pewforum.org/2009/11/05/scientists-and-belief/

Pobiner, B. (2016). Accepting, understanding, teaching, and learning (human) evolution: Obstacles and opportunities. *American Journal of Physical Anthropology*, *159*, 232-274. doi:10.1002/ajpa.22910

Rice, J. W., Clough, M. P., Olson, J. K., Adams, D. C., & Colbert, J. T. (2015). University faculty and their knowledge & acceptance of biological evolution. *Evolution: Education and Outreach*, *8*(1), 8.

Rice, J.W., Olson J.K., & Colbert J.T. (2010). University evolution education: the effect of evolution instruction on biology majors' content knowledge, attitude toward evolution, and theistic position. *Evolution Education Outreach*, 4, 137–144.

Sickel, A. J., & Friedrichsen, P. (2013). Examining the evolution education literature with a focus on teachers: Major findings, goals for teacher preparation, and directions for future research. *Evolution: Education and Outreach, 6*(1).

Smith, C. M. (2010). A three-step method for teaching the principles of evolution to non-biology major undergraduates. *Evolution: Education and Outreach,4*(2), 293-297.

Smith, M. U. (2009a). Current status of research in teaching and learning evolution: I. philosophical and epistemological Issues. *Science & Education, 19*(6-8), 523-538.

Smith, M. U. (2009b). Current status of research in teaching and learning evolution: II. pedagogical issues. *Science & Education, 19*(6-8), 539-571.

Smith, S. L., & Eve, R. A. (2009). Texas biology and biological anthropology faculty express their views on teaching evolution. *Evolution: Education and Outreach,2*(4), 636-642.

Tekkaya, C., Akyol, G., & Sungur, S. (2012). Relationships among teachers' knowledge and beliefs regarding the teaching of evolution: A case for Turkey. *Evolution: Education and Outreach, 5*(3), 477-493.

University of California Museum of Paleontology. (2019, April). Understanding evolution. Retrieved from The University of California Museum of Paleontology, Berkeley, and the Regents of the University of California. Web site: https://evolution.berkeley.edu/evolibrary/misconceptions_faq.php

Wilbur, N. & Withers, M. (2015). Teaching practices and views of evolution instructors at post-secondary institutions. *Evolution Education Outreach* 8, 12.

Wiles, J.R., & Branch, G. (2008). Teachers who won't, don't, or can't teach evolution properly: A burning issue. *The American Biology Teacher*, 70 (1): 6-7.

Appendix A: Informed Consent and Demographics

Thank you for participating in this questionnaire. Compensation for your time spent on the questionnaire will be a $10 amazon gift card. Gift cards will only be distributed to participants who complete all of the question on the questionnaire.

Informed Consent to Participate in Research

Introduction/Purpose I understand that I am being invited to participate in a research study for Rebecca Christian's Master's thesis. The Biology Graduate Department is sponsoring this study at Point Loma Nazarene University in order for Rebecca D. Christian to complete BIO 683. The purpose of the thesis is determine preparedness of new teachers (pre-service to two years) to teach evolution.

Procedures I understand that the proposed length of my participation in this study consists of one 30-45-minute digital questionnaire and possibly a 30-minute follow-up interview. The entire project will last approximately 60-75 minutes. During this time I will complete a digital questionnaire and possibly a 1-on-1 follow-up interview. Participants will answer honestly and will not use outside resources to complete the questionnaire.

Risks [**Describe what the risk is, and how you are seeking to minimize it.]** Foreseeable risks are that participants may feel uncomfortable talking about evolution since it is a controversial subject. They may also feel uncomfortable talking about their personal and religious beliefs. To minimize the risk, both the questionnaire and the interview will be voluntary and this will be explained to the participants beforehand. In addition, since it the study is on pre-service teachers they may feel that their answers could jeopardize their completion of a credential program or a future employment opportunity. To minimize these risks, participants will be told that there will be anonymity in the published results and findings. The risks of participants feeling uncomfortable talking about their personal beliefs or that they may be jeopardizing their education or future employment is justifiable in order to determine the level of preparedness of the pre-service teacher to help improve evolution education with the thesis findings.

Benefits. Participants are new science teachers and it would be beneficial to assess evolutionary content knowledge to be aware of both strengths and areas to improve.

