The Effect of an Historical Geology Course on Students’ Attitudes Towards Science and Their Knowledge of Deep Time as a Threshold to Their Knowledge of Evolution

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The Effect of an Historical Geology Course on Students’ Attitudes Towards Science and Their Knowledge of Deep Time as a Threshold to Their Knowledge of Evolution

by

Allan W. Nolan

A Dissertation
Submitted to the Graduate School,
the College of Science and Technology
and the Center for Science and Mathematics Education
at The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

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ABSTRACT

In America there exists a conflict between a small group of its citizens and the concept of evolution. Researchers have studied this conflict and the ways in which teachers might approach educational methodologies that not only address evolution in a sensitive manner, but also remain legally acceptable.

This research was designed to address teaching evolution in the context of deep time – the concept that time is vast and that geology and biology operate in a timescale of hundreds of millions to billions of years. In previous peer-reviewed works, it has been stated that deep time acts as a threshold concept, preventing students from making the proximal leap to fully learning evolution except through the context of deep time. Students in Principles of Biology II (n = 100) were compared to those in Historical Geology (n=51). These students were scored on their responses to a pre-test/post-test research instrument which combined selected items from previously validated instruments – the Scientific Attitude Inventory II (40 items), the Geoscience Concept Inventory (15 items), the Conceptual Inventory of Natural Selection (10 items), and the Measure of Understanding of Macroevolution (10 items) – to address concepts of attitudes towards science, deep time, and evolution. A selection of open-ended questions (4 items in the pre-test, and 5 items in the post-test) at the end attempted to probe students’ views of evolution and deep time, as well as their methods of conflict avoidance if there were any conflicts between their own personal beliefs and the content being taught in the class.

Statistical analysis of the data was conducted using 2-way mixed ANOVAs to account for differences in means as well as any statistical differences between groups.
during the pre-test, multiple linear regressions to determine any correlations between the attitude and deep time scores with the participants’ evolution scores, a path model analysis to determine relationships between the various components of the Historical Geology instrument, and convergent parallel coding of open-ended responses using a data validation design to determine any changes in religious and/or evolution perceptions between pre- and post-tests.

These analyses indicated that knowledge of deep time did not act as a threshold to learning evolution, as indicated by non-significant ($p = .077$) differences between evolution scores in both the pre-test and post-test scores for both courses, despite Historical Geology students scoring significantly higher ($p < .001$) on their post-test deep time scores than their Principles of Biology II counterparts. This would imply that knowledge of evolution may not necessarily require prior knowledge of deep time.
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DEDICATION

I would like to dedicate this dissertation to the student who, in my first year of teaching middle school, asked me, “Mr. Nolan, is it true that humans evolved from monkeys?” Without you, this study would never have been conducted. Thank you for the inspiration.
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CHAPTER I - INTRODUCTION

“…we find no vestige of a beginning, no prospect of an end.”

-- James Hutton, Theory of the Earth, 1788

Nature of the Problem and Rationale

James Hutton first proposed the enormity of time and the concept of uniformitarianism; as far as humans were concerned, time is so extensive, there is no beginning or end to it (Hutton, 1788). He understood that Earth was shaped by long, time-consuming processes after observing weathering, erosion, and deposition, and concluding that these processes must occur through time. His premise can easily be transferred to other concepts requiring large amounts of time in which to operate – specifically biological evolution.

Constructivism is a learning theory in education in which students struggle to attain new knowledge unless instruction is provided which allows students to actively build their own, new knowledge based on the students’ own personal experiences (Howe, 2001). If the instructor does not understand what the student already knows, the instructor will not be able to teach so that students assimilate the new knowledge into their previous cognitive framework. Students do not necessarily passively learn, they actively construct new knowledge (Howe, 2001). This coincides closely with Vygotsky’s (1978) zone of proximal development where students can only reach new knowledge that is slightly outside of their current zone of knowledge. Whereas this is generally accepted by the educational community, another idea, that of threshold concepts, may also hinder the students from progressing. In other words, unless the student acquires the threshold
concept, they cannot learn the final concept (Ramseyer, 2012). If the threshold concept is skipped, then students may have difficulty learning or comprehending the final objective of the instruction.

By understanding where students begin their science knowledge and their attitudes towards science as a discipline, educators and those who create curricula may begin to reconstruct the pathways through which students progress to attain a greater knowledge of each subject area.

For this dissertation, students’ prior knowledge of evolution – the unifying theory of all modern biology – and deep time (which is required for evolution to work) was assessed. By using these data, this study attempted to examine the hypothesis that exposure to *Historical Geology*, a freshman-level course in which the concept of evolution is firmly set within the context of deep time (the threshold concept), will affect students' knowledge of evolution and their attitudes towards science. As a comparison, a selection of students in *Principles of Biology II* were also tested for the same attitude and conceptual changes as those in *Historical Geology*. In *Principles of Biology II*, students are taught the tenets of microevolution and macroevolution, but deep time is only discussed in one lecture and rarely discussed thereafter. This will provide a comparison between those that do not receive heavy contextual information regarding deep time and those that do. Collected data indicated that some students from each class (94.1% from the geology course and 82% from the biology course) had been exposed to previous courses in which evolution/deep time concepts may have been discussed.

To assess changes in knowledge and attitudes, three concept inventories and one attitude survey were combined into a single instrument. This instrument measured
concepts of deep time, evolution, and attitudes towards science and was used to
determine if there were any significant difference in student scores before and after
completing *Historical Geology* and *Principles of Biology II*.

**Background and Significance**

*Evolution and Deep Time*

Dobzhansky (1973) gave his article the title, “Nothing in Biology Makes Sense except in the Light of Evolution.” To extend this further, it can be said that nothing in evolution makes sense except in the light of deep time. In other words, the processes of evolution may require massive amounts of time in which to operate (Dodick, 2007). Unfortunately, these two concepts are usually not taught concurrently, and deep time is rarely taught at all in evolution instruction (Libarkin & Anderson, 2005).

Young-Earth Creationism creates a cognitive disconnect with these concepts. If the core foundation of young-Earth Creationism is a 6,000 year-old planet, then the deep time argument is considered moot by young-Earth Creationists, and therefore evolution is rejected (Cotner, Brooks, & Moore, 2010). Cotner *et al.* stated that deep time is therefore a significant conceptual change for a lot of students and must be taken into consideration with implementing lesson plans and curricula. Pulling (2001) argued that this should be addressed as early as middle school.

*Historical Geology*

*Historical Geology* is, by its very nature, perfectly suited for this study. As opposed to *Physical Geology*, which focuses more on processes and features, historical geology focuses on these aspects within the context of *time*. Depending on the textbook being used, historical geology is usually taught by providing students with the basics of
physical geology (e.g., rocks vs. minerals, sedimentary processes, plate tectonics, volcanology, seismology, etc.), and then using these tools to help them understand the planet’s rock record through more than four-and-a-half billion years of Earth history (Wicander & Monroe, 2015). Each component of time is divided into its lithologic history and its biologic history. This provides the perfect intersection of biological evolution with its deep time component.

Purpose of the Study

In the 2014 Religious Landscape Study (Pew Research Center, 2015), 64% of respondents believed that humans have evolved over time, whereas only 34%, more than one-third, believe that humans always existed in their current form. This closely resembles other Pew studies of the recent past (Pew Research Center, 2007, 2013). Evolution is a concept that is central to the understanding of all modern biology (Kendall/Hunt Publishing Company, 2006), and if one-third of modern Americans reject it outright, this indicates a fundamental gap in the education of the U.S. population.

In Mississippi, deep time appears in the state standards only through the seventh grade, according to the 2010 Mississippi Science Frameworks (Mississippi Department of Education, 2008b) (Appendix A) and the K-8 Mississippi Earth and Space Science Vertical Alignment (Mississippi Department of Education, 2008a) (Appendix B). After eighth-grade, Mississippi students may only encounter deep time in elective courses such as Biology II, Earth and Space Science, Geology (a half-credit course), and Astronomy (a half-credit course); and of those, only Biology II teaches evolution in the context of deep time. Alternatively, all Mississippi public school students must take the standardize state test for 8th Grade Science (which mentions evolution and adaptive change with no deep
time context) as well as pass Biology I (which mentions diversity of life, biological evolution, and molecular heredity with no deep time context) and its standardized state test for that subject.

As will be established in Chapter II, evolution is usually at significant odds with young-Earth Creationism or highly religious paradigms. As such, teachers, especially in the southern, so-called Bible Belt region, can sometimes be at odds with their students and their subject matter (Berkman & Plutzer, 2011; Long, 2012). To address the cognitive barriers that prevent basic knowledge of the core concept of evolution, this study probes whether deep time as a threshold concept that should be taught before students (and teachers) can firmly grasp the basics of biological evolution and dispel any misconceptions that may have been held beforehand.

Few studies have been conducted addressing this specific interaction, and they will be discussed in Chapter II. If the research hypotheses are not rejected, then the data from this study may be used to aid in creating textbook and curricula which integrate deep time into any conversation about evolution, or at the very least, include deep time as a fundamental scientific concept that must be addressed and mastered before any lessons regarding biological evolution.

Research Questions

What is the effect of Historical Geology on undergraduate knowledge of evolution?

a. Is there a difference in Principles of Biology II and Historical Geology student scores concerning evolution, deep time, and scientific attitude?
b. Are there relationships between student scientific attitude, deep time, and evolution scores in *Historical Geology*?

c. Are there relationships between pre-test and post-test evolution, deep time, and/or scientific attitude scores of participants in *Historical Geology*?

d. Do more students move from Creation-based views of evolution to scientific-based views of evolution after exposure to *Historical Geology* than *Principles of Biology II*?

**Research Hypotheses**

1. There is a significant mean change ($p < 0.05$) in student evolution scores when comparing *Principles of Biology II* participants with *Historical Geology* participants.

2. There is a significant mean change ($p < 0.05$) in student deep time scores when comparing *Principles of Biology II* participants with *Historical Geology* participants.

3. There is a significant mean change ($p < 0.05$) in student scientific attitude scores when comparing *Principles of Biology II* participants with *Historical Geology* participants.

4. There is a significant relationship ($p < 0.05$) between student scientific attitude scores and evolution scores of participants in *Historical Geology*.

5. There is a significant relationship ($p < 0.05$) between student scientific attitude scores and deep time scores of participants in *Historical Geology*.

6. There is a significant relationship ($p < 0.05$) between deep time scores and evolution scores of participants in *Historical Geology*.

7. There is a significant relationship ($p < 0.05$) between pre-test and post-test evolution scores of participants in *Historical Geology*.
8. There is a significant relationship \((p < 0.05)\) between pre-test and post-test deep time scores of participants in *Historical Geology*.

9. There is a significant relationship \((p < 0.05)\) between pre-test and post-test scientific attitude scores of participants in *Historical Geology*.

10. A higher percentage of students whose views of evolution are Creation-based will move to a scientific-based perception of evolution after participating in *Historical Geology* than those in *Principles of Biology II*.

Delimitations, Limitations, and Assumptions

**Delimitations**

1. This study does not attempt to determine any specific degree of change beyond statistical significance and effect size for any of the components of the research questions.

2. This study will be limited to two independent groups from two sequential semesters.

3. The post-survey instrument will be given to the participants approximately three-fourths of the way through the course, as this will be the point where all concepts have been reviewed, and further exposure to the course will only be repeated variations of the same topics (i.e., Precambrian lithology/biology, Paleozoic lithology/biology, Mesozoic lithology/biology, etc.).

**Limitations**

1. This research is limited in scope to undergraduate students at The University of Southern Mississippi.
2. Due to the specific nature of the research, the participants in the treatment group will be limited to those participating in a single section of *Historical Geology*.

3. Participants in the comparison group will be limited to those participating in three sections of *Principles of Biology II*.

4. The curriculum and instruction methodology will be set by the Instructor of Record for the courses under study, and not by the researcher.

**Assumptions**

1. Students in *Historical Geology* have had limited or no exposure to specific deep time instruction.

2. Students in *Historical Geology* have had some explicit instruction concerning evolution, either in high school or from prior college courses (or are currently enrolled in a college course which will teach evolution by the time of the post-instrument).

3. Students responded honestly and to the best of their ability on all instrument items.

4. Students in the course are representative of the general college population of public universities in Mississippi.

**Definitions of Terms**

1. *Christianity*: an Abrahamic (Judaism, Islam, Christianity), monotheistic religion based on the teachings of Jesus of Nazareth, who is viewed as the son of God and the messiah of mankind. Primarily, Christianity can be divided into Catholicism, Eastern Orthodoxy, or Protestantism denominations, though other subdivisions do exist.
2. **Constructivism**: learning theory in which students actively construct new knowledge through connections with prior knowledge.

3. **Creationism**: a cosmological and/or religious belief system in which an omnipotent creator (for this research, the Judeo-Christian God) created the universe and everything in it. Does not necessarily conflict with deep time or biological evolution. This differs from young-Earth Creationism (see below).

4. **Deep Time**: a geologic concept requiring vast amounts of time to accommodate the planetary processes seen in the natural world, including evolution by means of natural selection. This can be used interchangeably with *geologic time*.

5. **Epistemology**: any theory that attempts to explain knowledge, or how knowledge is obtained (Anfara & Mertz, 2006).

6. **Evolution**: the Darwin/Wallace mechanism by which one species changes over time – or undergoes a speciation event – to eventually produce new, genetically distinct species. This can be used interchangeably with *biological evolution*.

7. **Historical geology**: subdiscipline of geology in which both biological and geological processes are viewed through 4.6 billion years of Earth history.

8. **Misconception**: any concept held by a student that is either factually incorrect or justifiably misleading which can be persistent and resistant to change.

9. **Rock Record**: the geologic and biologic history of the planet as viewed through interpretation of rocks and structures. This can be used interchangeably with *geologic record*. 
10. **Teleology**: psychological premise in which every feature of an organism and/or inanimate object has a defined purpose (To, Tenenbaum, & Hogh, 2017), or that natural properties are explained by their final causes.

11. **Threshold concept**: a concept which must be mastered before a further, interconnected concept can be attained (Trend, 2009).

12. **Young-Earth Creationism**: a cosmological and/or religious belief system in which an omnipotent creator (for this research, the Judeo-Christian God) created the universe and everything in it less than 10,000 years ago.
CHAPTER II – LITERATURE REVIEW

Young-Earth Creationism as a Barrier in the K-12 Classroom

Many biology teachers in the United States are faced with a unique and decidedly controversial decision during a school year that many other teachers do not experience. These teachers have been shown to choose whether to teach evolution (despite what standards may require), and if they are to include some form of Creationism (Berkman & Plutzer, 2011; Branch & Scott, 2008; Hall & Woika, 2018). Even though Creationism is primarily an American phenomenon (Pennock, 2002), other countries also experience their fair share of controversy (Foster, 2012); currently Turkey has removed evolution from the high school curriculum for the 2017-2018 school year (Tuysuz, 2017). Michael Ranney (2012) asserted that this is directly connected to a sense of manifest destiny and nationalism. There are currently many laws in place that attempt to dictate if and how teachers should teach evolution, and these will be discussed in detail below.

For the last 25 years, American views of evolution have hovered between 45-50% acceptance with a little over a third claiming that they are well informed about evolution or Creationism (Plutzer & Berkman, 2008). Despite this, they found that nearly two-thirds of Americans want Creationism taught alongside evolution. For the most part, Creationist advocacy groups would like creation science to be taught concurrently with biological evolution to show two opposing theories. These advocacy groups claim that both concepts have merits and weaknesses, and both should be argued based on a sense of fairness and balance (Pennock, 2002).

Young-Earth Creationism cannot be a valid, alternate scientific theory to evolution because it disregards factual evidence that has been corroborated for well over
a century, as well as invoking claims that cannot be tested. Therefore, it is not a science and we cannot use its assertions to know something about the natural world. As we will see later, the U.S. law agrees with this. The Georgia Court of Appeals, in *Moeller v. Schrenko*, stated that “creationism is not a scientific theorem capable of being proven or disproven through scientific methods” (R. Moore, Jensen, & Hatch, 2003).

Fundamentalists originally used science to interpret scripture – God’s creation should supplement His word. Creationists eventually abandoned this methodology in favor of strict literalism seated in the story of a global flood (Montgomery, 2012). In 1857, Philip Henry Gosse invoked the modern colloquial equivalent to “because God made it that way” when he asserted that God made the Earth appear old by design. Even Victorian citizens scoffed at the idea that fossils were placed into rocks at the time of creation to make strata appear older than it was (Montgomery, 2012). In 1923, an amateur geologist by the name of George McCready Price claimed that there was no visible fossil succession (which is a major component of our reconstruction of geologic history, and by extension, deep time) and used this as a foundation for his flood geology (Price, 1923), disregarding also that Oxford theologian and geologist, Reverend William Buckland, published in 1836 that the amount of physical evidence collected worldwide argued strongly against a literal, Biblical interpretation of Earth history (Buckland, 1836). Price’s book can now be traced as the basis for all modern young-Earth Creationism (Matzke, 2010; Montgomery, 2012; Numbers, 1982; Numbers & Stenhouse, 2000).

One way to utilize young-Earth Creationism in a classroom is to group it with other misconceptions of science and show how the nature of science can overcome these misconceptions considering new evidence. Pennock (2002) states that this is the only way
that young-Earth Creationism could be responsibly taught in public schools – using it as an example of what not to do in science. Reiss (2008), alternatively asserted the opposite – that young-Earth Creation can only been viewed as a worldview and not a misconception, and science lessons should be engaging and stimulating without being threatening or attempting to overtly supplant young-Earth Creationist worldviews.

The introduction of socio-cognitive conflicts (when someone is faced with new information that is in direct disagreement with their current paradigm) is an effective way to address misconceptions (Contant, Bass, Tweed, & Carin, 2017; Liem, 1987; Limón, 2001; Sauriol, Riopel, & Potvin, 2015). Addressing young-Earth Creationism, like other misconceptions, could be used to teach critical thinking and advance understanding of evolution (Foster, 2012). When categorized among other misconceptions such as flat earth, geocentrism, humors, and phlogiston, students can see the weaknesses in young-Earth Creationism and can analyze the evidence for themselves.

Both Foster and Pennock agreed that young-Earth Creationism should be taught as a misconception, but they do not agree as to when this should be addressed. Pennock (2002) claimed that this should wait until the students reach college, because they do not have enough content knowledge to sufficiently critique young-Earth Creationism. Foster (2012) saw this as problematic insomuch that state standards require evolution to be taught in the nation’s high schools. The conundrum here is that if young-Earth Creationism is not addressed at the same time as evolution, then students are expected to simply memorize the knowledge. Memorization, unfortunately, requires a lower level of thinking and prevents deeper understanding of scientific relationships (Howe, 2001). This is the opposite of the nature of science (NOS) and science learning.
Handelsman, Miller, & Pfund (2007) defined the nature of science as, “representation of science as a process that includes analysis, collaboration, communication, experimentation, evaluation, inquiry, and knowledge” (p.21). Moreover there needs to be a clarification that NOS is not the same thing as the processes of science; although there may be times when the two interact with each other, the processes of science are a set of tools and practices, whereas NOS is an epistemological architecture for all of science (Lederman, Lederman, & Antink, 2013). This leads to the idea that science should not be taught as a collection of facts to be memorized, but as a collection of practices and ideologies illustrating the concepts of science. This is the nature of science as a whole, and as such, it should be at the core of any science instruction, as stated in educational standards for more than 100 years (Lederman & Niess, 1997). Although specific definitions of NOS tend to vary widely, the assertion that students should learn NOS as a relevant aspect of their daily lives is wholly accepted (Lederman et al., 2013). For it is only with this general knowledge of NOS that students and global citizens can make objective decisions regarding scientific claims (Lederman & Niess, 1997).