Voluntary Participation [Describe how you will maintain confidential data.] I understand that my participation is voluntary and that I may refuse or withdraw from the study at any time without penalty. The results of this study will be presented with complete anonymity of participants. No names will be used nor information that could identify participants.

Confidentiality I understand that data collected will remain confidential. Only signatures are required for proof of consent and they will be kept separate from the other materials. Both video and audio recordings will be made during the 1-on-1 interviews. These will be transcribed to find patterns and trends among pre-service science teachers to determine their preparedness to teach evolution. Only Rebecca D. Christian will have access to them and will kept secure on her personal computer that is accessible only with a password. The recordings will be kept until thesis the thesis is defended and will be destroyed by May 2020.

Debriefing I understand that I have the right to have all questions about the study answered in sufficient detail for me to clearly understand the level of my participation as well as the significance of the research. I understand that at the completion of this study, I will have an opportunity to ask and have answered all questions pertaining to my involvement in this study by contacting Rebecca D. Christian at rchristian0204@pointloma.edu after the study is complete, around May 1, 2020.

Receipt of informed consent I acknowledge having received two copies of the consent form, one to be returned to the researchers and one for me to keep for my reference. I may call the investigators involved in the study, or supervising professor, Dr. April Maskiewicz Cordero, in order to discuss confidentially any questions about participation in the study. Also, should I have any concerns about the nature of this study I can also contact the Chair of PLNU's IRB (IRB@pointloma.edu). I agree to not look up any answers to the questions in this questionnaire as I understand that this would negatively impact the reliability of this study.

Name: _____ Age: _____
Signature: _____ Date: _____
(I am 18 years old or older.)

Investigator(s):
Rebecca D. Christian, rchristian0204@pointloma.edu, 661-203-0204

Supervising professor:
Dr. April Maskiewicz Cordero, acordero@pointloma.edu

1. **Age Range**

18-24
25-34
35-44
45-54
Over 55

2. **Gender**

Male
Female
Prefer not to answer
Other: _____

3. **Name of institution where you are completing your preliminary credential program**

_____

4. **Progress in Credential Program**

Not Started
In Progress
Completed

5. **If you answered "in progress" on the previous question, how many semesters or**

quarters have you completed? _____
Have you completed your science methods course? _____

6. **Highest Education Level completed**
   Bachelor's degree
   Masters
   Doctorate
   Other: _____
7. **Undergraduate Major _____**
8. **Have you completed a college level course that focused at least 25% on evolution?**
8. **What subject and age level do you intend to teach? _____**

Studies have been shown that people's religious beliefs can conflict with their understanding and acceptance of evolution, therefore several questions are included in this questionnaire about religion.

9. **Religion**
   Agnostic
   Atheist
   Buddhist
   Catholic
   Protestant/Evangelical
   Protestant/Other
   Jehovah's Witness
   Mormon
   Muslim
   Hindu
   Other: _____

10. My religion or faith is an important part of my identity
   Strongly agree
   Agree
   Neither agree or disagree
   Disagree
   Strongly disagree

11. I attend religious services at least once per month
   Strongly agree
   Agree
   Neither agree or disagree
   Disagree
   Strongly disagree

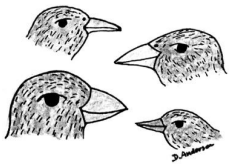
Appendix B: CINS

Conceptual Inventory of Natural Selection (CINS)

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.

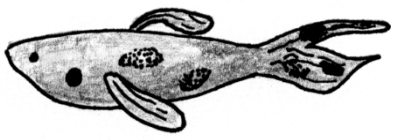
5. A population of finches has hundreds of birds of a single species. Which sentence best describes the group of finches?

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 <u>first appear</u> 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: MUM

Measure of Understanding of Macroevolution (MUM)

Nadelson, L. & Southerland, S. (2010). Development and Preliminary Evaluation of the Measure of Understanding of Macroevolution: Introducing the MUM. The Journal of Experimental Education. 78. 151-190.

This section made up questions 11-20 on the questionnaire.

Directions: Read each of the passages. Select the best option for each of the associated items that follow.

Consider the following paragraph and Figure 2 & 3 below to answer Questions 11-13.
The evolution of the eye has been studied extensively. It is a good example of an organ that at present has a wide range of forms in a wide variety of species (see Figure 2). Most experts think that all modern eyes have their origins dating back some 540 million years. An examination of the density of photoreceptors of the pigment cup and the complex eye reveal a variation within species as well as between species. The plots of the relative density of photoreceptors of the present day Nautilus and Octopus are presented in Figure 3.

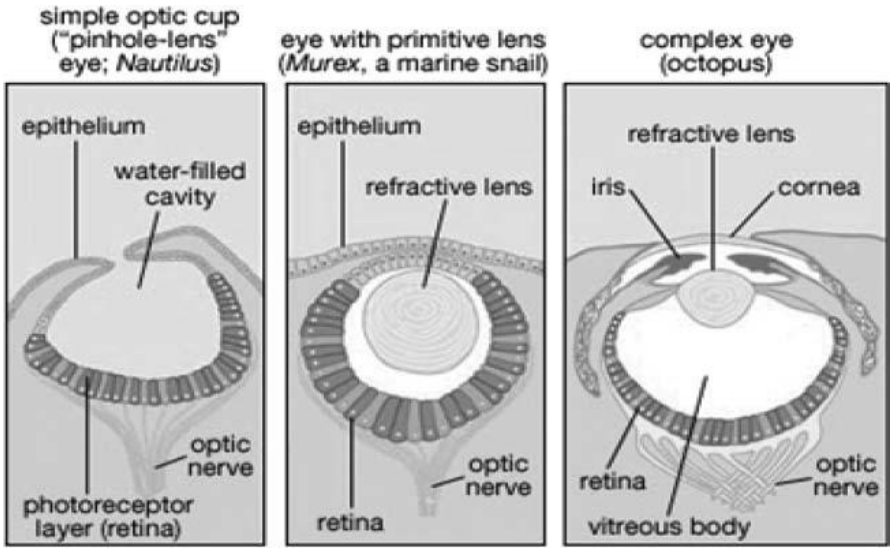


FIGURE 2 The different levels of eye complexity in mollusks.

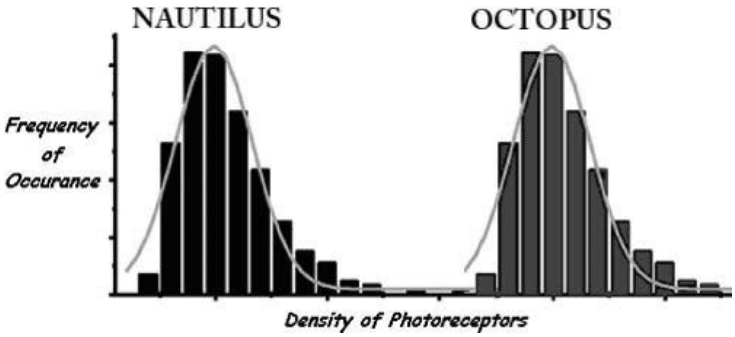


FIGURE 3 Variation in the relative density of photoreceptors in nautilus and octopus eyes.

11. Some speculate that the eye is too complex to have resulted from evolution. Yet, evidence suggests organisms may have had eyes for nearly 500 million years. What might scientists infer about the eyes of ancient organisms?
    a. Only animals living in the bright sunlight develop eyes because they need them and use them.
    b. Eyes would bear no resemblance to how eyes are structured today, and would not be recognized as eyes.
    c. The eyes of ancient organisms would have some characteristics that are similar to eye found in organisms alive today.
    d. Only animals with bones would really be trying to develop useful eyes.
12. There is a variation in the number and density of photoreceptors in the eyes (see Figure 3) within a population. This is an important consideration when trying to understand evolution because:
    a. Some individuals in a population are trying harder to see better than others.
    b. The variation in eye structure within a population can lead to the development of new eye structures.
    c. There are variations happening within all populations and they have no evolutionary significance.
    d. Variations indicate a species is no longer evolving but now stabilized.
13. Different organisms are classified based on similar functions and forms. All of the eyes above in Figure 2 are from a group of animals referred to as mollusks. Yet, the eyes of these three species of organisms do not seem to be very similar in structure, which suggests that classification of these organisms has been based on evidence that indicates:
    a. They can be traced back to a common ancestor that had a primitive eye.
    b. That they all live in a similar location and need eyes that allow them to see in the water.
    c. They want to be able to see in the water to catch prey and avoid predators.
    d. Mollusks' eyes are not considered when grouping these organisms together.