A final way to address young-Earth Creationism in the science classroom would be to eliminate it altogether – as young-Earth Creationism is definitively not science. This approach has been supported numerous times over the decades (Berkman & Plutzer, 2012; Brush, 2000) by scientists and numerous U.S. court cases (Table 1 for an abbreviated list of selected major cases), which legislated that Creationism was not to be taught in public classrooms.
<table>
<thead>
<tr>
<th>Year</th>
<th>Legislation</th>
<th>Ruling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>Epperson v. Arkansas</td>
<td>First Amendment does not allow a state to require teachings based on any one faith or doctrine. Laws banning teaching evolution are unconstitutional.</td>
</tr>
<tr>
<td>1974</td>
<td>Willoughby v. Stever</td>
<td>Publicly funded textbooks cannot be tailored to any specific religious belief system.</td>
</tr>
<tr>
<td>1978</td>
<td>Crowley v. Smithsonian Institute</td>
<td>Smithsonian exhibits are treated as science and not religion. Exhibits do not prevent the exercise of one's religion.</td>
</tr>
<tr>
<td>1981</td>
<td>Arkansas Act 509</td>
<td>Required teaching of both evolution-science and creation-science if either is taught.</td>
</tr>
<tr>
<td>1981</td>
<td>Segraves v. State of California</td>
<td>Teaching evolution does not violate one's freedom to exercise their own religion.</td>
</tr>
<tr>
<td>1990</td>
<td>Webster v. New Lenox School District</td>
<td>School districts may prohibit the teaching of Creationism to prevent violating the Establishment Clause.</td>
</tr>
<tr>
<td>1994</td>
<td>Peloza v. Capistrano School District</td>
<td>A school district's requirement to require the teaching of evolution does not violate a teacher's right to exercise their own religion.</td>
</tr>
<tr>
<td>2000</td>
<td>Rodney LeVake v. Independent School District 656 et al</td>
<td>Free speech rights are not violated when a teacher is required to adhere to a school district's curriculum.</td>
</tr>
<tr>
<td>2001</td>
<td>Moeller v. Schrenko et al.</td>
<td>Found that it is not unconstitutional for schools to use textbooks that claim, “creationism is not a scientific theorem capable of being proven or disproven through scientific methods.”</td>
</tr>
</tbody>
</table>
Table 1 (continued).

<table>
<thead>
<tr>
<th>Year</th>
<th>Case</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td><em>Selman et al. v. Cobb County School District et al.</em></td>
<td>Disclaimer stickers in biology textbooks containing evolution are a violation unconstitutional under the Establishment Clause.</td>
</tr>
<tr>
<td>2005</td>
<td><em>Kitzmiller et al v. Dover</em></td>
<td>Intelligent design is not science, but an attempt to violate the Establishment Clause.</td>
</tr>
</tbody>
</table>

By allowing young-Earth Creationism into the classroom at all, teachers begin to enable doubt in science, undermining instruction and learning (Suhay, Druckman, Berkman, & Plutzer, 2015). This can sometimes be at odds with science teachers when they themselves hold Creationism beliefs. Berkman & Plutzer (2010) found that 14-21% of all public school biology teachers endorsed the validity of creation science or Intelligent Design.

One of the reasons that this issue is so controversial is because it is so personal (Ranney, 2012). Creationism, which is decidedly religious in nature, can be deeply rooted in socio-cultural perspectives. Evolution, which circumvents this idea of being “chosen,” is in direct conflict with many Christian (and, by extension, American nationalism) ideals (Ranney, 2012). Long (2012) goes so far as to claim that when confronted by Foster’s socio-cognitive conflicts directly related to their epistemological and ontological allegiance, students may experience existential angst. This places biology teachers in an “ethically tenable” position. Long stated that schools should not bow to local politics at the expense of science education. Properly educated science teachers should be able to administer standards in ways that their education deems necessary.

Science teachers need instruction on how to properly mediate conversation concerning evolution and/or Creationism (Hermann, 2012; Long, 2012; Rutledge &
Warden, 2000, 2000; Trani, 2004). Although all states have evolution curricula standards – either in general or specifically addressing human evolution – both Herman (2012) and Long (2012) agreed that, no matter the content objectives provided in a curriculum, the responsibility ultimately rests with individual teachers. In most cases, this means that the beliefs of the individual teachers, as well as their understanding of evolution and the nature of science, directly correlate with how they teach evolution/Creationism in their classrooms; a teacher is more likely to reject evolution and endorse Creationism as science-based on religious beliefs (Trani, 2004). Moreover, a correlation between teachers who do not accept evolution and their depth of understanding of evolution and NOS has been identified (Rutledge & Warden, 2000). In their study, Rutledge & Warden (2000) stated that teachers’ low acceptance of evolution had strong relationships to their low levels of understanding of evolution and NOS. They explained that if teachers do not understand evolution and the epistemological underpinnings of science as a whole, then those teachers would be less likely to accept evolution as both components are required to fully accept or reject a claim.

To solve this gap in understanding amongst science teachers, proposed suggestions include evolution-specific courses in all college science major curricula (Long, 2012), including evolution-specific courses in all preservice science teacher curricula (Rutledge & Warden, 2000), or hiring only qualified science teachers by thorough prescreening (Trani, 2004). To be able to hire qualified science teachers implies that there are enough science teachers that selections could be made between those that are highly qualified and those that are not. In states like Mississippi, where 48 school
districts are currently experiencing teacher shortages (Mississippi Department of Education, 2017), the selection pool of science teachers may be too slim to discriminate.

Not only must teachers understand, in its entirety, what they are teaching, but they must also be prepared to encounter their students’ beliefs. Some research suggests that evolutionary concepts should be taught from an early age, even at the elementary school level (Hermann, 2012). Long (2012) claimed that even though young children can grasp that everything alive today can essentially be “cousins,” the public equates this notion as the equivalent of telling their children that there is no Santa Claus. If we wait, then, until middle school to begin teaching evolutionary concepts, we run into the problem of conflicting established beliefs that are part of the students’ social order, and at conflict with their supportive institutions. To quote Long, we are asking Creationist students “to change their relationship to the epistemological authority of their religious commitments,” (p. 129) resulting in existential angst.

Evolution, Creationism, and Legislation

Due to the advocacy of the young-Earth Creationist movement, it has become almost impossible to teach young-Earth Creationism, in any context, inside of a public school classroom (R. Moore et al., 2003). Unfortunately, teachers, as a whole, are completely unaware of the relevant laws concerning both evolution and Creationism/Intelligent Design (Meikle, 2011).

In 1925, the famous Scope’s Monkey Trial was held in Tennessee after a substitute teacher broke the law (for a brief list of relevant legislations, see Table 1) by teaching evolution in his classroom. John Thomas Scopes v. The State of Tennessee brought the Butler Act of 1925 – which specifically banned the teaching of human
evolution in public school classrooms (R. Moore et al., 2003) – to the forefront of American public school science teaching. Before the trial, the American Civil Liberties Union stated that they would defend anyone who chose to challenge the Butler Act (Burnett, 2012). In Dayton, Tennessee, John Scopes was already part of a small group of men who opposed the law and was teaching evolution despite the ruling. Scopes was arrested, tried, and convicted (though this was later overturned on a technicality by the Tennessee Supreme Court) for his lessons on evolution (English, 2008). Similar laws to the Butler Act were enacted throughout the 1920s and later, but those laws could easily be circumvented by a few critical thinking strategies, as some teachers did (Meikle, 2011).

These antievolution laws were on the books until Epperson v. Arkansas (Epperson v. Arkansas, 1968) declared those laws unconstitutional when they prohibited science content based on the tenets of a single doctrine. If the laws were to change to allow one creation doctrine, it could easily extend to the necessity of teaching all creation doctrines, leaving science behind and leading to direct conflict between all students (Pennock, 2002).

Alternately, young-Earth Creationist advocates have tried to turn the table on science in public schools. Willoughby v. Stever (1975) made the claim that science is a religion known as secular humanism, and that the United States was endorsing secular humanism as the official religion of the country (R. Moore et al., 2003). In both Willoughby v. Stever (1975) and Crowley v. Smithsonian Institution (1980), the Washington, D.C., Circuit Court of appeals struck down these claims, ruling that science was not a religion by any definition (R. Moore et al., 2003).
Creation science has eventually lost every legal battle that it has entered. No ruling has ever remained stating that Creationism can be taught in a public classroom, as it clearly violates the Establishment Clause and is always found to be a form of religious advocacy (Matsumura & Mead, n.d.; R. Moore et al., 2003). Despite this, there is a subset of biology teachers known as “the cautious 60%” (Berkman & Plutzer, 2011). These 60% of biology teachers are neither strong advocates of evolution in the classroom, nor do they explicitly teach non-science alternatives such as Creationism. These teachers might sometimes teach only microevolution or claim to students that they are only teaching it because it is required. Whatever the case may be, these cautious 60% probably do more harm than good when they do everything they can to avoid controversy – they can unintentionally give credibility to Creationism by skipping critical skills and evidence that is usually taught by properly educated biology teachers (Berkman & Plutzer, 2011).

Deep Time and Large Numbers as a Cognitive Barrier

As early naturalists studied the rock record, they continued to run into observations that contradicted the Biblical creation stories that had been used as a foundation for geology (Wicander & Monroe, 2015). Eventually, estimates continued to climb as more evidence was gathered. The estimated age of Earth was in a constant state of growth as naturalists of the 18th and 19th centuries – Georges Louis de Buffon with his work on the cooling rate of iron in the late 1700s and John Joly and Lord Kelvin in the late 1800s with their work on ocean salinity rates and rock cooling rates, respectively – stretched the age from thousands of years old to tens and hundreds of millions of years (Wicander & Monroe, 2013; Zen, 2001).
In a group of K-12 teachers and administrators, Zen taught her group this history of geology, showed them a video of the basics of stratigraphy, and then took them on an expedition to explore and date local sequences. Using basic rules of growth, cooling, and logic, they easily came to millions of years in those Montana outcrops. Feedback from the teachers stated that field trips such as these could certainly help supplement in-class lectures.

Zen stated that even non-geologists should understand deep time, as much as they understand Kepler’s laws and Euclid’s geometry. Deep time is not faith-based – it is open to scrutiny and falsification. It is under constant revision as new evidence and discoveries are found. Deep time also gives humanity an indication of the amount of time needed for regeneration of Earth’s resources. If citizens cannot understand how long it takes to replenish a depleted resource, then they may (and do) use the resources unwisely (Zen, 2001).

Also attempting to understand how adults perceive deep time, Teed and Slattery (2011) analyzed the geoscience (deep time) content knowledge of preservice teachers planning on entering the workforce as K-3 classroom teachers – as most teachers who have minimal content knowledge will be less likely to teach that concept in their classroom. Using an abbreviated, 15-question version of the Geoscience Concept Inventory (GCI), Teed and Slattery determined how much deep time content these preservice teachers gained over the course of a single class – Concepts in Geology. Depending on the preservice teacher’s original misconceptions and the complexity of the concept on the GCI, teachers generally made significant gains in their deep time knowledge when comparing individual responses on their pre-test to responses on their
post-test. An exception occurred when asked about the original configuration of Earth’s continents after its initial formation. Preservice teachers here chose an incorrect Pangaea model for the pre-test, and most kept that answer for the post-test, despite covering Pangaea multiple times over the course of the inquiry-based class. Additionally, as with the study by Cheek (2011), the authors of this study found that college students, as well as their K-12 counterparts, struggled with basic mathematics skills, especially proportional reasoning, leading to their misconceptions about deep time.

Based on the results of their analysis, Teed and Slattery concluded that the Concepts of Geology class should be modified in such a way as to be able to spend more time on core topics instead of the “mile-wide-inch-deep” method formerly employed. This style of class would be better suited to brief lectures and guided inquiry with a few demonstrations and appropriate videos. The authors propose the idea of making timelines in class that reflect both personal events, as well as geologic events, furthering the idea of stressing the activity to address misconceptions regarding temporal-spatial concepts in general, and deep time specifically. This type of activity has been successfully conducted in middle school settings (Clary & Wandersee, 2015, 2009; Richison, Herrington, & Mattox, 2017).

Elementary and middle school students visiting the Dunn-Seiler Museum in the Department of Geosciences at Mississippi State University were asked how old they thought the Earth was. Their answers ranged anywhere from a few decades to a few million years, revealing that they had little grasp of the enormity of deep time (Clary, Brzuszek, & Wandersee, 2009). Even when addressing the concept of 4.6 billion years, their responses indicated the shortcoming of the human brain to grasp extremely large
numbers. When queried about the ability of a human to clap once per second, 4.6 billion times, they would tend to respond that yes, it is indeed possible for a human to clap 4.6 billion times, once per second. This is untrue. The task would take almost 146 years – well beyond a normal human lifetime (Clary & Wandersee, 2009).

The use of a petrified wood survey developed by Clary & Wandersee (2007) showed that more than half of the students (54%) came into a university Landscape Architecture Design 1 course with Creationism-based beliefs concerning fossilization and time. The students were asked to place major events in Earth’s history on a timeline with one endpoint designated for the present and another for the formation of the Earth. All of the students had difficulty with relative time scales and distances between events. Most students either chose to cluster a lot of the events towards the beginning of the timeline (Earth’s Origin) or to place events equidistant from each other (Clary et al., 2009). This study supported results of Cheek’s (2011) analysis and those of Catley & Novick (2009), which found that the ability to discriminate very large numbers was rare and that students tend to clump the origin of life and the origin of Earth together.

Dodick & Orion (2003) measured how well middle and high school students could activate specific diachronic (the ability to represent changes over time) schemes, and in the process, propose any implications to earth science education. Several tests were given to the students to test their knowledge of specific earth science (i.e., geology) concepts and how well these concepts correlated to the diachronic schemes. As would be expected, students progressed to more difficult and complex schemes as their grade levels increased, but there were some concepts, independent of the scheme, which gave the students difficulty, no matter the age or amount of geology content they had been
exposed to (i.e., incorrectly associating size of strata with time). The authors also recognized that there are significant differences between written tests, and how those skills might be utilized in field settings. The results of this study clearly indicated that students at various grade levels may or may not have formed the necessary correlative and temporal-spatial skills to properly interpret geological structures. This would mean that teachers could only master specific benchmarks in class, so long as the content falls within the developed skills of the students in their classroom.

Cheek (2011) set out to determine if students of differing grade levels (including postsecondary) might have some difficulty in understanding significantly large numbers that may, in turn, inhibit their understanding of geologic time, continuing along similar lines as that of Dodick and Orion (2003). For Cheek’s study, students were given three sets of numbers, each to map out on a timeline. These sets of numbers grew progressively larger and proportionally more complex. After the timelines were finished, the students were interviewed to gather information about their thought processes, and to see if they understood more than their timeline would suggest. It was found that when split into three performance levels, students in the bottom two levels had difficulty understanding the timeline and wanted to place a marker in relationship to its most adjacent counterpart, as opposed to the entire timeline. Although the students in the higher categories did not always perform perfectly, they did show higher aptitude in problem-solving skills, and regularly applied them to the timeline, usually seeing it with proportions seen across the board. Here it can be seen that as students consider large numbers and their corresponding placements in time, an inability to grasp temporal placement relative to a whole impedes their progress with understanding deep time. If students do not understand
the expanse of time between numbers, they cannot hope to understand the breadth of time required for the formation and development of a planet as well as the time required for evolution to occur.

This inability of students to understand temporal-spatial position can be attributed to a disconnect between the length of a human lifetime and the lengths of deep time. Therefore, one of the major barriers with the use of visualization as an analogy for deep time is that most timeline analogies for teaching deep time are scaled inappropriately (Parker, 2011). Essentially, when common analogies are used – such as a clock, calendar year, or playing fields – times of the smallest human scale becomes microscopic in the analogy, and therefore useless. Parker claims that the scale should fit into a size no smaller than 0.5 mm and no longer than a day’s drive, or approximately 100-600 kilometers. He claimed that to aid student understanding of the scale of deep time, they should be able to drive through time. This is a scale that is relatable at both ends of the timeline. Parker received much positive feedback, both from undergraduate students as well as from adults in public talks, concerning this methodology. In his technique, he proposes to use Google Earth as a medium to illustrate conceptually appropriate distances in deep time. With this, a teacher can map scaled distances to familiar landmarks (customized to each teacher’s exact location on the planet), and by beginning in the classroom, mark off the smaller distances (i.e., human lifespan, emergence of \textit{H. sapiens} and \textit{H. neanderthalensis}, etc.) before showing slides of the larger distances in Google Earth, or even taking a field trip to the designated landmarks, especially when working with children who may never have been out of their own city.
Parker’s method seems to hold merit. Students, creating their own timeline, may have to use the tiniest of scales, as noted by Parker. But by utilizing both a properly scaled, student-made timeline in a lab, and combining it with the lectures or field trips showing larger, relatable distances in Google Earth, teachers may be able to begin to help students properly grasp and visualize the massive numbers associated with deep time.

Additionally, Parker (2011) explicitly stated that one of the barriers to understanding evolution is that students also do not grasp the enormity of time in Earth’s past, reinforcing Gould’s (1987) assertion that deep time is so outside of our experience that its conceptualization is almost impossible except through metaphor. By extension, students then cannot conceptualize the amount of time necessary for evolution to take place. In any case, understanding of deep time, by anyone, gives them the ability to view it critically, and make informed decisions affected by its concepts.

Misconceptions Regarding Evolution

The mechanics of microevolution (e.g., meiosis, genetic mutations, etc.) are the primary evolution-oriented content objectives in K-12 curricula, and almost no emphasis is given in grade-school biology textbooks to Darwin’s claim that all life descended from a single, common ancestor. Darwin explicitly illustrated this claim in his diagram in *On the Origin of Species*, and it is the foundation for macroevolutionary concepts (e.g., natural selection, speciation, etc.) (Catley, 2006). According to Catley, this creates a poor understanding of the processes that operate at much larger scales, and therefore a thorough understanding of the history of life on Earth. To understand evolution in its entirety, concepts beyond genetic mutations, meiosis, mitosis, and DNA need to be addressed. Generally, students lack sufficient education in the macroevolutionary
concepts of natural selection, fitness, extinctions, speciation (including allopatric speciation), extinction events, and cladogenesis (formation of new clades, or groups, of organisms), let alone an understanding of the complex relationships between these concepts and others such as ecology, deep time, and phylogenies (Catley, 2006).

In a study with non-majors biology undergraduate students, Bishop and Anderson (1990) showed that students lacked understanding of the evolutionary concepts of Lamarckian (need-driven, inheritance of acquired traits) versus Darwinian evolution. In summary, Darwinian evolution highlights the role of normal variation within a population due to random genetic mutations and crossing-over, which, in turn, leads to selective reproductive success. With selective reproductive success, individuals with detrimental variations (due to the previous mutations and crossing-over) are prevented from procreating, meaning that those variations are removed from the gene pool. Therefore, traits do not gradually change in all members of a population, but rather the proportion of individuals born with a trait that contributes to reproductive success within that environment will increase (i.e., non-random natural selection).

In Bishop and Anderson’s (1990) analysis, students saw the process of change as a single entity – the environment caused a trait to change in the population. There is no regard to the role of genetic mutation in their conceptualizations. Despite the Lamarckian nature of the explanations, even those who rejected Lamarckian evolution could not give a fully functional explanation that satisfied the evolutionary concept of change. They claimed that the current need for the trait is enough of an explanation for the current existence of that trait.
Bishop and Anderson (1990) attributed common misconceptions such as the one above to scientific terminology commonly confused with their colloquial counterparts, such as *adapt* and *fitness*. Gregory (2009) also claimed that anthropomorphic wording used by layman and authorities alike – *learn, outsmart, grow, develop, resist, chooses, prefers, selects for,...* – provide the false impression that the driving force of evolution is intent. R. Moore, Froehle, Kiernan, and Greenwald (2006) agreed with this, as their students claimed that theory was synonymous with an educated guess or idea. They went on to say that high school students believed that the theory of evolution was full of contradictions and conflicts, that there were multiples scientific theories to explain the diverse life on Earth, and these ideas persisted into college.

This language has the unfortunate side-effect of supporting the soft inheritance based on acquired characteristics, which is when traits acquired during a single lifetime of an organism are passed down to the next generation. Soft inheritance has been shown to be a common, persistent misconception of evolution that arises early in youth and is difficult to replace (Gregory, 2009). This model of soft inheritance is in direct opposition to the two-step model set forth by modern biologists – random genetic mutation and non-random natural selection. Terms such as those listed above are misleading and can imply a motive or intent.

The problem can be compounded by teacher instructional methodologies. Woods and Scharmann (2001) concluded that teachers who utilized direct instruction reported higher degrees of overall classroom difficulty with teaching evolution when compared to other topics. Results also indicated that difficulty could be found by teachers coming from small, more conservative areas, indicating that these teachers were mindful of their
community’s social paradigm. Regardless, when more inquiry-based instruction was used, students were more likely to understand evolutionary concepts, moving away from “unsure” models to evolutionary schema. According to the authors, students primarily focused on common descent and/or human-specific evolution when asked to speak about the theory of evolution in their own words. But even those with little or no understanding of evolution had an opinion on whether it should be taught in the classroom, and that the theory of evolution is dualistically accepted or rejected by students based on higher authorities than themselves (i.e., God, church, parents, or teachers).