Use the following paragraph and Figure 4 to answer question 14.

Extinction is extremely important in the history of life. It can be a frequent or rare event within a lineage. Every lineage has some chance of becoming extinct. Over 99% of the species that have ever lived on Earth have gone extinct. This diagram illustrates the evolution lineages of several animal species.

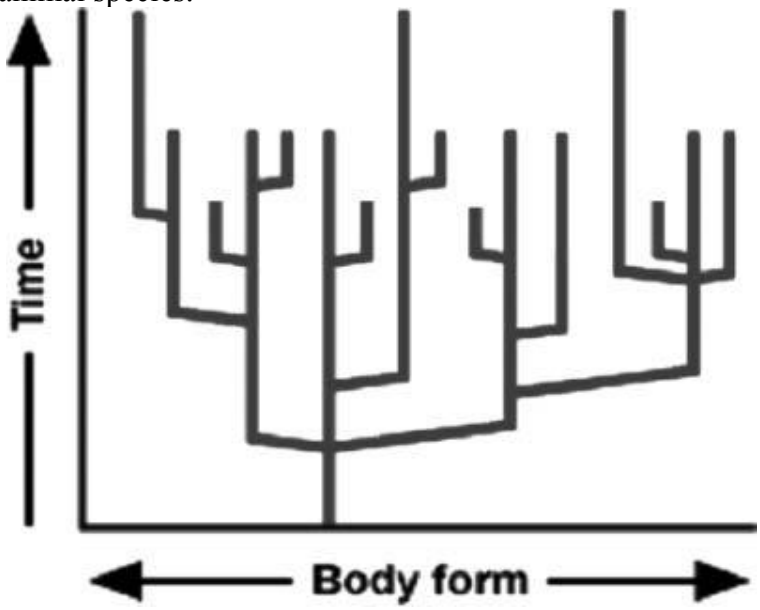


FIGURE 4 The historical development of the lineages of several animal species.

14. The branching of the animal species as displayed above would happen:
    a. Everyday
    b. Over relatively long periods of time—millions of years.
    c. Occur within a few generations.
    d. Within the life span of an organism.

Use the following paragraph and Figure 5 to answer questions 15-17. This is a suggested evolutionary pathway of the African Great Apes. The arrangement of this pathway is based on genetic information taken from the mitochondria of the various apes.

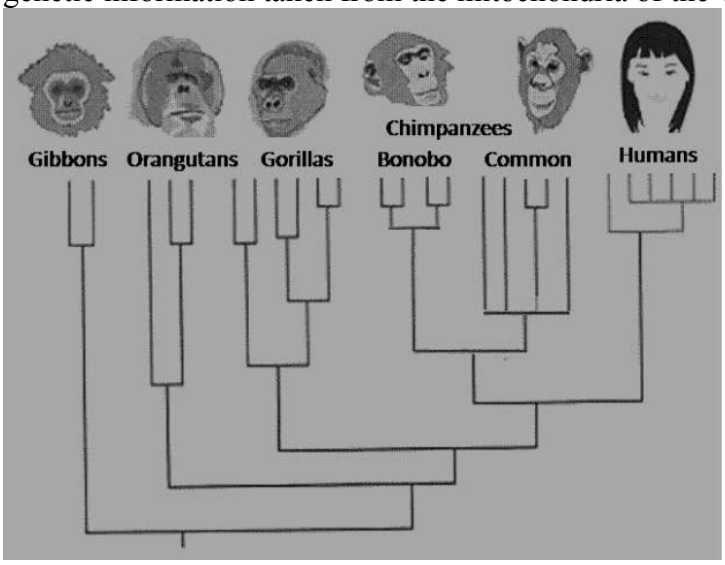


FIGURE 5 A hypothesized evolutionary lineages of the African Great Apes.

15. The diagram above suggests that:
    a. Gibbons and Orangutans are more closely related than Gibbons and Humans.
    b. Humans are much more complex than the other apes.
    c. Humans and Chimpanzees are the most closely related of all the Great Apes.
    d. Gibbons are unrelated to Humans.
16. The diagram above suggests that:
    a. Orangutans include the most recently evolved species and Gibbons are the most ancient species of apes.
    b. There has always been at least 5 species of Great Apes.
    c. Gorillas represent the most diverse of the different groups of Great Apes.
    d. Humans and Chimpanzees share a more recent common ancestor than Gibbons and Orangutans.
17. The fossil record for early humans is very sparse compared to many other organisms. In the context of the Great Ape tree this means:
    e. Much of the evolutionary relationships of humans and the other Great Apes is opinion and based on guess.
    f. Analysis of genetic codes and anatomy are used to derive such relationships.
    g. The evolutionary relationships of humans are relative easy to determine based on the wide variety of humans alive today.
    h. Humans have not undergone many evolutionary changes and remain at the top of the tree.

Use the following paragraph and Figure 6 to answer Questions 18-20.
Figure 6 is a map depicting where the fossils of various organisms have been found on different continents. This map also depicts our best understanding of the relative position of some of the continents in the earth's early history.

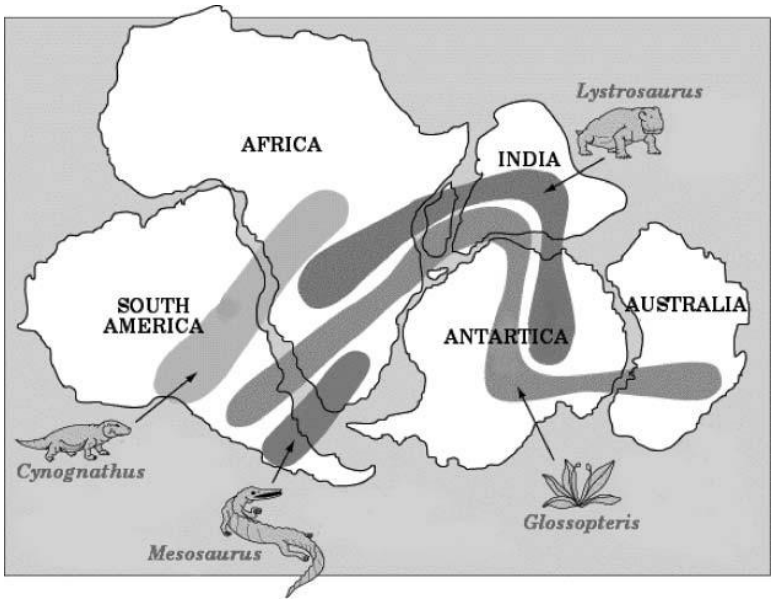


FIGURE 6 The distribution of fossils for 4 species across today's continents. The map shows how the continents may have once been located.

18. The separation of the continents and the separation of the organisms on these continents allowed for:
    a. Extinction, as the organisms were separated they could not survive as smaller groups.
    b. The production of new species, as groups of organisms were permanently separated.
    c. Organisms to remain unchanged, given the very slow movement of the continents and the slow rate of evolution.
    d. Organisms to interbreed, as their home ranges changed they joined together with other groups of organisms.
19. If a similar fossil was found on different continents, scientists might infer that:
    e. The continents involved were once connected.
    f. Eventually, the organisms will want to spread out and will be found on every continent.
    g. They must have come from different species but all look the same.
    h. The organisms were aware enough to know it was vital to move between continents.
20. The theory of plate tectonics was largely discredited when it was first proposed. Fossil evidence (as shown on the graphic seen in Figure 6) gave additional support to this theory. The theory then began to be much more widely accepted by scientists. This demonstrates that:

a. Theories are often supported by a number of different lines of evidence.
b. Scientific theories change very easily and are frequently just seen as hunches.
c. Knowledge about historical events is particularly weak.
d. Nobody can ever really know how plate movement as described by plate tectonics takes place.

Appendix D: I-SEA

Inventory of Student Evolution Acceptance (I-SEA)
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.

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

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

Appendix E: Lesson Plan Prompt

Evolution Lesson

Nadelson, L. S. (2009). Preservice Teacher Understanding and Vision of how to Teach Biological Evolution. *Evolution: Education and Outreach, 2*(3), 490-504.

Sickel, A. J., & Friedrichsen, P. (2013). Examining the evolution education literature with a focus on teachers: Major findings, goals for teacher preparation, and directions for future research. *Evolution: Education and Outreach,6*(1).

Instructions: "Based on your experience and course work so far, create a lesson idea that you would use to teach evolution to high school biology students. Just a reminder, per the informed consent, you have agreed to not use any outside resources to answers these questions in order to avoid negatively impacting the reliability of this study. You are tasked with teaching a 50-minute lesson to a sophomore college prep high school biology class. The lesson standard should align with The Next Generation Science Standard HS-LS4-1 which states, "Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence."