To et al. (2017) found that students used both intuitive and scientific ideas when explaining scientific phenomena, and began to use relevant terminology at age 14, but mostly in the colloquial sense, and not the scientific sense. This supports Gregory’s (2009) conclusion that teleological explanations (every part – or property – of an organism has a purpose in its design) are more basic than scientific ones, and therefore tend to get suppressed, rather than overridden by scientific concepts. These explanations often lead to incorrect cause-and-effect relationships between circumstances (e.g., snakes had to adapt to survive, there are earthworms in the dirt to aerate the soil, etc.). In their study, students also tended to generalize the teleological (Gregory, 2009; To et al., 2017), purpose-driven view of evolution and apply it to an individual (i.e., Lamarckian evolution), and not a population.

To et al. (2017) attributed multiple epistemologies (ways of knowing) to misconceptions regarding evolution. Naïve theories such as essentialism (e.g., organisms vary, but the core of species does not) and teleology stem from personal and direct world experiences. Socio-cultural milieu are epistemologies found in the environment of a
student’s upbringing, such as the tenets of evolutionary theory. Integration of new knowledge depends on the detection of inconsistencies between conflicting epistemologies and the new source of authority. Upon detecting these inconsistencies, one of three things can happen: (1) all contradictions are ignored, and the original conceptions are maintained; (2) both conceptions are kept, existing concurrently; or (3) a new conceptual framework is created which integrates the original, naïve conceptions as well as the new scientific data.

As students learn more core concepts relating to biological evolution, they will integrate the new understanding into their preexisting schema. But when their understanding of key words (adapt vs. evolve vs. change) is flawed, their reasoning will show this flaw and allow them to keep their naïve theoretical representations. Lucero, Petrosino, and Delgado (2017) research supported the retention of naïve theoretical representations in their study using the Conceptual Inventory of Natural Selection to determine subject matter knowledge of high school teachers and knowledge of student conceptions of their students. A group of high school science teachers (n = 4) and their students (n = 339) provided consent for the study. Knowledge of evolution by the four teachers was demonstrated by their ability to easily answer questions concerning concepts dealing with natural resources, variations within a population, and limited survival. The student responses were used to determine if the teachers of the study understood their own students’ misconceptions. It was found that the teachers’ greatest misconception of evolution centered on their struggle with concepts of change in a population. The two primary student misconceptions were the ideas that we should be able to see humans evolving now, and that populations somehow have control over their
characteristics, reflecting again, the Lamarckian version of evolution found by Bishop and Anderson (1990).

Deep Time as a Threshold Concept

Whereas the antiquated forms of thought surrounding geocentrism and the idea of a flat Earth have all but become extinct, Cotner et al. (2010) claimed that young-Earth Creationists still contribute to a large fraction of the populace and reject outright most the claims made by scientists concerning deep time and biological evolution. These Creationists were found to not support either old-Earth claims in the context of evolutionary theory, or evolutionary theory in the context of an old-Earth. These findings indicate that old-Earth beliefs positively impact a student’s ability to grasp the complex theoretical concepts underlying evolution, whereas young-Earth beliefs affect a student’s ability to grasp those same concepts negatively, and both measures are impacted by their high school biology course content knowledge (Cotner et al., 2010).

Deep time provides the context for all geology. Without the context of deep time, other concepts such as mountain building, environmental change, and evolution, may remain obscure. Trend (2009) claimed that deep time is a threshold concept, wherein upon learning by the student, a transformed view of the academic discipline is developed, irreversibly altering the world-view of the learner. Cotner et al. (2010) stated, “Teaching about time requires teaching for conceptual change” (p.862). This means that teachers must address students’ misconceptions about deep time in order to lead them to the new understanding.

Ramseyer (2012) attempted to determine if deep time could be used as a threshold concept for students’ conceptualization of evolution as proposed by Trend (2009).
Ramseyer hypothesized that if deep time is more consistently taught, especially preceding evolutionary instruction, then students might more easily grasp and accept evolution. His research yielded no significant results, and he concluded that perhaps the method of instruction by the teachers may have more of an impact on student learning than the simple inclusion of the deep time concept, or that in some cases, independent of the instruction or content, students will sometimes reject evolution outright based on non-curricular factors.

In a study of high school biology textbooks, Decker, Summers, and Barrow (2007) found that all textbooks (n = 11) chosen for the study contained some form of Earth history and a visualization of it, but they were inconsistent in their presentations and language. Only one studied textbook devoted any space to how science can be conducted when direct observations cannot be made, which is a core component to address when students claim that one cannot be scientific about the past, when there was no one there to witness it.

Dodick (2007) agreed that deep time should be included to aid understanding of evolution. He claimed that teachers should start instruction using the “concrete” fossil record as a visual representation of the processes of evolution. This step should naturally lead to the students asking why and how, following actual scientific methodologies where observations precede the theory. The use of fossils places the process of evolution in temporal strata, or deep time, addressing the threshold concept before teaching the core concept of evolution in its entirety.
Science Attitudes and Content Knowledge

As far back as 1947, connections between content knowledge and student attitudes were clear (Barkley, 1948). Barkley studied college freshman in a selection of introductory science and math courses compared to students in a one-year commercial course with a curriculum which did not include any sciences or mathematics. He compared the two groups to determine if their attitudes towards evolution changed following exposure to certain classes. He concluded that all students showed a favorable shift to evolution for all classes taken (even the non-science and math group), though not all changes were significant, and the non-science group showed a tendency “to be prejudiced against evolution” (p. 207) based on the scale of means generated by the creators of the test.

Rice, Olson, and Colbert (2011) wanted to compare first-year students’ and senior biology majors’ understanding and/or acceptance of evolution, followed by an analysis of their theological positions. These students’ results indicated that both acceptance and knowledge of evolution increased with instruction, without impacting the participants’ theological stance.

Carter (2013) studied the movement of attitudes concerning evolution and global climate change, their effects on students’ (n = 620) conceptualizations regarding NOS, and their performance in an introductory biology course in the northeastern United States. Following his research, Carter concluded that there was a positive and significant correlation ($r = .355$) between a student’s conceptualization of NOS and their acceptance of evolution, such that when they have greater attitudes towards science, they were more likely to accept the theory of evolution. This is supplemental to Rice, Olson, and Colbert
(2011) who stated that the correlation of attitudes and acceptance may be dependent on the amount of instruction each student has received at the time of the study.

Conversely, Hildering, Consoli, and van den Born (2013), in a Dutch study of Protestants that reject evolution, found that all respondents (n = 10) fostered a positive attitude towards science and its role in their everyday lives. Ironically, they all continued to reject evolution due to an *a priori* decision to accept the Christian Bible as fact, and that evolution does not meet the stringent criteria for “good science.” This denotes a lack of understanding of either NOS or the core tenets of biological evolution. Though, for clarity, it should be noted that not all Christian groups reject evolution outright; Pope John Paul II claimed that evolution was more than an hypothesis in his message to the Pontifical Academy of Sciences (Pope John Paul II, 1996), making biological evolution canon in the Catholic faith.

There appears to be a clear correlation between science attitudes and evolution knowledge and acceptance (Barkley, 1948; Carter, 2013; Rice et al., 2011), but there are exceptions (Hildering et al., 2013). There also appears to be an unclear directionality of effect between attitudes and content knowledge; it is the hope of this research to fill this gap.
CHAPTER III – METHODOLOGY

Research Design

The data collected in this study were from a repeated-measures, quasi-experimental, mixed-methods design utilizing a convergent parallel approach, data validation design (Edmonds & Kennedy, 2017) with non-random, convenience sampling of the participants enrolled in Historical Geology (n = 51, 75% response rate) and Principles of Biology II (n = 100, 26.5% response rate) over two consecutive semesters. The students’ attitudes towards science, knowledge of deep time, and knowledge of evolution were measured using one custom survey (see Appendix C) consisting of parts from the Scientific Attitude Inventory II (SAI II) (R. W. Moore & Foy, 1997), Geoscience Concept Inventory (GCI) (Libarkin, Ward, & Clark, 2011), Conceptual Inventory of Natural Selection (CINS) (D. L. Anderson & Evans, 2013), and the Measure of Understanding of Macroevolution (MUM) (Nadelson & Southerland, 2009). Questions were also added to the survey to collect demographic data and qualitative data from open-ended questions. Four open ended questions were added to the pre-test, and one additional question was added to the post-test. Table 2 illustrates a breakdown of questions found in this instrument.

Table 2

List of Research Instrument Item Numbers, Their Corresponding Content, and Their Original Instruments

<table>
<thead>
<tr>
<th>Item Numbers</th>
<th>Topic</th>
<th>Original Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 40</td>
<td>Attitude Towards Science</td>
<td>SAI II</td>
</tr>
<tr>
<td>41 - 55</td>
<td>Deep Time</td>
<td>GCI</td>
</tr>
<tr>
<td>56 - 65</td>
<td>Evolution - Natural Selection</td>
<td>CINS</td>
</tr>
</tbody>
</table>
Table 2 (continued).

<table>
<thead>
<tr>
<th>Page</th>
<th>Topic</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>66</td>
<td>Evolution - Macroevolution</td>
<td>MUM</td>
</tr>
<tr>
<td>75</td>
<td>Qualitative Perceptions</td>
<td>Woods &amp; Scharmann Interviews</td>
</tr>
</tbody>
</table>

Participants

At The University of Southern Mississippi, *Historical Geology* is a required course for those in both Geology and Construction Engineering Technology majors. Additionally, *Historical Geology* can be used by non-majors as a laboratory science elective. As a laboratory science, all students enrolled in the course must take a three-credit-hour lecture with a one-credit-hour laboratory accompaniment. Whether the students are taking it as a requirement for their major or as an elective laboratory science, *Historical Geology* has no prerequisite courses, and students may or may not have had other biology and/or geology courses beforehand. The students enrolled in the 2017-2018 academic school year (fall and spring semesters) were asked for voluntary participation in this study. Only one section of *Historical Geology* was taught per semester. Demographic data were collected as part of the research instrument for students’ gender, race, age, academic status, college major, and prior biology/geology undergraduate coursework. Students from this course were part of the treatment group.

The comparison group consisted of undergraduate students in *Principles of Biology II* (n = 100). The students enrolled in the 2017-2018 academic school year (fall and spring semesters) were asked for voluntary participation in this study. Only two sections of *Principles of Biology II* are taught in the fall semester, and both were used in this study. In the spring semester, multiple sections of the course were taught, but only one was taught by the same professor from the fall semester. As such, only the single
spring semester section was used. Demographic data were also collected as part of the research instrument for students’ gender, race, age, academic status, college major, self-described religious affiliation, and prior biology/geology undergraduate coursework.

Instruments

*Attitudes Towards Science*

The original Scientific Attitude Inventory (SAI) survey has been in use since 1970, with translations in both Hebrew and Thai. In 1997 an attempt to eliminate certain socio-cultural biases was made, leading to the development of the revised SAI, the SAI II (R. W. Moore & Foy, 1997). The SAI II provides a way for researchers to apply scientific constraints to attitudes concerning science and scientific concepts. All of this was conducted to gauge student interest in STEM subjects, and by extension, STEM careers (Maroo, 2013).

The SAI II consists of 40 questions (items 1 – 40 of the research instrument, Appendix C) which were scored using a five-item Likert-type response. These 40 questions reflect 12 position statements (six positive positions, and six negative positions) on student attitudes towards science. Point values are assigned to the scales and their reflection of positivity or negativity, giving the entire SAI II a range of scores from 40 – 200, with higher scores indicating a more positive attitude towards science. Content validity of the SAI II was claimed on the basis of a panel of judges regarding the relation of the items to the attitude positions, and construct validity was demonstrated using the field test and comparing the bottom and top 27% of respondents (R. W. Moore & Foy, 1997). Permission to use the SAI II can be found in Appendix D.
Knowledge of Deep Time

To determine student knowledge of deep time concepts, selections from the Geoscience Concept Inventory (GCI) were used. Originally, the GCI consisted of 69 validated questions that could be customized to create a sub-test on specific content areas. Using community feedback, the authors (Libarkin & Anderson, 2005) created a question bank of over 200 items. Over time, utilizing interviews, questionnaires, and piloted test items at more than 40 institutions with over 5000 students, the authors revised and developed the third version of the GCI (Clark & Libarkin, 2011; Libarkin & Anderson, 2005, 2006; Libarkin, Ward, Anderson, Kortemeyer, & Raeburn, 2011; Libarkin, Ward, Anderson, et al., 2011) with all items individually validated and deemed reliable using both item analysis and Rasch analysis techniques. The individual item validation was confirmed again through verbal response from Dr. Renee Clary during the proposal for this research. Fifteen items (items 41 – 55, Appendix C) concerning deep time were selected from this version for the research instrument used in this study with a possible score range of 0 – 15. Permission to use a subset of the GCI can be found in Appendix E.

Knowledge of Evolution

A combination of two concept inventories were used to determine student knowledge of evolution. Twenty items (items 56 – 75) were selected from these two inventories for use in this study’s research instrument with a possible score range of 0 – 20.

The first inventory that was used to determine student knowledge of evolution was the revised Conceptual Inventory of Natural Selection (CINS) (Evans & Anderson, 2013), and supplied 10 of the next 20 survey items (items 56 – 65, Appendix C) with a
possible score range of 0 – 10. Anderson attempted to create the CINS without demonstrating the semantic problems illustrated previously in Chapter II by Bishop & Anderson (1990), Gregory (2009), and R. Moore et al. (2006). The original form of the CINS (D. L. Anderson, Fisher, & Norman, 2002) illustrates 10 concepts relating to natural selection (biotic potential, carrying capacity, limited resources, limited survival, genetic variation, origin of variation, inherited variation, differential survival, changes in population, and origin of species) each of which is tested with two questions. Only one question from each concept was used in this study’s research instrument. Distractors for each question were developed by the authors of the instrument based on known student misconceptions. The questions in this instrument have been tested for face validity and internal validity, and results are reliable and consistent (D. L. Anderson et al., 2002; Evans & Anderson, 2013; Ramseyer, 2012). Individual item validation was confirmed by the instrument’s author via email. Ten years after the completion of the first CINS, the author piloted a study attempting to create a middle-school appropriate version of the survey, and in doing so also created an updated version of the CINS for high school/college level students. It is from this revised survey that items 56-65 for this research instrument were taken. Permission to use questions from the CINS and confirmation of individual item validation can be found in Appendix F.

The second inventory to be used to determine student knowledge of evolution was the Measure of Understanding of Macroevolution (MUM) (Nadelson & Southerland, 2009). This moves the students from general concepts of natural selection and microevolutionary change in the CINS – the “driving forces” of evolution – to its largest theme of long-term speciation. Items on the MUM have been individually validated
through expert feedback from evolutionary educators and biology professors and open-ended questions to gauge understanding. The MUM consists of 27 multiple-choice items relating to one of five macroevolutionary strands (phylogenetics, speciation, deep time, fossils, and nature of science). These questions were analyzed by the authors and experts in evolution education for content validity and the results were found to be consistent and reliable. Individual validation of the items was confirmed via email with the author of the instrument. The second 10 evolution-based items (items 66 – 75, Appendix C) for this dissertation’s research instrument were chosen from the MUM, with a possible score range of 0 – 10; two items came from the each of the five strands, completing the final 10 quantitative questions. Permission to use questions from the MUM and confirmation of individual item validation can be found in Appendix G.

Qualitative Data

Nadelson & Southerland (2009) determined that the original open-ended questions assisted with the validity of their instrument but added little to the quantitative data; when students scored low on the quantitative, multiple-choice questions in the MUM, their responses to the open-ended questions were also weak.

In a study conducted at a mid-western high school (Woods & Scharmann, 2001), a selection of open-ended questions were used, in much the same was as Nadelson & Southerland (2009), but the author followed the content questions with belief and perceived conflict/resolution questions. Woods and Scharmann coded the interviews according to a model laid out by Nelson in 1986. Nelson’s chapter in Science and Creation: Geological, Theological, and Educational Perspectives creates five nominal (not ordinal) choices that a person can make when attempting to accept evolution and its
compatibility with religion: (a) Atheistic Evolution, (b) Nontheistic Evolution, (c) Gradual Creation, (d) Progressive Creation, and (e) Quick Creation. Woods and Scharmann used these same nominal categories to classify their interviewed students, then added their own sixth category – Lacks Knowledge of Evolution. A modified form of these questions were the final items (items 76 – 79 [pre-test] or items 76 – 80 [post-test], Appendix C) used for the research instrument. In addition to their questions, this current study required similar questions concerning deep time, to supplement those by Woods and Scharmann concerning evolution. Permission to use these questions can be found in Appendix H. Below are the open-ended questions as presented at the end of the research instrument including notations for which questions are from Woods and Scharman, and which are original to the current study.

1. What are your perceptions of evolution? (Woods and Scharmann)

2. What are your perceptions of deep time? (original question)

3. Does the study of evolution conflict with your personal beliefs? (Woods and Scharmann) If so, how do you deal with those conflicts when they arise? (original question)

4. Does the study of deep time conflict with your personal beliefs? (Woods and Scharmann) If so, how do you deal with those conflicts when they arise? (original question)

5. Post-test question depending on the course:

   a. What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way? (original question)
b. What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way? (original question)

This research used both Likert-style and multiple-choice questions to determine misconceptions and changes in student knowledge. Additionally, the use of 4 (pre-test) or 5 (post-test) open-ended questions in this study probed the students’ relationship with deep time and evolution to identify thought processes and any other potential barriers to learning. By utilizing open-ended questions directly in the research instrument, every student participant was asked to provide qualitative data for this study and illustrate their own knowledge of the content as well as any conflict coping mechanisms that they may have had to utilize during the course.

Procedure

Prior to beginning the study, permission to conduct this research was obtained from The University of Southern Mississippi’s Institutional Review Board (Appendix I). Potential participants (n = 68) were students enrolled in Historical Geology for the Fall 2017 semester and the Spring 2018 semester. All procedures below apply to both semesters, unless otherwise indicated.

An explanation of the informed consent permission statement was given during the first lecture meeting, and signed forms (Appendix J) were obtained from consenting participants (n = 51). The parameters of the study were presented to all students and were informed that they can withdraw from the study at any time without repercussions.

The Fall 2017 and Spring 2018 Historical Geology course and its accompanying lab served as the treatment for this study and is described in detail below. Both semesters
only had one section of the course offered. This provided two total sections of participants (n = 51) with a 75% response rate. The pre-test was administered on the first day of lecture immediately following the discussion of the course syllabus from the instructor. Students were informed of the study after the discussion of the syllabus and were told that if they wanted to participate, they would need to complete the IRB consent form. During the final lecture meeting, the post-test instrument was given to the students for the final analysis, prior to completion of their final exam. Students would be given the research instrument to complete, then turn it in to the researcher. The instructor for the course then gave the final exam. As an incentive, students were offered bonus points by the instructor and pizza by the researcher for both the pre-test and post-test.

Participants in the comparison group were undergraduate students enrolled in *Principles of Biology II* (see Appendix K for an abbreviated lecture syllabus and Appendix L for an abbreviated lab syllabus) for the Fall 2017 semester and the Spring 2018 semester. The Fall 2017 semester had two sections available for study, and the Spring 2018 semester had one section. This provided a total of three sections of participants (n = 100) with a 26.5% response rate. A brief description of the study was given to the sections of students immediately following the first day of lecture, during the last five minutes of instructional time. Students who chose to participate were either moved to an empty classroom (for the first section of the Fall 2017 course) or stayed in the lecture hall (for the second section of the Fall 2017 semester and the Spring 2018 section) to sign the informed consent and complete the pre-test survey. Permission was not given to the researcher to conduct the pre- and post-test during normal lecture hours, and thus was conducted outside of normal instructional time. As an incentive, students
were offered bonus points by the instructor and pizza by the researcher for both the pre-
test and post-test.

*Treatment Group – Historical Geology*

*Historical Geology* was a one-semester course that can be used to fulfill non-
major science electives or was a required course for graduation under certain
undergraduate degrees. This course was offered for one section every semester and has
enrolled an average of 31.5 students during each enrollment period since the Fall 2015
semester.

*General Course Overview.* This course, to meet the minimum required enrollment
numbers, requires no prerequisites at The University of Southern Mississippi. However,
other schools *do* sometimes require Physical Geology to be mastered before entering
*Historical Geology*. Dr. Renee Clary (2011), wrote in a discussion board introduction to
her *Historical Geology* course, “A former colleague of mine once said that Geology I
(Physical Geology) provides the dictionary of the terms and the rules of grammar for
reading the ‘book’ of Geology II (Historical Geology). The problem with our ‘book’ is
that it has been laid face down in a campfire, and the earliest chapters are all but
obliterated.” This quote provides an excellent context to *Historical Geology*. Before one
can learn the history of the planet, one must understand the tools geologists use to study
it. Because of this, *Physical Geology* must be taught *before* *Historical Geology*.

At The University of Southern Mississippi, *Historical Geology* taught that content
in the first several weeks of the course. This allowed students to understand the context
for the rest of the material when conclusions are made about conditions of the ancient
past. In lab students were given the opportunity to utilize these tools first-hand. The
objectives for the course and an abbreviated syllabus for the lecture can be found in Appendix M, and the objectives and an abbreviated syllabus for the lab can be found in Appendix N.

**Readings and Resources.** The first required textbook for this course was *Historical Geology: Evolution of Earth and Life Through Time* (Wicander & Monroe, 2015). As an introduction to historical geology for both majors and non-majors, this text attempted to move away from the presentation of historical geology as collection of facts into a more cohesive, integrated and interdisciplinary text (Wicander & Monroe, 2015). The authors organized the content of the text into three unifying themes: plate tectonics, time, and evolutionary theory. These three themes serve to illustrate the interconnectedness of the course material. Chapters 1-6 of the text were devoted to physical geology concepts as preparation for the rest of the course, chapter 7 explained evolutionary theory and provided the foundation for the second theme stated above. Chapters 8-19 were devoted to the journey though Earth’s history where the concepts from the first seven chapters were used to support the content being presented concerning the Earth history and life history of the ancient past, from the Hadean through the Cenozoic (Appendix O).

The second book required for this course was *The Story of Life in 25 Fossils: Tales of Intrepid Fossil Hunters and the Wonders of Evolution* (Prothero, 2015). This book, told in an informal, conversational tone, presents twenty-five chapters (Appendix P), each devoted to a single evolutionary wonder, the fossils surrounding it, and the fossil hunters responsible for their discoveries. At the end of every chapter, Prothero listed places – museums, road cuts, mountains, and so forth – where the mentioned fossils can
be seen, if one was inclined to go looking for them, and/or further suggested readings which explain the conclusions presented throughout the chapter. In the course of study, his book served as a supplemental text meant to spur discussions alongside classroom lecture material.

The final text for this course was the lab manual, *Deciphering Earth History: Exercises in Historical Geology* (Gastaldo, Savrda, & Lewis, 2006). The manual attempted to teach the basic principles of geoscience (exercises 1-8) to interpret the rock record by using data across multiple continents and blending information from multiple disciplines. Exercises 9-12 focused specifically on evolution and fossils, and exercises 13-15 had the students using their skills for interpretation of real-world data. Appendix Q lists all exercises for this manual. Most exercises began with a few introductory pages, followed by hands-on activities, and some exercises end in either *thought questions* or Internet-based supplemental exercises.

**Assessments.** This class was taught by an instructor other than the researcher, with the same instructor teaching both semesters. To assess student understanding of the course material, the instructor utilized several different methods. In addition to standard exams, of which four were administered, the course conducted online quizzes for each chapter, random attendance quizzes, and online discussion boards. The online discussion boards provided a means by which students read articles – some which were scientific, and some which were not – to provide background and foundational understanding of core scientific concepts. The discussion boards are also where students were to read and discuss the supplemental text, *The Story of Life in 25 Fossils.* The discussion boards also
served a secondary purpose by meeting many of the General Education Curriculum 02 requirements set forth by The University of Southern Mississippi listed below:

1. Students will develop a topic and present ideas through writing in an organized, logical, and coherent form and in a style that is appropriate for the discipline and the situation.

2. Students will use Standard English grammar, punctuation, spelling, and usage.

3. Students will write a coherent analytical essay of a rhetorical situation or through written communication effectively analyze the components of an argument.

4. Students will differentiate the basic concepts in a discipline of science.

5. Students will employ the scientific method, interpret scientific data, and reach a plausible conclusion.

6. Students will demonstrate the ability to work with real world situations involving fundamental math concepts.

7. Students will evaluate major developments in world history, the historical roots of contemporary global cultures, or the literary, philosophical, or religious contributions of world cultures.

8. Students will comprehend and proficiently interpret text.

9. Students will understand the influence of art, music, theatre and/or dance on culture.

10. Students will actively provide their own reasoned judgment of art, music, theatre and/or dance.

11. Students will identify theories of human behavior, societal development, human decision making, and group/social processes and apply theories and methodologies to real world situations and current issues and concerns.
12. Students will recognize the effects of diversity among individuals or within/among groups/social systems.

13. Students will demonstrate basic technology literacy and apply knowledge of basic application software to the creation of structured documents and research.

14. Students will find, use, and cite relevant sources of information.

15. Students will use appropriate strategies to speak effectively in professional, social, or personal contexts.

*Writing. Courses in the first five GEC categories, with the exception of Mathematics, require students to write a minimum of 2500 words.

**Comparison Group – Principles of Biology II**

*Principles of Biology II* was a one-semester course required by all Biological Sciences majors at The University of Southern Mississippi. This course is offered every semester and has been taught in the past by multiple instructors. For this research, one instructor was chosen who has been known to teach at least one section every semester for the last seven years. This allowed the research to use this instructor for both semesters of the study.

*General Course Overview.* This course does not require any prerequisite courses in either biology or geology. This is evidenced by the responses by the participants indicating that only 82% had previously had any biology and/or geology course beforehand. *Principles of Biology II* is a course designed for biology majors to explore the biological sciences within the realms of systematics, biodiversity, form and function, evolution, and ecology. As a science course, it also partially fulfills the General
Education Curriculum 02 requirements set forth by The University of Southern Mississippi as stated above.

Readings and Resources. The first required textbook for this course was *Principles of Biology* (Brooker, Widmaier, Graham, & Stiling, 2015). Similar to the textbook for the geology class, the textbook for this biology class has less of an emphasis on rote memorization of facts, and instead focuses on a comprehensive, integrated approach that leverage pedagogical features including “Focus on Core Concepts,” “Learning Outcomes,” “Formative Assessment,” “Quantitative Analysis,” and “BioConnections and Evolutionary Connections” (p. iv). The text also provided McGraw-Hill Connect access to online content which students could use to supplement their in-class lectures. The textbook for this class was used for both *Principles of Biology I* and *Principles of Biology II*. As such, as noted in the abbreviated syllabus listed in Appendix K, not all chapters (Appendix R) were used in *Principles of Biology II*. Most of the content for the comparison group came from chapters 18 – 47 of the textbook.

The second required text for this course was the lab manual, *Principles of Biological Sciences II Lab Manual* (Sellers, 2015). This manual was meant to serve as a compliment to the lecture material and provide a means by which students could create hands-on experiences with the content being provided in during the lecture by creating activities for a micro- and macroscopic level. Due to the writing-heavy portion of the lab reports and literature review required by the lab, students were also assigned a third and final book for the course, *A Short Guide to Writing About Biology* (Pechenik, 2013), to assist students with the proper techniques in which to write up scientific protocols and technical reports.
Assessments. This class was taught by an instructor other than the researcher, with the same instructor teaching both semesters. To assess student understanding of the course material, the instructor utilized several different methods. In addition to standard exams, of which five were administered, the course conduced online pre-chapter readings and post-chapter quizzes, daily clicker grades for instant feedback, a lab report, a literature review, and a laboratory practical.

Data Analysis

Because the comparison group was taught evolution without the emphasis of deep time, and the treatment group was taught evolution firmly rooted within the context of deep time, data analysis for this dissertation attempted to determine the relationship deep time has to a student’s knowledge of evolution, and if original attitudes towards science were altered by exposure to the content.

Quantitative analysis of the research instrument included a path model analysis to determine meaningful relationships between student attitudes towards science and deep time, student attitudes towards science and evolution, and deep time and evolution. The path model analysis was also used to determine the indirect and total effects of attitudes towards science and deep time on students’ knowledge of evolution. Additionally, 2-way mixed ANOVAs and linear regressions were used to analyze each of the items, their core concepts, and their effects on each other, if any.

The qualitative data, in the form of the four-to-five open-ended questions at the end of the research instrument, attempted to illustrate any personal factors that may have affected the overall outcome of the quantitative data using content analysis (Merriam,
in a convergent parallel approach, data validation design (Edmonds & Kennedy, 2017).

Variable means were compared using a 2-way mixed analysis of variance (ANOVA), a linear regression, and a path model analysis. Three separate, 2-way mixed ANOVAs were conducted to determine if there were any main effects or interactions between which group a student was in (an indicator of their exposure to deep time content) and whether it was a pre-test or post-test as it related to their Scientific Attitude Inventory (SAI) score, their evolution score, or their deep time score. By using a pre-test/post-test comparison in 2-way mixed ANOVA, any differences between classes in pre-test scores could be accounted for. The linear regression was conducted to determine if student’s evolution scores correlated with their SAI and/or deep time scores, and by how much. In the research instrument for this study, student attitudes were derived from their scores for items 1 – 40, deep time scores were from items 41 – 55, and evolution scores were from items 56 – 75. The statistical computations were calculated using IBM SPSS, Version 25, for Windows.

To determine the strength of the relationships between the variables in the gathered data (Meyers, Gamst, & Guarino, 2013), a path model analysis was used. According to Schumacker & Lomax (2010), “path models permit theoretically meaningful relationships among variables that cannot be specified in a single additive regression model.” (p.156) In the case of this study, path model analysis was used to determine meaningful relationships between student attitudes towards science and deep time, student attitudes towards science and evolution, and deep time and evolution. Path model analysis was also used to determine the indirect and total effects of attitudes
towards science and deep time on students’ knowledge of evolution (Figure 1). The statistical computations were calculated using IBM SPSS AMOS 5, for Windows, and path coefficients in these path models were derived from the values of a standardized regression coefficient ($\beta$).

Figure 1. Path model analysis illustrating the hypothesized relationships of exposure to Historical Geology on students’ attitudes towards science and their understanding of deep time and evolution.

Coding of the open-ended questions utilized a convergent parallel approach, data validation design (Edmonds & Kennedy, 2017) attempted to categorize each of the participants into one of eight nominal Evolution/Creation categories, six of which were described by Woods and Scharmann (2001) and modified for this dissertation. A convergent parallel approach allowed for both quantitative and qualitative data to be collected simultaneously, followed by converging the two for analysis. By using a data validation design, the qualitative data are emphasized less than the quantitative data and
is used primarily to assist in validating the quantitative scores (Edmonds & Kennedy, 2017).

Because of the use of a previous coding scheme modified for this research, a content analysis (Merriam, 2009) technique was used when reviewing the open-ended responses, looking for repeated uses of a “certain phrase or speech pattern” (p.205). This technique allows for the analysis of the original responses to construct nominal categories. As such, the original coding scheme used by Woods and Scharmann (2011) was used to begin the analysis of the student responses, and is shown in Table 3. During the analysis, the researcher and assistant noted that many of the student responses did not fit neatly into the pre-constructed categories. As a result, the researcher added two more categories to accommodate novel participant responses, as well as a clarification that the eight categories are not intended to represent a stepwise progression from Quick Creation to Atheistic Evolution, but are instead, nominal, standalone categories. Table 4 lists the coding categories and their criteria from the modified, final version of the coding scheme used for the content analysis that was performed on the study’s open-ended questions.

The coding of the open-ended questions attempted to discern any underlying similarities or differences between students from the treatment and comparison groups.

Table 3

*Coding scheme used for the Woods & Scharmann study.*

<table>
<thead>
<tr>
<th>Coding Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atheistic Evolution</td>
</tr>
<tr>
<td>1. Atheism on other grounds is often coupled with imperfection in biological systems arguing against a creator.</td>
</tr>
<tr>
<td>Nontheistic Evolution</td>
</tr>
</tbody>
</table>
Table 3 (continued).

1. Scientific truth is objective and is (or should be) independent of religious assumptions.
2. Arguments for or against God from natural processes are logically flawed and vice versa.

Gradual Creation (theistic evolution)
1. Evolution is God's way of creation (just as gravitation is God's way of controlling the Earth's movement).

2. Creation is the ultimate origin of the universe and continuous at each moment in its maintenance.

Progressive Creation (limited evolution)
1. The great age of the universe, earth and life are accepted, as is the existence of as much evolutionary change as is directly shown by fossils.

2. New lineages (including humans) are regarded as separate acts of special creation. The complexity of the new forms when created increases progressively through time.

Quick Creation (“scientific creationist”)
1. The earth is only a few thousand years (up to 10,000 years) old.

2. The geological column was formed in a yearlong global flood.

3. Evolutionary change is only within "kind".

Lacks Knowledge of Evolution (or no response)

Table 4

_Coding scheme used for this study’s research, modified from Woods and Scharmann above._

No Knowledge
1. Student did not respond to questions.

2. Student did not describe any perceptions of evolution, or answers might have been nonsensical/irrelevant.
Table 4 (continued).

Atheistic Evolution

1. Atheism on other grounds is often coupled with imperfection in biological systems arguing against a creator.

2. May appear antagonistic towards religion or religious concepts.

Nontheistic Evolution

1. Scientific truth is objective and is (or should be) independent of religious assumptions.

2. Arguments for or against God from natural processes are logically flawed and vice versa.

Incomplete Evolution

1. Internal conflicts with the precepts of evolution arise from perceived "holes" in the theory.

2. Argument can be based on the notion that no one witnessed creation/evolution and therefore cannot be completely proven.

3. May be a gateway to movement into Progressive Creation or Quick Creation

Casual Creation

1. Evolution is God's way of creation (just as gravitation is God's way of controlling the Earth's movement.)

2. Creation is the ultimate origin of the universe and continues at each moment in its maintenance.

Progressive Creation
Table 4 (continued).

1. The great age of the universe, Earth, and life are accepted as is the existence of as much evolutionary change as is directly shown by fossils.

2. The origin of life and new lineages (including humans) regarded as separate acts of special creation. The complexity of the new forms when created increases progressively through time.

Graded Creation

1. The great age of the universe, Earth, and life are accepted as is the existence of as much evolutionary change as is directly shown by fossils

2. The concept of microevolution/adaptation is readily accepted, but only occurs within species - rejection of speciation as a whole.

Quick Creation

1. The Earth is only a few thousand years (<10,000) old.

2. The geological column was formed in a year-long global flood.

3. The concept of microevolution/adaptation may be accepted, but only occurs within species - rejection of speciation as a whole.

Each pre-test and post-test was examined by the researcher and another graduate student simultaneously. Considering each of the responses to the open-ended questions at the end of the research instrument, the participants were placed into one of the eight categories listed in Table 4. In special cases where the answers to the open-ended questions required more data, the participants’ answer to the demographic question, “Based on your knowledge, how old is the Earth?” may have been used to determine if
the participant was to be placed in the Quick Creation category or not. Because the researcher and assistant coded all responses concurrently, and a consensus was reached for each participant, an inter-rater reliability was not calculated.

A list containing four exemplars from each category is shown in Appendix U, representing >10% of the data collected from student responses. Because some categories were more heavily represented within the sample (Table 9), four responses from each category were randomly selected using an online random selection generator. Student responses were assigned ID numbers in sequence based on the order in which the instrument was completed. Numbers assigned to responses corresponding to each category were placed into the online random generator (e.g., all responses assigned No Knowledge). The generator randomized the list and the first four numbers (after removing the entries found in Appendices V, X, or X, to avoid duplications) were chosen to represent the sample for that category. This process was completed for all eight categories, providing four selections for each category, and 32 responses total, to act as exemplars for the eight categories.

Below are listed the open-ended questions participants completed that were used for the coding scheme in Table 4. Annotations have been added here to indicate which questions are from Woods and Scharmman, and which are original to the current study.

1. What are your perceptions of evolution? (Woods and Scharmman)
2. What are your perceptions of deep time? (original question)
3. Does the study of evolution conflict with your personal beliefs? (Woods and Scharmman) If so, how do you deal with those conflicts when they arise? (original)
4. Does the study of deep time conflict with your personal beliefs? (Woods and Scharmann) If so, how do you deal with those conflicts when they arise? (original)

5. Post-test question depending on the course:
   a. What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way? (original question)
   b. What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way? (original question)
CHAPTER IV – ANALYSIS OF DATA

Introduction

The purpose of this research was to determine the impact on students’ knowledge of evolution when it was contextualized using deep time. Variable means were compared using a 2-way mixed analysis of variance (ANOVA), a linear regression, and a path model analysis. Three separate 2-way mixed ANOVAs were conducted to determine if there were any main effects or interactions between which group a student was in and whether it was a pre-test or post-test as it related to their Scientific Attitude Inventory (SAI) score, their evolution score, or their deep time score. By using a pre-test/post-test comparison in 2-way mixed ANOVA, any differences between classes in pre-test scores could be accounted for. The linear regression was conducted to determine if student’s evolution scores correlated with their SAI and/or deep time scores. The path model analysis calculated the strength of the relationships between each of the three scores in the treatment group as well as the strength of each pre-test component with its accompanying post-test score in the treatment group. Because the treatment group was the only group to receive explicit instruction on deep time, the treatment group was the only group to have the path model analysis conducted. This attempted to determine any direct or indirect relationships between deep time and evolution scores.

Coding of the open-ended questions utilized a convergent parallel approach, data validation design (Edmonds & Kennedy, 2017) attempted to categorize each of the participants into one of eight Evolution/Creation categories. A convergent parallel approach allowed for both quantitative and qualitative data to be collected at the same time and then converging the two for analysis. By using a data validation design, the
qualitative data are emphasized less than the quantitative data and is used primarily to assist in validating the quantitative scores.

A content analysis (Merriam, 2009) technique was used when reviewing the open-ended responses, looking for the use of specific phrases or language. This technique allows for the analysis of the original responses to construct categories. The coding of the open-ended questions attempted to discern any underlying similarities or differences between students from the treatment and comparison groups.

Each pre-test and post-test was examined by the researcher and another graduate student simultaneously. Considering each of the responses to the open-ended questions at the end of the research instrument, the participants were placed into one of the eight categories listed in Table 4 of Chapter III.

Description of Sample

Demographic Data

In Principles of Biology II (BSC 111), 61 students completed both the pre- and post-test instruments in the fall 2017 semester (a response rate of 22.3%), and 39 students completed both instruments in the spring 2018 semester (a response rate of 37.1%), providing a total participation of n = 100 with a response rate of 26.5%. The participants in the fall 2017 semester were from two separate sections of the course, both taught by the same instructor. In Historical Geology (GLY 103), 21 students completed both the pre- and post-test instruments in the fall 2017 semester (a response rate of 75%), and 30 students completed both instruments in the spring 2018 semester (a response rate of 75%), providing a total participation of n = 51 with a response rate of 75%. Each semester Historical Geology only contained one section each, both taught by the same
instructor. The frequencies and percentages of participants’ gender, race, age group, academic classification, major (science vs. non-science) and self-described religious affiliation for each course are listed below in Tables 5 and 6. Table 7 is included as a reference to the university’s demographic makeup per the Fall 2017 Fact Book (Office of Institutional Research, 2018) and Mississippi Institutions of Higher Learning (IHL MIS, 2018).

Table 5

Frequencies and Percentages of Participants in BSC 111 by Gender, Race, Age Group, Academic Classification, Major, and Self-Described Religious Affiliation (n = 100)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>% of sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>29</td>
<td>29.0%</td>
</tr>
<tr>
<td>Female</td>
<td>71</td>
<td>71.0%</td>
</tr>
<tr>
<td>Race:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>60</td>
<td>60.0%</td>
</tr>
<tr>
<td>African American</td>
<td>30</td>
<td>30.0%</td>
</tr>
<tr>
<td>Asian</td>
<td>4</td>
<td>4.0%</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>4.0%</td>
</tr>
<tr>
<td>Native American</td>
<td>1</td>
<td>0.0%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1</td>
<td>1.0%</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Age:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-20</td>
<td>79</td>
<td>79.0%</td>
</tr>
<tr>
<td>21-23</td>
<td>18</td>
<td>18.0%</td>
</tr>
<tr>
<td>24-26</td>
<td>2</td>
<td>2.0%</td>
</tr>
<tr>
<td>27-29</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>&gt;30</td>
<td>1</td>
<td>1.0%</td>
</tr>
</tbody>
</table>
Table 5 (continued).