Briefly describe an activity you would use to teach the standard listed above and explain your reasoning for choosing the activity.

List possible misunderstandings you anticipate students may have about this topic and describe how you would address each possible student misunderstanding.

Briefly describe how you would handle a controversy that came up with administration, parents, students, or community members that may occur from teaching this evolution lesson.

Appendix F: 5 point rubric for questionnaire

Assessment	5	4	3	2	1
CINS	90-100% correct on multiple choice	80-89% correct on multiple choice	70-79% correct on multiple choice	60-69% correct on multiple choice	Below 60% correct on multiple choice
MUM	90-100% correct on multiple choice	80-89% correct on multiple choice	70-79% correct on multiple choice	60-69% correct on multiple choice	Below 60% correct on multiple choice
I-SEA Microevolution	5 Average on Likert Scale	4 Average on Likert Scale	3 Average on Likert Scale	2 Average on Likert Scale	1 Average on Likert Scale
I-SEA Macroevolution	5 Average on Likert Scale	4 Average on Likert Scale	3 Average on Likert Scale	2 Average on Likert Scale	1 Average on Likert Scale
I-SEA Human Evolution	5 Average on Likert Scale	4 Average on Likert Scale	3 Average on Likert Scale	2 Average on Likert Scale	1 Average on Likert Scale
Lesson Plan	Exceptional understanding of evolution standards Exceptional understanding of knowledge of learners Includes an exceptional plan to handle controversy.	Understands evolution standards Understands knowledge of learners Includes a plan to handle controversy.	Some understanding of evolution standards Some understanding of knowledge of learners Includes a plan to handle controversy but is somewhat unclear.	Very little understanding of evolution standards Very little knowledge of learners Includes a plan to handle controversy but it is very unclear.	No understanding of evolution standards No knowledge of learners Does not includes plan to handle controversy.

Appendix G: Rationale for lesson plan rubric

Participants are asked to create a lesson plan for a sophomore college prep biology lesson that meets the Next Generation Science Standard, HS-LS4-1, which states, "Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence". The lesson plan is broken into *four questions* on the questionnaire and four sections on the rubric.

The *first* category evaluates the participants' knowledge of the standard and the ability to plan an activity that meets the standard. The question states "Briefly describe an activity you would use to teach the, HS-LS4-1 standard and explain your reasoning for choosing the activity". Exceptional understanding of evolution standards (5 on the rubric) would include at least one of the four evidences of evolution (embryology, comparative anatomy i.e. homologous or analogous structures, molecular biology, or fossils) and an activity that corresponds with that evidence. A clear explanation of the reasoning behind how the activity meets the standards will also be required to receive a 5. Understanding evolution standards (4 on the rubric) would be earned by providing one of the four lines of evidence of evolution and choosing an activity that corresponds but does not give explanation how the activity meets the standard. Some understanding of evolution standards (3 on the rubric) would be earned with an activity such as the use of a cladogram (phylogenetic tree) which does show common ancestry but is no longer taught as part of the standards. Very little understanding of the evolutionary standards (2 on the rubric) would be earned if the activity taught about evolution but not common ancestry or evidence of evolution. For example, if participants teach on topics of natural selection or survival of the fittest, this would be deemed "very little understanding" because their activity is not meeting the standard. In addition, if the participant gives no detail, they would also earn a 2 on the rubric. For example, a one-word answer with no explanation would be "very little

understanding of the evolutionary standards." No understanding of evolution standards (1 on the rubric) would be in the activity had nothing to do with evolution or evolution is not mentioned. For example, if the participant had students dissecting frogs with no other explanation.