<table>
<thead>
<tr>
<th>Classification</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>54</td>
<td>54.0%</td>
</tr>
<tr>
<td>Sophomore</td>
<td>17</td>
<td>17.0%</td>
</tr>
<tr>
<td>Junior</td>
<td>17</td>
<td>17.0%</td>
</tr>
<tr>
<td>Senior</td>
<td>7</td>
<td>7.0%</td>
</tr>
<tr>
<td>Super-Senior</td>
<td>5</td>
<td>5.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Major</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>99</td>
<td>99.0%</td>
</tr>
<tr>
<td>Non-Science</td>
<td>1</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Religion</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Christian (non-specific, non-denominational)</td>
<td>34</td>
<td>35.0%</td>
</tr>
<tr>
<td>Baptist</td>
<td>17</td>
<td>17.0%</td>
</tr>
<tr>
<td>Catholic</td>
<td>15</td>
<td>15.0%</td>
</tr>
<tr>
<td>None</td>
<td>10</td>
<td>10.0%</td>
</tr>
<tr>
<td>Methodist</td>
<td>8</td>
<td>8.0%</td>
</tr>
<tr>
<td>N/A</td>
<td>4</td>
<td>4.0%</td>
</tr>
<tr>
<td>Agnostic</td>
<td>2</td>
<td>2.0%</td>
</tr>
<tr>
<td>Atheist</td>
<td>2</td>
<td>2.0%</td>
</tr>
<tr>
<td>Mormon</td>
<td>2</td>
<td>2.0%</td>
</tr>
<tr>
<td>Apostolic</td>
<td>1</td>
<td>1.0%</td>
</tr>
<tr>
<td>Episcopalian</td>
<td>1</td>
<td>1.0%</td>
</tr>
<tr>
<td>Muslim</td>
<td>1</td>
<td>1.0%</td>
</tr>
<tr>
<td>Pentecostal</td>
<td>1</td>
<td>1.0%</td>
</tr>
<tr>
<td>Reformist</td>
<td>1</td>
<td>1.0%</td>
</tr>
<tr>
<td>Spiritual</td>
<td>1</td>
<td>1.0%</td>
</tr>
</tbody>
</table>
Table 6  

*Frequencies and Percentages of Participants in GLY 103 by Gender, Race, Age Group, Academic Classification, Major, and Self-Described Religious Affiliation* (n = 51)  

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>% of sample</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>33</td>
<td>64.7%</td>
</tr>
<tr>
<td>Female</td>
<td>18</td>
<td>35.3%</td>
</tr>
<tr>
<td><strong>Race:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>29</td>
<td>56.9%</td>
</tr>
<tr>
<td>African American</td>
<td>12</td>
<td>23.5%</td>
</tr>
<tr>
<td>Native American</td>
<td>1</td>
<td>2.0%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>4</td>
<td>7.8%</td>
</tr>
<tr>
<td>Asian</td>
<td>2</td>
<td>3.9%</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>3.9%</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>1</td>
<td>2.0%</td>
</tr>
<tr>
<td><strong>Age:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-20</td>
<td>28</td>
<td>54.9%</td>
</tr>
<tr>
<td>21-23</td>
<td>15</td>
<td>29.4%</td>
</tr>
<tr>
<td>24-26</td>
<td>5</td>
<td>9.8%</td>
</tr>
<tr>
<td>27-29</td>
<td>2</td>
<td>3.9%</td>
</tr>
<tr>
<td>&gt;30</td>
<td>1</td>
<td>2.0%</td>
</tr>
<tr>
<td><strong>Classification:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
<td>14</td>
<td>27.5%</td>
</tr>
<tr>
<td>Sophomore</td>
<td>9</td>
<td>17.6%</td>
</tr>
<tr>
<td>Junior</td>
<td>17</td>
<td>33.3%</td>
</tr>
<tr>
<td>Senior</td>
<td>8</td>
<td>15.7%</td>
</tr>
<tr>
<td>Super-Senior</td>
<td>3</td>
<td>5.9%</td>
</tr>
</tbody>
</table>

Major:
Table 6 (continued).

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>36</td>
<td>70.6%</td>
</tr>
<tr>
<td>Non-Science</td>
<td>15</td>
<td>29.4%</td>
</tr>
</tbody>
</table>

Religion:

<table>
<thead>
<tr>
<th>religion</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christian (non-specific, non-denominational)</td>
<td>14</td>
<td>27.5%</td>
</tr>
<tr>
<td>N/A</td>
<td>10</td>
<td>19.6%</td>
</tr>
<tr>
<td>None</td>
<td>9</td>
<td>17.6%</td>
</tr>
<tr>
<td>Baptist</td>
<td>8</td>
<td>15.7%</td>
</tr>
<tr>
<td>Atheist</td>
<td>2</td>
<td>3.9%</td>
</tr>
<tr>
<td>Catholic</td>
<td>2</td>
<td>3.9%</td>
</tr>
<tr>
<td>Agnostic</td>
<td>1</td>
<td>2.0%</td>
</tr>
<tr>
<td>Lutheran</td>
<td>1</td>
<td>2.0%</td>
</tr>
<tr>
<td>Pentecostal</td>
<td>1</td>
<td>2.0%</td>
</tr>
<tr>
<td>Polytheistic</td>
<td>1</td>
<td>2.0%</td>
</tr>
<tr>
<td>Episcopalian</td>
<td>1</td>
<td>2.0%</td>
</tr>
<tr>
<td>Undecided</td>
<td>1</td>
<td>2.0%</td>
</tr>
</tbody>
</table>

Table 7

Demographic statistics for The University of Southern Mississippi undergraduates acquired from the USM Fact Book 2017-2018 and IHL MIS data (n = 11,815)

<table>
<thead>
<tr>
<th>Gender</th>
<th>n</th>
<th>% of University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>4408</td>
<td>37.3%</td>
</tr>
<tr>
<td>Female</td>
<td>7407</td>
<td>62.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Race</th>
<th>n</th>
<th>% of University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>7249</td>
<td>61.4%</td>
</tr>
<tr>
<td>African American</td>
<td>3369</td>
<td>28.5%</td>
</tr>
</tbody>
</table>
Table 7 (continued).

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hispanic</td>
<td>446</td>
<td>3.8%</td>
</tr>
<tr>
<td>Multiracial</td>
<td>327</td>
<td>2.8%</td>
</tr>
<tr>
<td>Asian</td>
<td>230</td>
<td>2.0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>128</td>
<td>1.1%</td>
</tr>
<tr>
<td>Native American</td>
<td>54</td>
<td>0.5%</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>12</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

Classification:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>2396</td>
<td>20.3%</td>
</tr>
<tr>
<td>Sophomore</td>
<td>1899</td>
<td>16.1%</td>
</tr>
<tr>
<td>Junior</td>
<td>2879</td>
<td>24.4%</td>
</tr>
<tr>
<td>Senior</td>
<td>4327</td>
<td>36.6%</td>
</tr>
<tr>
<td>Post Baccalaureates</td>
<td>314</td>
<td>2.7%</td>
</tr>
</tbody>
</table>

Major:

<table>
<thead>
<tr>
<th>Major</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>5060</td>
<td>42.8%</td>
</tr>
<tr>
<td>Non-Science</td>
<td>6885</td>
<td>58.3%</td>
</tr>
</tbody>
</table>

As noted above, there are some differences between class makeup, not only between the two groups of the study, but between the two groups and the demographics of The University of Southern Mississippi as a whole. In *Principles of Biology II*, the respondents were 71% female, compared to *Historical Geology* respondents at 35.3% female, and a 62.7% female overall makeup at the university.

Freshman on the campus of The University of Southern Mississippi account for 20.3% of the population, but represented 54% of the *Principles of Biology II* participants, and 27.5% of the participants of *Historical Geology*. 
When comparing science majors to non-science majors, the sample from *Principles of Biology II* was composed of 99% science majors and *Historical Geology* was composed of 70.6% science majors, whereas The University of Southern Mississippi has a 42.8% science major composition.

Some of the group demographics shared similarities to those of the undergraduate population at The University of Southern Mississippi. Of the *Principles of Biology II* participants, 60% were Caucasian, compared to 56.9% Caucasian participation in *Historical Geology*, and the university having a 61.4% Caucasian population. African Americans participating in the research were 30% of the participants in *Principles of Biology II* and 23.5% of the participants in *Historical Geology*. This would be compared to the 28.5% African American population for The University of Southern Mississippi.

17% of the *Principles of Biology II* participants were Sophomores, 17.6% of the *Historical Geology* participants were Sophomores, and 16.1% of The University of Southern Mississippi undergraduate students were Sophomores.

*Statistical Data*

Each participant who completed the pre- and post-test for each group received three scores – scientific attitude, derived from the Scientific Attitude Inventory II (SAI), with a possible score range of 40 – 200; evolution, derived from questions from the Concept Inventory of Natural Selection (CINS) and the Measure of Understanding of Macroevolution (MUM), with a possible score range of 0 – 20; and deep time, derived from the Geoscience Concept Inventory (GCI), with a possible score range of 0 – 15. Mean scores for these concepts are listed in Table 8.
Table 8

*Comparison of descriptive statistics of the three components of the research instrument - scientific attitude, evolution, and deep time.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Biology Pre-test</th>
<th>Biology Post-test</th>
<th>Geology Pre-test</th>
<th>Geology Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>SAI</td>
<td>150.99</td>
<td>13.47</td>
<td>148.43</td>
<td>16.16</td>
</tr>
<tr>
<td>Evolution</td>
<td>10.08</td>
<td>3.37</td>
<td>10.45</td>
<td>3.58</td>
</tr>
<tr>
<td>Deep Time</td>
<td>5.14</td>
<td>2.52</td>
<td>5.41</td>
<td>2.47</td>
</tr>
</tbody>
</table>

Analysis of the open-ended questions at the end of the research instrument were used to determine the participants’ position regarding evolution and/or deep time with their own personal beliefs. To properly assign each student to a category, answers regarding their perceptions of evolution were compared against their answer to the question concerning their perception of deep time and their method(s) of conflict resolution, if any. Listed below are the open-ended questions used for this analysis.

1. What are your perceptions of evolution?

2. What are your perceptions of deep time?

3. Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

4. Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

5. Post-test question depending on the course:
   a. What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
b. What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?

After analyzing all of the participant responses, using content analysis (Merriam, 2009) each student was placed into one of the eight categories (Table 9) as described above in Table 4 of Chapter III.

Table 9

Comparison of Evolution/Creation Categorization by self-identified perceptions and conflict resolutions.

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of BSC 111 Students (n = 100)</th>
<th>Number of GLY 103 Students (n = 51)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>No Knowledge</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Atheistic Evolution</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Nontheistic Evolution</td>
<td>50</td>
<td>49</td>
</tr>
<tr>
<td>Incomplete Evolution</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Casual Creation</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Progressive Creation</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Graded Creation</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Quick Creation</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Tests of Hypotheses

**Hypothesis 1.** There is a significant mean change ($p < 0.05$) in student evolution scores when comparing *Principles of Biology II* participants with *Historical Geology* participants.

The data collected for the evolution component – which combined the 10 questions from the CINS and 10 questions from the MUM – of the research instrument
scores contained a sample size of $n = 100$ (out of a total enrollment of 378, a 26.5% response rate) for the BSC 111 group and $n = 51$ (out of a total enrollment of 68, a 75% response rate) for the GLY 103 group. The evolution mean pre-test score for the BSC 111 group was $\bar{x} = 10.08$ ($s = 3.37$) and was $\bar{x} = 10.45$ ($s = 3.58$) for the BSC 111 post-test score, out of a possible 20 points. The evolution mean pre-test score for the GLY 103 group was $\bar{x} = 9.10$ ($s = 3.79$) and was $\bar{x} = 9.47$ ($s = 3.42$) for the GLY 103 post-test score, out of a possible 20 points. Levene’s test for homogeneity of variance was not violated for either the pre-test ($p = .209$) or the post-test ($p = .843$), indicating the variance in evolution mean scores is equal across the two groups. Table 10 illustrates the mean evolution scores for each of the two courses.

Table 10

*Descriptive statistics for the evolution scores between the BSC 111 and GLY 103 classes.*

<table>
<thead>
<tr>
<th>Class</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evolution Pre-test Scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>10.08</td>
<td>3.366</td>
<td>100</td>
</tr>
<tr>
<td>Geology</td>
<td>9.10</td>
<td>3.786</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>9.75</td>
<td>3.531</td>
<td>151</td>
</tr>
<tr>
<td>Evolution Post-test Scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>10.45</td>
<td>3.577</td>
<td>100</td>
</tr>
<tr>
<td>Geology</td>
<td>9.47</td>
<td>3.420</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>10.12</td>
<td>3.544</td>
<td>151</td>
</tr>
</tbody>
</table>

Significance testing was conducted using a two-way mixed analysis of variance (ANOVA) in SPSS, v.25. This ANOVA showed that there was no significant main effect of Group (BSC 111 or GLY 103) ($F(1,149) = 3.17, p = .077, \eta^2_p = .021$) on the Evolution scores. In addition, there was also no significant main effect of Time (Evolution Pre-test or Evolution Post-test) on evolution scores ($F(1,149) = 2.20, p = .140, \eta^2_p = .015$). The
analysis of the interaction between Group and Time showed no significant effect
\( F(1, 149) < .001, p = .996, \eta_{p}^2 < .001 \) on the evolution scores (Figure 2).

![Figure 2. SPSS output showing the lack of interaction between Time and Group for the 2-way Mixed ANOVA for the Evolution variable.](image)

A multiple linear regression was completed to predict *Principles of Biology II* Evolution Post-test scores based on respondents’ Scientific Attitude Inventory (SAI) Post-test scores and Deep Time Post-test scores. The data calculated that the mean Evolution Post-test score for this sample \((n = 100)\) was 10.45 with a highest score of 18 out of a possible 20.

A significant regression equation was found using SPSS, v.25, \( F(2, 97) = 38.02, p < .001 \), with an \( R^2 \) of .439, indicating that 43.9\% of the variance is accounted for by the model. Participant’s predicted Evolution Post-test scores is equal to \((-0.265) + (0.042)(SAIPost) + (0.828)(DeepTimePost)\). Participant’s Evolution Post-test scores
increased .042 points for each increase in SAI Post-test score and increased .828 points for each increase in Deep Time Post-test score. Deep Time Post-test scores were highly significant ($p < .001$), and SAI Post-test scores were significant ($p = .021$) (Table 11).

Table 11

*Table of regression coefficients for the BSC 111 class, illustrating the effects of the SAI and Deep Time scores on the participants’ Evolution scores.*

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Constant)</td>
<td>- .265</td>
<td>2.529</td>
<td>- .105</td>
</tr>
<tr>
<td>SAI Post</td>
<td>.042</td>
<td>.018</td>
<td>.190</td>
</tr>
<tr>
<td>Deep Time Post</td>
<td>.828</td>
<td>.117</td>
<td>.573</td>
</tr>
</tbody>
</table>

a. Dependent Variable: EvolutionPost

A second multiple linear regression was completed to predict Historical Geology Evolution Post-test scores based on respondents’ Scientific Attitude Inventory (SAI) Post-test scores and Deep Time Post-test scores. The data calculated that the mean Evolution Post-test score for this sample ($n = 51$) was 9.47 with a highest score of 16 out of a possible 20.

A significant regression equation was found using SPSS, v.25, $F(2,48) = 13.97$, $p < .001$, with an $R^2$ of .367, indicating that 36.7% of the variance is accounted for by the model. Participants’ predicted Evolution Post-test scores is equal to ($-1.270$) + (.045)(SAI Post) + (.594)(Deep Time Post). Participant’s Evolution Post-test scores increased .045 points for each increase in SAI Post-test score and increased .594 points for each increase in Deep Time Post-test score. Analysis indicated that Deep Time Post-
test scores were significant \((p < .001)\), but SAI Post-test scores were not \((p = .075)\) (Table 12).

Table 12

*Table of regression coefficients for the GLY 103 class, illustrating the effects of the SAI and Deep Time scores on the participants’ Evolution scores.*

<table>
<thead>
<tr>
<th></th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
</tr>
<tr>
<td>(Constant)</td>
<td>-1.270</td>
<td>3.422</td>
<td>-</td>
</tr>
<tr>
<td>SAIPost</td>
<td>.045</td>
<td>.025</td>
<td>.220</td>
</tr>
<tr>
<td>DeepTimePost</td>
<td>.594</td>
<td>.143</td>
<td>.501</td>
</tr>
</tbody>
</table>

a. Dependent Variable: EvolutionPost

*Hypothesis 2.* There is a significant mean change \((p < 0.05)\) in student deep time scores when comparing *Principles of Biology II* participants with *Historical Geology* participants.

The data collected for the Deep Time component – which contained 15 questions from the GCI – of the research instrument scores contained a sample size of \(n = 100\) for the BSC 111 group and \(n = 51\) for the GLY 103 group. The deep time mean pre-test score for the BSC 111 group was \(\bar{x} = 5.14\) \((s = 2.52)\) and was \(\bar{x} = 5.41\) \((s = 2.47)\) for the BSC 111 post-test score, out of a possible 15 points. The deep time mean pre-test score for the GLY 103 group was \(\bar{x} = 5.65\) \((s = 2.19)\) and was \(\bar{x} = 7.14\) \((s = 2.89)\) for the GLY 103 post-test score (Table 13). Levene’s test for homogeneity of variance was not violated for either the pre-test scores \((p = .434)\) or the post-test scores \((p = .130)\), indicating the variance in deep time mean scores is equal across the two groups.
Table 13

*Descriptive statistics for the deep time scores between the BSC 111 and GLY 103 classes.*

<table>
<thead>
<tr>
<th>Course</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep Time Pre-test Scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>5.14</td>
<td>2.519</td>
<td>100</td>
</tr>
<tr>
<td>Geology</td>
<td>5.65</td>
<td>2.189</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>5.31</td>
<td>2.417</td>
<td>151</td>
</tr>
<tr>
<td>Deep Time Post-test Scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>5.41</td>
<td>2.474</td>
<td>100</td>
</tr>
<tr>
<td>Geology</td>
<td>7.14</td>
<td>2.885</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>5.99</td>
<td>2.736</td>
<td>151</td>
</tr>
</tbody>
</table>

Significance testing was conducted using a two-way mixed analysis of variance (ANOVA) in SPSS, v.25. This ANOVA showed that there was a significant main effect of Group (BSC 111 or GLY 103) ($F(1,149) = 7.86, p = .006, \eta^2_p = .05$) on the deep time scores. In addition, there was a highly significant main effect of Time (Deep Time Pre-test or Deep Time Post-test) on deep time scores ($F(1,149) = 26.68, p < .001, \eta^2_p < .001$) (Figure 3). The analysis of the interaction between Group and Time showed a highly significant effect ($F(1,149) = 12.82, p < .001, \eta^2_p = .079$) on the Deep Time scores.

Due to the significant effects of the interaction, simple effects analysis was also conducted. This analysis showed that there were significant differences between the pre- and post-test scores and Group 2 (GLY 103) ($F(1,149) = 28.87, p < .001$) but there were no significant differences between pre- and post-test scores and Group 1 (BSC 111) ($F(1,149) = 1.86, p = .175$). Further analysis shows that there was no significant interaction ($F(1,149) = 1.49, p = .224$) between Group and the Deep Time Pre-test, but there was a significant interaction ($F(1,149) = 14.69, p < .001$) between Group and the Deep Time Post-test (Figure 3).
Hypothesis 3. There is a significant mean change \((p < 0.05)\) in student scientific attitude scores when comparing *Principles of Biology II* participants with *Historical Geology* participants.

The data collected for the Scientific Attitude Inventory (SAI) scores – which contained all 40 selections from the SAI II research instrument – contained a sample size of \(n = 100\) for the BSC 111 group and \(n = 51\) for the GLY 103 group. The SAI mean pre-test score for the BSC 111 group was \(\bar{x} = 150.99\) \((s = 13.47)\) and was \(\bar{x} = 148.43\) \((s = 16.16)\) for the BSC 111 post-test score, out of a possible 200. The SAI mean pre-test score for the GLY 103 group was \(\bar{x} = 145.78\) \((s = 13.32)\) and was \(\bar{x} = 143.67\) \((s = 16.59)\) for the GLY 103 post-test score (Table 14). Levene’s test for homogeneity of variance was not violated for either the pre-test \((p = .825)\) or the post-test \((p = .873)\), indicating the variance in SAI mean scores is equal across the two groups.
Table 14

Descriptive statistics for the scientific attitude scores between the BSC 111 and GLY 103 classes.

<table>
<thead>
<tr>
<th>Course</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAI Pre-Test Scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>150.985</td>
<td>13.4698</td>
<td>100</td>
</tr>
<tr>
<td>Geology</td>
<td>145.775</td>
<td>13.3166</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>149.225</td>
<td>13.6005</td>
<td>151</td>
</tr>
<tr>
<td>SAI Post-Test Scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>148.430</td>
<td>16.1608</td>
<td>100</td>
</tr>
<tr>
<td>Geology</td>
<td>143.667</td>
<td>16.5948</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>146.821</td>
<td>16.4097</td>
<td>151</td>
</tr>
</tbody>
</table>

Significance testing was conducted using a two-way mixed analysis of variance (ANOVA) in SPSS, v.25. This ANOVA showed that there was a significant main effect of Group (BSC 111 or GLY 103) ($F(1,149) = 4.7$, $p = .032$, $\eta^2_p = .031$) on the SAI scores. In addition, there was a significant main effect of Time (SAI Pre-test or SAI Post-test) on SAI scores ($F(1,149) = 4.17$, $p = .04$, $\eta^2_p = .043$). The analysis of the interaction between Group and Time showed no significant effect ($F(1,149) = .038$, $p = .845$, $\eta^2_p = .845$) on the SAI scores (Figure 4).
Figure 4. SPSS output showing the lack of interaction between Time and Group for the 2-way Mixed ANOVA for the SAI variable.

Relationships between Scores

A path model analysis (Figure 1) using IBM AMOS, v.5.0.1, was conducted on the data from the treatment group (GLY 103). The results from the three different components of the research instrument showed both significant and nonsignificant relationships between the three components and between the Pre- and Post-test scores of the same component.

Hypothesis 4. There is a significant relationship ($p < 0.05$) between student scientific attitude scores and evolution scores of participants in Historical Geology.

Hypothesis 5. There is a significant relationship ($p < 0.05$) between student scientific attitude scores and deep time scores of participants in Historical Geology.
Hypothesis 6. There is a significant relationship \((p < 0.05)\) between deep time scores and evolution scores of participants in *Historical Geology*.

In the pre-test data (Table 15), the relationship between Deep Time scores and Evolution scores was significant \((\beta = .276, p = .027)\) as was the relationship between Science Attitude scores and Deep Time scores \((\beta = .248, p = .039)\). Conversely, the relationship between Science Attitude scores and Evolution scores was not significant \((\beta = .181, p = .155)\).

<table>
<thead>
<tr>
<th>Pathway</th>
<th>(\beta)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep Time 1 (\rightarrow) Evolution 1</td>
<td>.276</td>
<td>.027</td>
</tr>
<tr>
<td>Attitude 1 (\rightarrow) Deep Time 1</td>
<td>.248</td>
<td>.039</td>
</tr>
<tr>
<td>Attitude 1 (\rightarrow) Evolution 1</td>
<td>.181</td>
<td>.155</td>
</tr>
</tbody>
</table>

Table 15

*Results of the Path Model Analysis conducted on pre-test scores in the Historical Geology treatment group.*

In the post-test data (Table 16), the relationship between Deep Time scores and Evolution scores was significant \((\beta = .410, p < .001)\), but the relationship between Science Attitude scores and Deep Time scores \((\beta = .167, p = .173)\) and the relationship between Science Attitude scores and Evolution scores were not significant \((\beta = .204, p = .083)\).

<table>
<thead>
<tr>
<th>Pathway</th>
<th>(\beta)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep Time 2 (\rightarrow) Evolution 2</td>
<td>.410</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Attitude 2 (\rightarrow) Deep Time 2</td>
<td>.167</td>
<td>.173</td>
</tr>
<tr>
<td>Attitude 2 (\rightarrow) Evolution 2</td>
<td>.204</td>
<td>.083</td>
</tr>
</tbody>
</table>

Table 16

*Results of the Path Model Analysis conducted on post-test scores in the Historical Geology treatment group.*
Hypothesis 7. There is a significant relationship \((p < 0.05)\) between pre-test and post-test evolution scores of participants in Historical Geology.

Hypothesis 8. There is a significant relationship \((p < 0.05)\) between pre-test and post-test deep time scores of participants in Historical Geology.

Hypothesis 9. There is a significant relationship \((p < 0.05)\) between pre-test and post-test scientific attitude scores of participants in Historical Geology.

The AMOS analysis (Table 17) of the relationships between pre-test and post-test scores of the same component indicated a significant relationship between pre- and post-test Scientific Attitude scores \((r = .749, p < .001)\), Deep Time scores \((r = .636, p < .001)\), and pre- and post-test Evolution scores \((r = .482, p = .002)\).

Table 17

Results of the Path Model Analysis conducted on pre- and post-test scores in the Historical Geology treatment group.

<table>
<thead>
<tr>
<th>Pathway</th>
<th>(r)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude 1 ↔ Attitude 2</td>
<td>.749</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Deep Time 1 ↔ Deep Time 2</td>
<td>.636</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Evolution 1 ↔ Evolution 2</td>
<td>.482</td>
<td>.002</td>
</tr>
</tbody>
</table>

Movement of Perceptions of Evolution

Hypothesis 10. A higher percentage of students whose views of evolution are Creation-based will move to a scientific-based perception of evolution after participating in Geology 103 than those in the Biology 111 course.

The open-ended questions used to place students into the 8 categories were:

1. What are your perceptions of evolution?
2. What are your perceptions of deep time?

3. Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

4. Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

5. Post-test question depending on the course:

   a. What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way? (original question)

   b. What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way? (original question)

Of the 151 students who participated in both the pre- and post-tests, only two moved from Creation-based evolution (Casual Creation, Progressive Creation, Graded Creation, Quick Creation) to scientific-based evolution (Atheistic Evolution, Nontheistic Evolution, Incomplete Evolution) – one participant from BSC 111 and one participant from GLY 103. Full responses for those two participants are listed below.

ID 171119 – BSC 111

*Pre-test – Progressive Creation

**Pre-test Question:** What are your perceptions about evolution?

Participant Answer: Evolution is basically the study of how earth came about. Honestly I do not believe in evolution, however, it does interest me.

**Pre-test Question:** What are your perceptions about deep time?
Participant Answer: [blank]

**Pre-test Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: The study of Evolution does in fact conflict with my personal religious beliefs. When those conflicts arise or when it is time to discuss the topic I do just that but I stay true to my beliefs throughout the process.

**Pre-test Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: [blank]

*Post-test – Nontheistic Evolution*

**Post-test Question: What are your perceptions about evolution?**

Participant Answer: Evolution has been greatly proven by scientists for a long time now that it really hard not to believe even considering my religious views of christianity. With all of the supported evidence I do believe that evolution is real and that humans have evolved over time from other animals.

**Post-test Question: What are your perceptions about deep time?**

Participant Answer: I am not sure about what deep time is.

**Post-test Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: Yes. As stated before, I am christian so the study of evolution does go against my beliefs but it is hard not to face the facts that have been proven. I have yet to deal with those conflicts and how I feel about the controversy.
Post-test Question: Does the study of deep time conflict with your personal beliefs?
If so, how do you deal with those conflicts when they arise?
Participant Answer: [blank]

Post-test Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: The study of the phylogenetic tree and all of the components of it had a great impact on informing me about evolution. Not only did it inform me, but it slightly shifted my view about evolution. Evolution has been a hard topic to grasp due to my religion but when hearing about all the facts and evidence behind the study I can not [sic] really go against it.

*Pre-test – Graded Creation

Pre-test Question: What are your perceptions about evolution?
Participant Answer: I do not believe evolution can change a species entirely. I do believe that species can gain better traits to suit their environments.

Pre-test Question: What are your perceptions about deep time?
Participant Answer: Scientists are constantly finding new information to explain time and how long the Earth has existed.

Pre-test Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes. I stick to what I believe

Pre-test Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Sort of. I investigate the specific idea further.

*Post-test – Nontheistic Evolution

**Post-test Question: What are your perceptions about evolution?**

Participant Answer: It is a lot more complex than I thought. Micro- and Macro- evolution exist.

**Post-test Question: What are your perceptions about deep time?**

Participant Answer: The Earth and its creatures take millions and billions of years to change.

**Post-test Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: No

**Post-test Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: No

**Post-test Question: What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?**

Participant Answer: This class covered the topic more in-depth than my other classes. Before this class, I hardly believed in evolution. The book on [The Story of Life in] 25 Fossils certainly helped.

Alternatively, some students (n = 17) shifted within each set of categories. Eight students moved within the Creation-based evolution categories (Casual Creation, Progressive Creation, Graded Creation, Quick Creation), and nine students moved within the scientific-based evolution categories (Atheistic Evolution, Nontheistic
Because the categories are nominal, as opposed to ordinal, movement within each set of categories does not indicate any progression from one set of categories to the other. These 17 responses can be seen in their entirety in Appendix V.

Lastly, five students (four from BSC 111 and one from GLY 103) moved between the two sets of categories opposite that of the proposed hypothesis. These five students moved from scientific-based perceptions to Creation-based perceptions, and their complete responses can be found in Appendix W.
CHAPTER V – CONCLUSIONS AND DISCUSSIONS

Summary

This dissertation set out to determine if knowledge of deep time is a necessary precursor to a deeper knowledge of evolution. To accomplish this, a comparison group (n = 100) in which evolution was taught solely from a biological standpoint (Principles of Biology II) was compared to a course in which evolution was taught within the context of deep time (Historical Geology) (n = 51). Variable means were compared using a 2-way mixed analysis of variance (ANOVA), a linear regression, and a path model analysis.

Three separate 2-way mixed ANOVAs were conducted to determine if there were any main effects or interactions between which group a student was in and whether it was a pre-test or post-test as it related to their Scientific Attitude Inventory (SAI) score, their evolution score, or their deep time score. The linear regression was conducted to determine if student’s evolution scores correlated with their SAI and/or deep time scores. The path model analysis calculated the strength of the relationships between each of the three scores as well as the strength of each pre-test component with its accompanying post-test score.

Multiple 2-way mixed analysis of variances (ANOVAs) and regressions were used to determine if there were any significant ($p < .05$) differences between scores (distinct subject area components and pre- and post-test differences) and classes, and/or the correlations between them. Further, a path model analysis determined the strength of any relationships between scores, specifically in Historical Geology.

Results of the 2-way mixed ANOVA conducted on students’ attitudes towards science indicated that their attitudes scores were significantly higher in Principles of
than Historical Geology, and that pre-test scores were significantly higher than post-test scores, indicating that though the biology students always had a better attitude towards science, both groups’ attitudes towards science dropped significantly after taking each course.

The 2-way mixed ANOVA analyzing students’ scores concerning evolution showed no significant differences between group scores (Principles of Biology II vs. Historical Geology) nor any significant differences between pre- and post-test scores. The interaction between these two variables also showed no significant effect on scores. This seems to indicate that, despite both courses teaching evolution, neither course had any gross effect on students’ knowledge of evolution, and more specifically, Historical Geology did not have a greater effect on student knowledge of evolution, as was hypothesized.

As would be assumed, the deep time scores were the most complex scores to be analyzed due to the fact that only one course specifically taught the concept during the semester. The 2-way mixed ANOVA analyzing deep time scores indicated that the course each student was in had a significant main effect on the deep time scores (the GLY 103 group scored significantly higher than their BSC 111 counterparts), as well as whether it was a pre-test or post-test (both groups scored significantly higher in post-test scores over their pre-test scores). More interestingly, the interaction between the two variables was highly significant. A significant interaction was found between pre- and post-test scores for the GLY 103 group. Another significant interaction was found between BSC 111 and GLY 103 groups with the post-test score. This would seem to imply that before each course, students from both groups had a relatively low score concerning their knowledge
of deep time, but after taking *Historical Geology*, the geology students showed a much larger increase in knowledge concerning deep time than their biology counterparts. As stated above, though, this increase in deep time knowledge seemed to have no discernable effect on the final evolution scores, as all of those scores were not significantly different from one another.

Each group’s scores were also analyzed using a linear regression in an attempt to determine if there were any influences in post-test evolution scores when considering the other two scores (Scientific Attitude and Deep Time). As indicated by the statistical tests completed, not all of the chosen factors created significant differences. In *Principles of Biology II*, of the two scores, the scientific attitude scores showed no significant influence on the students’ evolution scores, but their deep time scores had a highly significant influence on their evolution post-test scores. It should be noted, though, that despite the influence of the deep time scores on the evolution scores during the post-test, this was not enough to create a significant difference between the biology students’ pre-test and post-test scores, as illustrated by the ANOVA above.

Alternatively, the linear regression conducted on the *Historical Geology* students showed a different pattern of significance. In this analysis the scientific attitude post-test scores *did* have a significant influence on the post-test evolution scores, as did the deep time scores. For the geology students, this influence created the significant main effect and interaction effect seen in the ANOVA above.

The path model analysis also confirms this relationship between scores. When conducted on the *Historical Geology* student scores – as they were the ones directly exposed to deep time content – the path model analysis indicated that of all of the
relationships between the components of the research instrument, the strongest
significance was always between deep time scores and evolution scores.

Conclusions and Discussion

As indicated by the various analyses, deep time, though it may have a relationship
with evolution, does not appear to yield significantly higher evolution scores than would
have been predicted had it been a threshold concept as proposed by Trend (2009) and
Ramseyer (2012).

Attitudes

In the present study, attitudes towards science as measured by the Scientific
Attitude Inventory Survey II dropped from the beginning of the course to the end of the
course, independent of the course being taken. Intuitively, this might be expected from
students who are only taking the class as an elective for their degree, as are most of the
students in Historical Geology. But the scientific attitude scores from Principles of
Biology II also dropped, and all but one student in the biology course was a science
major. Also, despite scientific attitude scores dropping between the pre- and post-test,
students’ content scores from both the evolution and deep time components rose,
significant or not.

This would appear to indicate that the attitudes of students towards science as a
discipline do not directly affect the outcome of science content knowledge assessments.
This is substantiated further by the literature. Osborne, Simon, & Collins (2003) stated
that there exists research in support of three different causal links between attitude and
achievement: absence, moderate, and strong. Most of the literature supports the moderate
link.

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Gossard (2009), in her dissertation studying the compatibility of world views and scientific content, also found no true relationship between scientific attitudes and other measured variables. In some studies (Laird, Seifert, Pascarella, Mayhew, & Blaich, 2014; Oliver-Hoyo & Allen, 2005; Osborne et al., 2003; Ramseyer, 2012), instructor performance seems to have the greatest influence (or implied influence) on student attitudes, and therefore may be a factor in any one course, independent of the content. As such, it can be noted here that the instructor of Historical Geology was teaching the course for the first time during the Fall 2017 semester (the first semester that data were gathered). The instructor for Principles of Biology II, on the other hand, had been teaching that course for seven years prior to the beginning of this study.

Furthermore, gender and race (Villafañe & Lewis, 2016) may significantly influence individual student attitudes towards science. Some, all, or none of these factors may have contributed to the scores of the students included in either of the two courses of interest in this study.

A mixed ANOVA to compare race, gender, pre-/post-test, and course was conducted in the current study to attempt to parse out if any of those demographics might have had an impact on the scores. Based on the results of the ANOVA, race had no significant interaction with the scientific attitude scores ($p = .425$), the evolution scores ($p = .846$), or deep time scores ($p = .089$). Gender also had no significant interaction with the scientific attitude scores ($p = .544$), the evolution scores ($p = .734$), or deep time scores ($p = .641$).
**Class Makeup**

Due to the restrictions (or lack thereof) on *Historical Geology*, students enrolled in *Historical Geology* who participated in the research (n = 51) showed a wide degree of variation in majors and academic status (Table 6), whereas most of the *Principles of Biology II* students who participated in the study (n = 100) were freshman (54%) (Table 5). This would place the students in the biology course in a lower cognitively developed group than that of the geology students, which had more juniors than any other academic class (Laird et al., 2014). According to Laird, students in the lower group should both know less and desire to learn less, having been exposed to fewer college courses. From the research instrument, 94.1% (n = 48) of the geology group (n = 51) had previously taken biology and/or geology courses before, whereas only 82% (n = 82) of the biology group (n = 100) had previously taken biology and/or geology courses beforehand.

This would imply that the geology group, containing a higher percentage of upperclassmen (72.6% non-freshman vs. 46% non-freshman in the biology group), would have scored altogether higher than the younger, less cognitively developed group. This was not the case, though. The biology group scored higher on both the scientific attitude and evolution measures, but not higher than the deep time measure – which would be expected from a course which teaches deep time explicitly. This could easily be explained by the fact that almost every single person taking *Principles of Biology II* was a “STEM” major or some variation thereof, and therefore more likely to score higher on science-based content than the non-science majors of *Historical Geology*.

Another mixed ANOVA to compare participants’ STEM status, academic level (Freshman, Sophomore, etc.), K-12 schooling (private, public, homeschool), course, and
pre-/post-test scores was conducted to attempt to parse out if any of those demographics might have had an impact on the scores. Based on the results of the ANOVA, the student’s STEM status had no significant interaction with the scientific attitude scores \( (p = .935) \), the evolution scores \( (p = .460) \), or deep time scores \( (p = .615) \). Academic level had no significant interaction with the scientific attitude scores \( (p = .720) \), the evolution scores \( (p = .990) \), or deep time scores \( (p = .608) \). K-12 schooling also had no significant interaction with the scientific attitude scores \( (p = .926) \), the evolution scores \( (p = .094) \), or deep time scores \( (p = .713) \).

**Religion and Conflict Avoidance**

As mentioned in Chapter II, Long (2012) claimed that when a student’s epistemological and ontological allegiances create socio-cognitive conflicts, students may experience existential angst. For the researcher to gain insight into this, students could choose to respond to open-ended questions in the research instrument as it pertains to their own resolution style when those conflicts arise.

A common response from students coded into Creation-based evolution when asked how they address conflicts between concepts of evolution/deep time and their own personal beliefs was a form compartmentalization, or simply learning the material in order to pass the course. This would appear to indicate that students are actively in conflict with the scientific concepts being taught in class and their own personally held beliefs. A study attempting to aid in the effective teaching of evolution (Nelson, 2008) implies that there may be a false presupposition in a student’s mind in which they must choose either full young-Earth Creationism or atheistic evolution, as opposed to the several categories proposed by the current study. This is supported by Cook, Buck, &
Rogers (2012), where they concluded that students feel that evolution is simply a belief system, and therefore is either something that one agrees or disagrees with, and is usually based solely on personal opinion rather than any empirical evidence. This was apparent in the two exceptional cases sampled transcribed in Appendix V where students from the current study understood the presented content and its evidence and changed their views from a Creation-based system to a purely scientific one. They were, of course, in the minority when compared to others who either retained their Creation-based views (Appendix V) or moved from a scientific explanation of evolution to a Creation-based explanation (Appendix X).

Overall, when students had a conflict and responded to the open-ended question concerning their own conflict resolution, a large percentage (46.2%) chose to either respectfully disagree with evolution, memorize answers for the test, compartmentalize the content, or just avoid thinking about it altogether. This indicated that the students resolved the conflict without addressing the concept, and therefore retained their original perceptions, even in light of the presentation of empirical evidence. A smaller percentage (32.2%) chose to say that they were open to discussion, needed more evidence, or they would “side with science.”

For those students who may hold Creation-based views of evolution, but stated that evolution had no conflict with their beliefs, T. Anderson (2008) states that this is a concept known as, “independence,” and is a way in which students might avoid conflicts with their own beliefs. He claims that the concept may be attributed to “nonoverlapping magisteria,” (Gould, 1997) where science and religion are seen as separate entities, explaining two separate aspects of reality, as opposed to diametrically opposite to each
other. Unfortunately, the independence concept actively discourages scientific discourse. Independence may be the way to describe participants assigned to the “Casual Creation” category, but would not apply to those in any of the other Creation-based categories for this study. For those students, a more proactive approach to conflict avoidance was utilized.

For the larger majority of students with conflicts, the ones who stated that their version of conflict resolution was more active avoidance of the empirical evidence, they illustrate that one must not necessarily accept evolution to have knowledge of its concepts, and therefore pass the course. Of those students with conflicts, 50.8% scored higher on the post-test than they did on the pre-test. This indicates that acceptance and knowledge of a concept are two independent systems and therefore should be studied separately to be able to understand their underlying schema.

One final mixed ANOVA was conducted to determine any if any interactions existed with participants’ religion (Christian vs. non-Christian) and their component scores. The results indicated that there were no significant interactions with the participants’ religion and the scientific attitude score ($p = .579$, the evolution scores ($p = .417$), or deep time scores ($p = .592$).