The second category addresses the participants' knowledge of learners in the lesson plan and states: "List possible misunderstandings you anticipate students may have about this topic". University of California Museum of Paleontology (2019) lists common misconceptions students may have. These include that evolution is 'just' a theory, evolution occurs in one lifetime, humans do not evolve, species are not related, evolution is not science because it's not observable or testable, evolution is invalid, gaps in the fossil record disprove evolution, evolution and religion are incompatible. Exceptional understanding of knowledge of learners (5 on the rubric) would be earned if at least two of these misconceptions were provided by the participant. Understanding of knowledge of learners (4 on the rubric) would be earned if one of these misconceptions was provided by the participant. Some understanding of knowledge of learners (3 on the rubric) would be earned if the participant did not give one of the listed misconceptions but they did include at least 2 other misconceptions. For example, if the participant's lesson was on Darwin's birds' beaks (that does not meet the standard) and the participant lists a misconception that the birds' chose to change their beaks this would result in a 3 on the rubric. The reason being that that is a common misconception for natural selection, but it does not mention the misconceptions students have about common ancestry. Very little knowledge of learners (2 on the rubric) would provide one valid misconception of evolution that does not align with common ancestry standard provided in the prompt. No understanding of

learners (1 on the rubric) would be earned if the participant did not provide a misconception or provides a misconception that does not have to do with evolution.

The third category seeks to gain an understanding of participants' plan to handle controversy when teaching evolution. The prompt states, "Briefly describe how you would handle a controversy that came up with administration, parents, students, or community members, that may occur from teaching this evolution lesson." In order for a participant to score an "exceptional plan" (5 on the rubric), at least two of the following strategies will be listed: explaining the NOS as it applies to evolution, refers to the state standard that is required to be taught, or refers to evolution as a scientific fact and not a religion. In order for a participant to score a 4 on the rubric, at least one strategy listed above would be provided. In order to score a 3 on the rubric, the participant would provide a strategy in detail but not one of the listed strategies. In order to score a 2 on the rubric, the participant would provide a strategy but not one of the listed strategies and the details of the plan are vague. In order to score a 1 on the rubric, the participant would not provide any strategies.

Appendix H: Interview Protocol

Task 1: Religiosity Scale

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
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 strongly in the teachings of my religion or faith					
I believe in God					
I consider myself a religious person					
I consider myself a spiritual person					

Task 2: Open-Ended Questions

Adapted from Barnes, M. E., & Brownell, S. E. (2016). Practices and perspectives of college instructors on addressing religious beliefs when teaching evolution. *CBE-Life Sciences Education*, *15*(2), 1–19.

Griffith, J. A. and Brem, S. K. (2004), Teaching evolutionary biology: Pressures, stress, and coping. J. Res. Sci. Teach., 41: 791-809.

1. When did you first learn about evolution?
2. Was religion discussed when you learned about evolution?
3. Do you personally experience any worldview conflict between evolution and religion?
4. Could you give me an example of an evolution lesson that could make you feel uncomfortable? Have you ever heard of this thing happening to anyone? Where did you hear this example?

Task 3: External and Internal Conflicts

Adapted from Griffith, J. A. and Brem, S. K. (2004), Teaching evolutionary biology: Pressures, stress, and coping. J. Res. Sci. Teach., 41: 791-809.

When considering teaching evolution, which of the following concerns do you have? (Check all that apply)

- I am concerned about negative effects from parents that may occur when about teaching students evolution
- I am concerned about negative effects from administration that may occur when teaching students evolution

I am concerned about negative effects from students during class that may occur when teaching students evolution
I am concerned about negative effects from a religious authority that may occur when teaching students evolution
I am concerned that my religious beliefs may cause an internal conflict when I teach evolution
I am concerned about negative effects from community members that may occur when teaching students evolution
I am concerned about legal action that may be taken against me for teaching evolution
I am concerned that parents, students, colleagues, or administration at my school may say or do things that encourage me to teach creationism

Task 4: Compatibility of God and Religion

Barnes, M. E., & Brownell, S. E. (2016). Practices and perspectives of college instructors on addressing religious beliefs when teaching evolution. *CBE-Life Sciences Education*, *15*(2), 1–19.

Put the following statements in order from "most represents your personal beliefs" to "least represents your personal belief" about human evolution and God.

1 - Human beings have evolved over billions of years from older life-forms, and God guided this process
2 - Human beings have evolved over billions of years from older life-forms, and God started this process but did not intervene after
3 - Human beings have evolved over billions of years from older life-forms, and God was not involved in this process
4 - Human beings have evolved over billions of years from older life-forms, and I do not know whether or not God had anything to do with this process
5 - God created human beings more or less in their present form.

Task 5: Clarification from Quantitative Assessment

On the original questionnaire, you answered _____. Can you explain what you meant by that? Can you explain your reasoning for choosing that answer?