Limitations

The nature of this study prevented it from being truly experimental. Due to this fact, many outside factors could not be taken into account. Each student may have been exposed to other deep time/evolution/religious factors beyond those presented inside of each course. As such, those external factors may have been able to place unexpected influence on the outcome of the study.
A student’s honesty would also be a limitation to this study. When answering the quantitative questions, students would most likely answer to the best of their ability, but for the open-ended questions, there is a possibility that they might answer in a way that they thought the researcher might want, as opposed to stating their own beliefs and opinions.

Because The University of Southern Mississippi presents *Historical Geology* without any prerequisites, and can be taken at any time during the student’s academic career, the sample group used for this study is unique. Any generalization of the data found in this research would only apply to samples of similar makeup.

**Implications for Practice**

This study’s data would seem to indicate that although much research concludes that deep time is either a threshold concept (Ramseyer, 2012; Trend, 2009) or at least a necessary prerequisite/supplement to a deeper knowledge of evolution (Cotner *et al.*., 2010; Dodick, 2007, 2007; Zen, 2001), this is not necessarily the case in all situations. The quantitative data indicated that, in general, evolution scores were not affected by which course students were in, even though the deep time knowledge of the students in the geology course was significantly higher. The convergent parallel approach, data validation design of the study indicated that for most students, their religious beliefs had little impact on whether or not they learned more about evolution throughout the course. Using the data of the content analysis of the open-ended questions to validate the data from the quantitative portions of the ANOVA, this is further supported as religion had no interaction effect with any of the components of the research instrument.
Taking into account the experience of each of the professors, though, seems to imply that classroom environment may play a rather important role in the overall content acquisition of the course. If deep time is still to be considered a threshold concept, then the lack of evidence of *Historical Geology* to produce significant gains in student knowledge of evolution may not be the fault of the content, but rather the fault of the classroom culture, if it is to be assumed that the changes were measured adequately. Because the instructor for the geology course had never taught the course beforehand during the first semester of the study, and had only taught one prior section during the second semester of the study, this instructor’s confidence and methodology of instruction may have contributed to the lack of gains in knowledge of evolution for the students in that course. As such, teaching practices may contribute significantly to student knowledge of any subject (R. D. Anderson, 2007; Cook *et al.*, 2012; Nelson, 2008; Ramseyer, 2012). In this study more experienced teachers may be better suited to teaching evolution than newer teachers. If deep time does not fully act as a threshold concept as asserted by Trend (2009), then there may be no relevant reason to teach it as a prerequisite – or as a supplement – to evolutionary concepts. Current biology curricula usually make a cursory mention of deep time (and may not even state it explicitly) during instruction. This study would indicate that there may be no real need to change that, as it relates to increasing student content knowledge of evolution.

**Recommendations for Future Research**

To completely understand the depth to which student knowledge of evolution is affected by knowledge of deep time, especially in college settings, further research would
need to focus on teacher methodology. Teachers in both biology and geology courses would need to be of similar experience levels with their courses and would need to utilize similar teaching strategies during the course of the semester. In this way, variables could be controlled for differences in methodologies and might yield more conclusive cause-effect relationships between deep time and knowledge of evolution. Alternatively, student evaluations of teacher performance could be acquired and analyzed for differences in teacher methodologies and classroom environment.

Due to the differences in ages and academic levels between the two courses, further research may focus on eliminating those differences. More students in the geology course were older and at a higher academic status than those in the biology course, leading to a confounding variable in the data, and affecting their content knowledge as well as their desire to learn (Laird et al., 2014). Those studies would need to find students of similar ages at the same academic status, with similar previous courses.

One piece of data which was not collected in this study, but might provide insight into explanations concerning students’ attitudes and knowledge, a follow up question concerning whether or not participants are “practicing” or “non-practicing” members of their religion could be asked.

As discussed in Chapter III, much research has been conducted on individual’s acceptance of evolution and coping mechanisms, little research has been conducted on their acceptance and responses to internal conflicts with deep time. This would represent a place where much future research could be conducted.
SEVENTH GRADE

CONTENT STRANDS:

<table>
<thead>
<tr>
<th>Inquiry</th>
<th>Physical Science</th>
<th>Life Science</th>
<th>Earth and Space Science</th>
</tr>
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COMPETENCIES AND OBJECTIVES:

INQUIRY

1. Design and conduct a scientific investigation utilizing appropriate process skills and technology.
   
   a. Design, conduct, and draw conclusions from an investigation that includes using experimental controls. (DOK 3)
   b. Discriminate among observations, inferences, and predictions. (DOK 1)
   c. Collect and display data using simple tools and resources to compare information (using standard, metric, and non-standard measurement). (DOK 2)
      - Tools (e.g., English rulers [to the nearest one-sixteenth of an inch], metric rulers [to the nearest millimeter], thermometers, scales, hand lenses, microscopes, balances, clocks, calculators, anemometers, rain gauges, barometers, hygrometers, telescopes, compasses, spring scales, pH indicators, stopwatches)
      - Types of data (e.g., linear measures, mass, volume, temperature, area, perimeter)
      - Resources (e.g., Internet, electronic encyclopedias, journals, community resources, etc.)
   d. Organize data in tables and graphs and analyze data to construct explanations and draw conclusions. (DOK 3)
   e. Communicate results of scientific procedures and explanations through a variety of written and graphic methods. (DOK 2)
   f. Explain how science and technology are reciprocal. (DOK 1)
   g. Develop a logical argument to explain why scientists often review and ask questions about the results of other scientists’ work. (DOK 3)
   h. Make relationships between evidence and explanations. (DOK 2)

PHYSICAL SCIENCE

2. Develop an understanding of chemical and physical changes, interactions involving energy, and forces that affect motion of objects.

   a. Identify patterns (e.g., atomic mass, increasing atomic numbers) and common characteristics (metals, nonmetals, gasses) of elements found in the periodic table of elements. (DOK 2)
b. Categorize types of chemical changes, including synthesis and decomposition reactions, and classify acids and bases using the pH scale and indicators. (DOK 2)

c. Compare the force (effort) required to do the same amount of work with and without simple machines (e.g., levers, pulleys, wheel and axle, inclined planes). (DOK 2)

d. Describe cause and effect relationships of electrical energy. (DOK 2)
   - Energy transfers through an electric circuit (using common pictures and symbols)
   - Electric motor energy transfers (e.g., chemical to electrical to mechanical motion) and generators

e. Distinguish how various types of longitudinal and transverse waves (e.g., water, light, sound, seismic) transfer energy. (DOK 2)
   - Frequency
   - Wavelength
   - Speed
   - Amplitude

f. Describe the effects of unbalanced forces on the speed or direction of an object’s motion. (DOK 2)
   - Variables that describe position, distance, displacement, speed, and change in speed of an object
   - Gravity, friction, drag, lift, electric forces, and magnetic forces

LIFE SCIENCE

3. Distinguish the characteristics of living things and explain the interdependency between form and function using the systems of the human organism to illustrate this relationship.

a. Assess how an organism’s chances for survival are influenced by adaptations to its environment. (DOK 2)
   - The importance of fungi as decomposers
   - Major characteristics of land biomes (e.g., tropical rainforests, temperate rainforests, deserts, tundra, coniferous forests/taiga, and deciduous forests)
   - Adaptations of various plants to survive and reproduce in different biomes

b. Classify the organization and development of living things to include prokaryotic (e.g., bacteria) and eukaryotic organisms (e.g., protozoa, certain fungi, multicellular animals and plants). (DOK 2)

c. Evaluate how health care technology has improved the quality of human life (e.g., computerized tomography [CT], artificial organs, magnetic resonance imaging [MRI], ultrasound). (DOK 3)
d. Compare and contrast reproduction in terms of the passing of genetic information (DNA) from parent to offspring. (DOK 2)
   - Sexual and asexual reproduction
   - Reproduction that accounts for evolutionary adaptability of species
   - Mitosis and meiosis
   - Historical contributions and significance of discoveries of Gregor Mendel and Thomas Hunt Morgan as related to genetics

e. Compare and contrast how organisms obtain and utilize matter and energy. (DOK 1)
   - How organisms use resources, grow, reproduce, maintain stable internal conditions (homeostasis) and recycle waste
   - How plants break down sugar to release stored chemical energy through respiration

**EARTH AND SPACE SCIENCE**

4. Describe the properties and structure of the sun and the moon with respect to the Earth.

   a. Justify the importance of Earth materials (e.g., rocks, minerals, atmospheric gases, water) to humans. (DOK 3)

   b. Explain the causes and effects of historical processes shaping the planet Earth (e.g., movements of the continents, continental plates, subduction zones, trenches, etc.) (DOK 2)

   c. Describe the causes and effects of heat transfer as it relates to the circulation of ocean currents, atmospheric movement, and global wind patterns (e.g., trade winds, the jet stream). Provide examples of how these global patterns can affect local weather. (DOK 2)
   - Characteristics of the Gulf Stream and other large ocean currents
   - Effects on climate in Eastern North America and Western Europe
   - Effects of heat transfer to the movement of air masses, high and low pressure areas, and fronts in the atmosphere

   d. Conclude why factors, such as lack of resources and climate can limit the growth of populations in specific niches in the ecosystem. (DOK 2)
   - Abiotic factors that affect population, growth, and size (quantity of light, water, range of temperatures, soil compositions)
   - Cycles of water, carbon, oxygen, and nitrogen in the environment
   - Role of single-celled organisms (e.g., phytoplankton) in the carbon and oxygen cycles
e. Research and develop a logical argument to support the funding of NASA’s Space Programs. (DOK 3)
   - Space exploration (e.g., telescopes, radio telescopes, X-ray telescopes, cameras, spectro-meters, etc.)
   - Spinoffs (e.g., laser, pacemaker, dehydrated food, flame retardant clothing, global positioning system [GPS], satellite imagery, global weather information, diagnostic imagery)
   - Mississippi’s contributions to the space industry

f. Distinguish the structure and movements of objects in the solar system. (DOK 2)
   - Sun’s atmosphere (corona, chromosphere, photosphere and core)
   - How phenomena on the sun’s surface (e.g., sunspots, prominences, solar wind, solar flares) affect Earth (e.g., auroras, interference in radio and television communication)
   - Eclipses relative to the position of the sun, moon, and Earth
   - Contributions of Copernicus, Galileo, and Kepler in describing the solar system

g. Research and evaluate the use of renewable and nonrenewable resources and critique efforts in the United States including (but not limited) to Mississippi to conserve natural resources and reduce global warming. (DOK 3)
   - How materials are reused in a continuous cycle in ecosystems, (e.g., Mississippi Ethanol Gasification Project to develop and demonstrate technologies for the conversion of biomass to ethanol)
   - Benefits of solid waste management (reduce, reuse, recycle)
   - Conserving renewable and nonrenewable resources (e.g., The Recycling and Solid Waste Reduction Program in Jackson, MS)

h. Predict weather events by analyzing clouds, weather maps, satellites, and various data. (DOK 3)
Eighth Grade

CONTENT STRANDS:

Inquiry
Physical Science

Life Science
Earth and Space Science

COMPETENCIES AND OBJECTIVES:

INQUIRY

1. Draw conclusions from scientific investigations including controlled experiments.
   a. Design, conduct, and analyze conclusions from an investigation that includes using experimental controls.  (DOK 3)
   b. Distinguish between qualitative and quantitative observations and make inferences based on observations.  (DOK 3)
   c. Summarize data to show the cause and effect relationship between qualitative and quantitative observations (using standard, metric, and non-standard units of measurement).  (DOK 3)
      - Tools (e.g., English rulers [to the nearest one-sixteenth of an inch], metric rulers [to the nearest millimeter], thermometers, scales, hand lenses, microscopes, balances, clocks, calculators, anemometers, rain gauges, barometers, hygrometers, telescopes, compasses, spring scales, pH indicators, stopwatches, graduated cylinders, medicine droppers)
      - Types of data (e.g., linear measures, mass, volume, temperature, area, perimeter)
      - Resources (e.g., Internet, electronic encyclopedias, journals, community resources, etc.)
   d. Analyze evidence that is used to form explanations and draw conclusions.  (DOK 3)
   e. Develop a logical argument defending conclusions of an experimental method.  (DOK 3)
   f. Develop a logical argument to explain why perfectly designed solutions do not exist.  (DOK 3)
   g. Justify a scientist's need to revise conclusions after encountering new experimental evidence that does not match existing explanations.  (DOK 3)
   h. Analyze different ideas and recognize the skepticism of others as part of the scientific process in considering alternative conclusions.  (DOK 3)
PHYSICAL SCIENCE

2. Apply concepts relating to an understanding of chemical and physical changes, interactions involving energy, and forces that affect motion of objects.

a. Identify patterns found in chemical symbols, formulas, reactions, and equations that apply to the law of conservation of mass. (DOK 1)
   - Chemical symbols and chemical formulas of common substances such as NaCl (table salt), H₂O (water), C₆H₁₂O₆ (sugar), O₂ (oxygen gas), CO₂ (carbon dioxide), and N₂ (nitrogen gas)
   - Mass of reactants before a change and products after a change
   - Balanced chemical equations such as photosynthesis and respiration

b. Predict the properties and interactions of given elements using the periodic table of the elements. (DOK 2)
   - Metals and nonmetals
   - Acids and bases
   - Chemical changes in matter (e.g., rusting [slow oxidation], combustion [fast oxidation], food spoilage)

c. Distinguish the motion of an object by its position, direction of motion, speed, and acceleration and represent resulting data in graphic form in order to make a prediction. (DOK 2)

d. Relate how electrical energy transfers through electric circuits, generators, and power grids, including the importance of contributions from Mississippi companies. (DOK 2)
   - The Electrical Power Products Division of Howard Industries, a leading manufacturer of electrical distribution equipment in such locations as Laurel and Ellisville, MS
   - Kuhlman Electric Corporation, located in Crystal Springs, MS

e. Contrast various components of the electromagnetic spectrum (e.g., infrared, visible light, ultraviolet) and predict their impacts on living things. (DOK 2)

f. Recognize Newton’s Three Laws of Motion and identify situations that illustrate each law (e.g., inertia, acceleration, action, reaction forces). (DOK 2)

LIFE SCIENCE

3. Compare and contrast the structure and functions of the cell, levels of organization of living things, basis of heredity, and adaptations that explain variations in populations.

a. Analyze how adaptations to a particular environment (e.g., desert, aquatic, high altitude) can increase an organism’s survival and reproduction and relate organisms and their ecological niches to evolutionary change and extinction. (DOK 3)
b. Compare and contrast the major components and functions of different types of cells. (DOK 2)
   • Differences in plant and animal cells
   • Structures (nucleus, cytoplasm, cell membrane, cell wall, mitochondrion, and nuclear membrane)
   • Different types of cells and tissues (e.g., epithelial, nerve, bone, blood, muscle)

c. Describe how viruses, bacteria, fungi, and parasites may infect the human body and interfere with normal body functions. (DOK 1)

d. Describe heredity as the passage of instructions from one generation to another and recognize that hereditary information is contained in genes, located in the chromosomes of each cell. (DOK 2)
   • How traits are passed from parents to offspring through pairs of genes
   • Phenotypes and genotypes
   • Hierarchy of DNA, genes, and chromosomes and their relationship to phenotype
   • Punnett square calculations

e. Explain energy flow in a specified ecosystem. (DOK 2)
   • Populations, communities, and habitats
   • Niches, ecosystems and biomes
   • Producers, consumers and decomposers in an ecosystem

f. Develop a logical argument for or against research conducted in selective breeding and genetic engineering, including (but not limited to) research conducted in Mississippi. Examples from Mississippi include the following: (DOK 3)
   • The Animal Functional Genomics Laboratory at Mississippi State University
   • The Stoneville Pedigreed Seed Company in Stoneville, MS
   • Catfish Genetics Research Unit at the Thad Cochran National Warm Water Aquaculture Center in Stoneville, MS

h. Research and draw conclusions about the use of single-celled organisms in industry, in the production of food, and impacts on life. (DOK 3)

h. Describe how an organism gets energy from oxidizing its food and releasing some of its energy as heat. (DOK 1)
EARTH AND SPACE SCIENCE

4. Describe the Earth’s System in terms of its position to objects in the universe, structure and composition, climate, and renewable and nonrenewable resources.

a. Compare and contrast the lithosphere and the asthenosphere. (DOK 1)
   - Composition, density, and location of continental crust and oceanic crust
   - Physical nature of the lithosphere (brittle and rigid) with the asthenosphere (plastic and flowing)
   - How the lithosphere responds to tectonic forces (faulting and folding)

b. Describe the cause and effect relationship between the composition of and movement within the Earth's lithosphere. (DOK 1)
   - Seismic wave velocities of earthquakes and volcanoes to lithospheric plate boundaries using seismic data
   - Volcanoes formed at mid-ocean ridges, within intra-plate regions, at island arcs, and along some continental edges
   - Modern distribution of continents to the movement of lithospheric plates since the formation of Pangaea

c. Examine weather forecasting and describe how meteorologists use atmospheric features and technology to predict the weather. (DOK 2)
   - Temperature, precipitation, wind (speed/direction), dew point, relative humidity, and barometric pressure
   - How the thermal energy transferred to the air results in vertical and horizontal movement of air masses, Coriolis effect
   - Global wind patterns (e.g., trade winds, westerlies, jet streams)
   - Satellites and computer modeling

d. Research the importance of the conservation of renewable and nonrenewable resources, including (but not limited to) Mississippi, and justify methods that might be useful in decreasing the human impact on global warming. (DOK 3)
   - Greenhouse gases
   - The effects of the human population
   - Relationships of the cycles of water, carbon, oxygen, and nitrogen

e. Explain how the tilt of Earth’s axis and the position of the Earth in relation to the sun determine climatic zones, seasons, and length of the days. (DOK 2)

f. Describe the hierarchical structure (stars, clusters, galaxies, galactic clusters) of the universe and examine the expanding universe to include its age and history and the modern techniques (e.g., radio, infrared, ultraviolet and X-ray astronomy) used to measure objects and distances in the universe. (DOK 2)
g. Justify the importance of continued research and use of new technology in the
development and commercialization of potentially useful natural products,
including, but not limited to research efforts in Mississippi. (DOK 3)
   • The Thad Cochran National Center for Natural Products Research,
     housed at the University of Mississippi
   • The Jamie Whitten Delta States Research Center in Stoneville, MS,
   • The Mississippi Polymer Institute, housed at the University of Southern
     Mississippi

h. Justify why an imaginary hurricane might or might not hit a particular area, using
important technological resources including (but not limited to) the following:
   (DOK 2)
   • John C. Stennis Space Center Applied Research and Technology Project
     Office in Hancock County
   • National Oceanic and Atmospheric Administration (NOAA)
   • The National Weather Service
INTRODUCTION TO BIOLOGY
- one credit -

CONTENT STRANDS:
Inquiry
Life Science
Physical Science

COMPETENCIES AND OBJECTIVES:

INQUIRY
1. Apply inquiry-based and problem-solving processes and skills to scientific investigations.
   a. Conduct a scientific investigation demonstrating safe procedures and proper care of laboratory equipment. (DOK 2)
      • Safety rules and symbols
      • Proper use and care of the compound light microscope, slides, chemicals, etc.
      • Accuracy and precision in using graduated cylinders, balances, beakers, thermometers, and rulers
   b. Identify questions that can be answered through scientific investigations. (DOK 3)
   c. Identify and apply components of scientific methods in classroom investigations. (DOK 3)
      • Predicting, gathering data, drawing conclusions
      • Recording outcomes and organizing data from a variety of sources (e.g., scientific articles, magazines, student experiments, etc.)
      • Critically analyzing current investigations/problems using periodicals and scientific scenarios
   d. Interpret and generate graphs (e.g., plotting points, labeling x- and y-axis, creating appropriate titles and legends for circle, bar, and line graphs. (DOK 2)
   e. Analyze procedures and data to draw conclusions about the validity of research. (DOK 3)
   f. Formulate and revise scientific explanations and models using logic and evidence (data analysis). (DOK 3)
   g. Communicate effectively to present and explain scientific results, using appropriate terminology and graphics. (DOK 3)
PHYSICAL SCIENCE

2. Investigate and summarize the chemical basis of life.
   a. Compare and contrast atoms, ions, elements, molecules, and compounds in terms of the relationship of the bond types (e.g., ionic, covalent, and hydrogen bonds) to chemical activity and explain how this is relevant to biological activity. (DOK 2)
   b. Classify pH solutions (e.g., acids, bases, neutrals) and explain the importance of pH in living systems. (DOK 2)
   c. Compare the composition and primary properties of carbohydrates, proteins, lipids, and nucleic acids and relate these to their functions in living organisms. (DOK 2)
   d. Compare and contrast the basic processes of photosynthesis and cellular respiration. (DOK 2)

LIFE SCIENCE

3. Investigate and explain how organisms interact with their environment.
   a. Describe the criteria that must be present to distinguish between living and nonliving. (DOK 1)
      • Homeostasis, adaptation, and response to stimuli
      • Growth, development, reproduction, energy use
      • Levels of organization
   b. Analyze and explain the interactions among organisms for each level of biological organization. (DOK 2)
      • Biotic and abiotic
      • Predation, competition, symbiosis, mutualism, commensalism, parasitism, etc.
      • Food chains, food webs, and food pyramids
   c. Analyze energy flow through an ecosystem by assessing the roles of carnivores, omnivores, herbivores, producers, and decomposers and determine their effects on an ecosystem. (DOK 2)
   d. Predict the impact of human activities (e.g., recycling, pollution, overpopulation) on the environment. (DOK 3)

4. Investigate, compare, and contrast cell structures, functions, and methods of reproduction.
   a. Compare and contrast cell structures, functions, and methods of reproduction to analyze the similarities and differences among cell types. (DOK 2)
      • Prokaryotic/eukaryotic
      • Unicellular/multicellular
      • Plant/animal/bacterial/protist/fungal
b. Describe and explain the relationships between structures and functions of major eukaryotic organelles (e.g., cell wall, cell membrane, chromosomes, mitochondrion, nucleus, chloroplast, vacuole, endoplasmic reticulum, ribosomes, centrioles, cytoplasm/cytosol, Golgi apparatus, vesicles, lysosomes, microtubules, microfilaments, cytoskeleton, nucleolus, nuclear membrane.) (DOK 2)

c. Describe how active, passive, and facilitated transports relate to the maintenance of homeostasis. (DOK 1)

d. Compare and contrast the processes and results of mitosis and meiosis. (DOK 2)

5. Analyze the roles DNA and RNA play on the mechanism of inheritance.

   a. Utilize genetic terminology and principles to solve monohybrid crosses involving dominant and recessive traits. (DOK 2)

   b. Identify inheritance patterns using pedigrees and karyotypes. (DOK 2)

   c. Explain and distinguish among the roles of DNA and RNA in replication, transcription, and translation. (DOK 1)

6. Apply the concept of evolution to the diversity of organisms.

   a. Classify organisms into groups based on their unique characteristics (e.g., cell type, nutrition, reproductive methods, organism examples, etc.) and trace the evolutionary relationships among the groups. (DOK 2)

   b. Describe how natural selection relates to adaptation, survival, and speciation. (DOK 1)
BIOLOGY I
- one credit -

CONTENT STRANDS:

Inquiry           Physical Science
Life Science

COMPETENCIES AND OBJECTIVES:

INQUIRY

1. Apply inquiry-based and problem-solving processes and skills to scientific investigations.
   a. Conduct a scientific investigation demonstrating safe procedures and proper care of laboratory equipment. (DOK 2)
   b. Safety rules and symbols
   c. Proper use and care of the compound light microscope, slides, chemicals, etc.
   d. Accuracy and precision in using graduated cylinders, balances, beakers, thermometers, and rulers
   e. Formulate questions that can be answered through research and experimental design. (DOK 3)
   f. Apply the components of scientific processes and methods in classroom and laboratory investigations (e.g., hypotheses, experimental design, observations, data analyses, interpretations, theory development). (DOK 2)
   g. Construct and analyze graphs (e.g., plotting points, labeling x- and y-axis, creating appropriate titles and legends for circle, bar, and line graphs). (DOK 2)
   h. Analyze procedures, data, and conclusions to determine the scientific validity of research. (DOK 3)
   i. Recognize and analyze alternative explanations for experimental results and to make predictions based on observations and prior knowledge. (DOK 3)
   j. Communicate and defend a scientific argument in oral, written, and graphic form. (DOK 3)

PHYSICAL SCIENCE

2. Describe the biochemical basis of life and explain how energy flows within and between the living systems.
   a. Explain and compare with the use of examples the types of bond formation (e.g., covalent, ionic, hydrogen, etc.) between or among atoms. (DOK 2)
   b. Subatomic particles and arrangement in atoms
• Importance of ions in biological processes

b. Develop a logical argument defending water as an essential component of living systems (e.g., unique bonding and properties including polarity, high specific heat, surface tension, hydrogen bonding, adhesion, cohesion, and expansion upon freezing). (DOK 2)

c. Classify solutions as acidic, basic, or neutral and relate the significance of the pH scale to an organism's survival (e.g., consequences of having different concentrations of hydrogen and hydroxide ions). (DOK 2)

d. Compare and contrast the structure, properties, and principle functions of carbohydrates, lipids, proteins, and nucleic acids in living organisms. (DOK 2)
  • Basic chemical composition of each group
  • Building components of each group (e.g., amino acids, monosaccharides, nucleotides, etc.)
  • Basic functions (e.g., energy, storage, cellular, heredity) of each group

e. Examine the life processes to conclude the role enzymes play in regulating biochemical reactions. (DOK 2)
  • Enzyme structure
  • Enzyme function, including enzyme-substrate specificity and factors that affect enzyme function (pH and temperature)

f. Describe the role of adenosine triphosphate (ATP) in making energy available to cells. (DOK 1)
  • ATP structure
  • ATP function

g. Analyze and explain the biochemical process of photosynthesis and cellular respiration and draw conclusions about the roles of the reactants and products in each. (DOK 3)
  • Photosynthesis and respiration (reactants and products)
  • Light-dependent reactions and light independent reactions in photosynthesis, including requirements and products of each
  • Aerobic and anaerobic processes in cellular respiration, including products of each and energy differences

LIFE SCIENCE

3. Investigate and evaluate the interaction between living organisms and their environment.

a. Compare and contrast the characteristics of the world's major biomes (e.g., deserts, tundra, taiga, grassland, temperate forest, tropical rainforest). (DOK 2)
  • Plant and animal species
  • Climate (temperature and rainfall)
  • Adaptations of organisms

b. Provide examples to justify the interdependence among environmental elements. (DOK 2)
• Biotic and abiotic factors in an ecosystem (e.g., water, carbon, oxygen, mold, leaves)
• Energy flow in ecosystems (e.g., energy pyramids and photosynthetic organisms to herbivores, carnivores, and decomposers)
• Roles of beneficial bacteria
• Interelationships of organisms (e.g., cooperation, predation, parasitism, commensalism, symbiosis, and mutualism)

c. Examine and evaluate the significance of natural events and human activities on major ecosystems (e.g., succession, population growth, technology, loss of genetic diversity, consumption of resources). (DOK 2)

4. Analyze and explain the structures and function of the levels of biological organization.

a. Differentiate among plant and animal cells and eukaryotic and prokaryotic cells. (DOK 2)
   • Functions of all major cell organelles and structures (e.g., nucleus, mitochondrion, rough ER, smooth ER, ribosomes, Golgi bodies, vesicles, lysosomes, vacuoles, microtubules, microfilaments, chloroplast, cytoskeleton, centrioles, nucleolus, chromosomes, nuclear membrane, cell wall, cell membrane [active and passive transport], cytosol)
   • Components of mobility (e.g., cilia, flagella, pseudopodia)

b. Differentiate between types of cellular reproduction. (DOK 1)
   • Main events in the cell cycle and cell mitosis (including differences in plant and animal cell divisions)
   • Binary fission (e.g., budding, vegetative propagation, etc.)
   • Significance of meiosis in sexual reproduction
   • Significance of crossing over

c. Describe and differentiate among the organizational levels of organisms (e.g., cells, tissues, organs, systems, types of tissues.) (DOK 1)

d. Explain and describe how plant structures (vascular and nonvascular) and cellular functions are related to the survival of plants (e.g., movement of materials, plant reproduction). (DOK 1)

5. Demonstrate an understanding of the molecular basis of heredity.

a. Analyze and explain the molecular basis of heredity and the inheritance of traits to successive generations by using the Central Dogma of Molecular Biology. (DOK 3)
   • Structures of DNA and RNA
   • Processes of replication, transcription, and translation
   • Messenger RNA codon charts

b. Utilize Mendel's laws to evaluate the results of monohybrid Punnett squares involving complete dominance, incomplete dominance, codominance, sex linked, and multiple alleles (including outcome percentage of both genotypes and phenotypes.) (DOK 2)
c. Examine inheritance patterns using current technology (e.g., pedigrees, karyotypes, gel electrophoresis). (DOK 2)

   d. Discuss the characteristics and implications of both chromosomal and gene mutations. (DOK 2)
      - Significance of nondisjunction, deletion, substitutions, translocation, and frame shift mutation in animals
      - Occurrence and significance of genetic disorders such as sickle cell anemia, Tay-Sachs disorder, cystic fibrosis, hemophilia, Downs Syndrome, color blindness

6. Demonstrate an understanding of principles that explain the diversity of life and biological evolution.

   a. Draw conclusions about how organisms are classified into a hierarchy of groups and subgroups based on similarities that reflect their evolutionary relationships. (DOK 2)
      - Characteristics of the six kingdoms
      - Major levels in the hierarchy of taxa (e.g., kingdom, phylum/division, class, order, family, genus, and species)
      - Body plans (symmetry)
      - Methods of sexual reproduction (e.g., conjugation, fertilization, pollination)
      - Methods of asexual reproduction (e.g., budding, binary fission, regeneration, spore formation)

   b. Critique data (e.g., comparative anatomy, Biogeography, molecular biology, fossil record, etc.) used by scientists (e.g., Redi, Needham, Spallanzani, Pasteur) to develop an understanding of evolutionary processes and patterns. (DOK 3)

   c. Research and summarize the contributions of scientists (including Darwin, Malthus, Wallace, Lamarck, and Lyell) whose work led to the development of the theory of evolution. (DOK 2)

   d. Analyze and explain the roles of natural selection, including the mechanisms of speciation (e.g., mutations, adaptations, geographic isolation) and applications of specialization (e.g., pesticide and antibiotic resistance). (DOK 3)

   e. Differentiate among chemical evolution, organic evolution, and the evolutionary theory of natural selection.
BIOLOGY II
- one credit -

CONTENT STRANDS:

Inquiry
Life Science

COMPETENCIES AND OBJECTIVES:

INQUIRY

1. Apply inquiry-based and problem-solving processes and skills to scientific investigations.
   a. Use current technologies such as CD-ROM, DVD, Internet, and on-line data search to explore current research related to a specific topic. (DOK 3)
   b. Clarify research questions and design laboratory investigations. (DOK 3)
   c. Demonstrate the use of scientific inquiry and methods to formulate, conduct, and evaluate laboratory investigations (e.g., hypotheses, experimental design, observations, data analyses, interpretations, theory development). (DOK 3)
   d. Organize data to construct graphs (e.g., plotting points, labeling x-and y-axis, creating appropriate titles and legends for circle, bar, and line graphs), draw conclusions, and make inferences. (DOK 3)
   e. Evaluate procedures, data, and conclusions to critique the scientific validity of research. (DOK 3)
   f. Formulate and revise scientific explanations and models using logic and evidence (data analysis). (DOK 3)
   g. Collect, analyze, and draw conclusions from data to create a formal presentation using available technology (e.g., computers, calculators, SmartBoard, CBL’s, etc.). (DOK 3)

LIFE SCIENCE

2. Describe and contrast the structures, functions, and chemical processes of the cell.
   a. Relate the structure and function of a selectively permeable membrane to its role in diffusion and osmosis. (DOK 2)
   b. Summarize how cell regulation controls and coordinates cell growth and division. (DOK 2)
   c. Analyze and describe the function of enzymes in biochemical reactions.
      (DOK 2)
      • The impact of enzymatic reactions on biochemical processes
      • Factors that affect enzyme function (e.g., pH, concentration, temperature, etc.)
d. Differentiate between photosynthesis and cellular respiration. (DOK 2)
   - Cellular sites and major pathways of anaerobic and aerobic respiration
     (with reactants, products, and ATP per monosaccharide)
   - Cellular respiration with respect to the sites at which they take place, the
     reactions involved, and the energy input and output in each stage (e.g.,
     glycolysis, Krebs cycle, electron transport chain)
   - Pigments, absorption, reflection of light, and light-dependent and light-
     independent reactions of photosynthesis
   - Oxidation and reduction reactions

3. Investigate and discuss the molecular basis of heredity.
   a. Explain how the process of meiosis clarifies the mechanism underlying Mendel's
      conclusions about segregation and independent assortment on a molecular
      level. (DOK 1)
   b. Research and explain how major discoveries led to the determination of DNA
      structure. (DOK 2)
   c. Relate gene expression (e.g., replication, transcription, translation) to protein
      structure and function. (DOK 2)
      - Translation of a messenger RNA strand into a protein
      - Processing by organelles so that the protein is appropriately packaged,
        labeled, and eventually exported by the cell
      - Messenger RNA codon charts to determine the effects of different types
        of mutations on amino acid sequence and protein structure (e.g., sickle
        cell anemia resulting from base substitution mutation)
      - Gene expression regulated in organisms so that specific proteins are
        synthesized only when they are needed by the cell (e.g., allowing cell
        specialization)
   d. Assess the potential implications of DNA technology with respect to its impact
      on society. (DOK 3)
      - Modern DNA technologies (e.g., polymerase chain reaction (PCR), gene
        splicing, gel electrophoresis, transformation, recombinant DNA) in
        agriculture, medicine and forensics
   e. Develop a logical argument defending or refuting bioethical issues arising from
      applications of genetic technology (e.g., the human genome project, cloning,
      gene therapy, stem cell research). (DOK 3)

4. Demonstrate an understanding of the factors that contribute to
   evolutionary theory and natural selection.
   a. Explain the history of life on Earth and infer how geological changes
      provide opportunities and constraints for biological evolution. (DOK 2)
      - Main periods of the geologic timetable of Earth's history
      - Roles of catastrophic and gradualistic processes in shaping planet Earth
b. Provide support for the argument based upon evidence from anatomy, embryology, biochemistry, and paleontology that organisms descended with modification from common ancestry. (DOK 2)

c. Identify and provide supporting evidence for the evolutionary relationships among various organisms using phylogenetic trees and cladograms. (DOK 2)

d. Formulate a scientific explanation based on fossil records of ancient life-forms and describe how new species could originate as a result of geological isolation and reproductive isolation. (DOK 2)

e. Compare and contrast the basic types of selection (e.g., disruptive, stabilizing, directional, etc.). (DOK 2)

f. Cite examples to justify behaviors that have evolved through natural selection (e.g., migration, parental care, use of tools, etc.). (DOK 1)

g. Research and explain the contributions of 19th century scientists (e.g., Malthus, Wallace, Lyell, Darwin) on the formulation of ideas about evolution. (DOK 2)

h. Develop a logical argument describing ways in which the influences of 20th century science have impacted the development of ideas about evolution (e.g., synthetic theory of evolution, molecular biology). (DOK 3)

i. Analyze changes in an ecosystem resulting from natural causes (succession), changes in climate, human activity (pollution and recycling), or introduction of non-native species. (DOK 2)

5. Develop an understanding of organism classification.

a. Classify organisms according to traditional Linnaean classification characteristics (e.g., cell structure, biochemistry, anatomy, fossil record, methods of reproduction) and the cladistic approach. (DOK 2)

b. Categorize organisms according to the characteristics that distinguish them as Bacteria, Archaea, or Eucarya. (DOK 1)

• Bacteria, fungi, and protists

• Characteristics of invertebrates (e.g., habitat, reproduction, body plan, locomotion) as related to phyla (e.g., Porifera, Cnidarians, Nematoda, Annelida, Platyhelminthes, and Arthropoda) and classes (e.g., Insecta, Crustacea, Arachnida, Mollusca, Echinodermata)

• Characteristics of vertebrates (e.g., habitat, reproduction, body plan, locomotion) as related to classes (e.g., Agnatha, Chordichthyyes, Osteichthyes, Amphibia, Reptilia, Aves, Mammalia)

• Nomenclature of various types of plants (e.g., Bryophyta, Tracheophyta, Gymnospermae, Angiospermae, Monocotyledonae, Dicotyledonae, vascular plants, nonvascular plants).
EARTH AND SPACE SCIENCE
- one credit -

CONTENT STRANDS:

Inquiry
Earth and Space Science

COMPETENCIES AND OBJECTIVES:

INQUIRY

1. Apply inquiry-based and problem-solving processes and skills to scientific investigations.
   a. Conduct a scientific investigation demonstrating safe procedures and proper care of laboratory equipment. (DOK 2)
      • Safety rules and symbols
      • Proper use and care of the compound light microscope, slides, chemicals, etc.
      • Accuracy and precision in using graduated cylinders, balances, beakers, thermometers, and rulers.
   b. Formulate questions that can be answered through research and experimental design. (DOK 3)
   c. Apply the components of scientific processes and methods in classroom and laboratory investigations (e.g., hypotheses, experimental design, observations, data analyses, interpretations, theory development). (DOK 3)
   d. Construct and analyze graphs (e.g., plotting points, labeling x-and y-axis, creating appropriate titles and legends for circle, bar, and line graphs). (DOK 2)
   e. Analyze procedures, data, and conclusions to determine the scientific validity of research. (DOK 3)
   f. Recognize and analyze alternative explanations for experimental results and to make predictions based on observations and prior knowledge. (DOK 3)
   g. Communicate and defend a scientific argument in oral, written, and graphic form. (DOK 3)

EARTH AND SPACE SCIENCE

2. Develop an understanding of the history and evolution of the universe and Earth.
   a. Summarize the origin and evolution of the universe. (DOK 2)
      • Big Bang theory
      • Microwave background radiation
      • The Hubble constant
 Evidence of the existence of dark matter and dark energy in the universe and the history of the universe  

b. Differentiate methods used to measure space distances, including astronomical unit, light-year, stellar parallax, Cepheid variables, and the red shift. (DOK 1)

c. Interpret how gravitational attraction played a role in the formation of the planetary bodies and how the fusion of hydrogen and other processes in "ordinary" stars and supernovae lead to the formation of all other elements. (DOK 2)

d. Summarize the early evolution of the Earth, including the formation of Earth's solid layers (e.g., core, mantle, crust), the distribution of major elements, the origin of internal heat sources, and the initiation of plate tectonics. (DOK 2)
  - How the decay of radioactive isotopes is used to determine the age of rocks, Earth, and the solar system
  - How Earth acquired its initial oceans and atmosphere

3. Discuss factors which are used to explain the geological history of Earth.

a. Develop an understanding of how plate tectonics create certain geological features, materials, and hazards. (DOK 1)
  - Plate tectonic boundaries (e.g., divergent, convergent, and transform)
  - Modern and ancient geological features to each kind of plate tectonic boundary
  - Production of particular groups of igneous and metamorphic rocks and mineral resources
  - Sedimentary basins created and destroyed through time

b. Compare and contrast types of mineral deposits/groups (e.g., oxides, carbonates, halides, sulfides, sulfates, silicates, phosphates). (DOK 2)

c. Categorize minerals and rocks by determining their physical and/or chemical characteristics. (DOK 2)

d. Justify the causes of certain geological hazards (e.g., earthquakes, volcanoes, tsunamis) to their effects on specific plate tectonic locations. (DOK 2)

e. Interpret and explain how rock relationships and fossils are used to reconstruct the geologic history of the Earth. (DOK 2)

f. Apply principles of relative age (e.g., superposition, original horizontality, cross-cutting relations, and original lateral continuity) to support an opinion related to Earth’s geological history. (DOK 3)
  - Types of unconformity (e.g., disconformity, angular unconformity, nonconformity)
  - Geological timetable

h. Compare and contrast the relative and absolute dating methods (e.g., the principle of fossil succession, radiometric dating, and paleomagnetism) for determining the age of the Earth. (DOK 1)
4. Demonstrate an understanding of Earth systems relating to weather and climate.

a. Explain the interaction of Earth Systems that affect weather and climate. (DOK 1)
   - Latitudinal variations in solar heating
   - The effects of Coriolis forces on ocean currents, cyclones, anticyclones, ocean currents, topography, and air masses (e.g., warm fronts, cold fronts, stationary fronts, and occluded fronts)

b. Interpret the patterns in temperature and precipitation that produce the climate regions on Earth and relate them to the hazards associated with extreme weather events and climate change (e.g., hurricanes, tornadoes, El Niño/La Niña, global warming). (DOK 2)

c. Justify how changes in global climate and variation in Earth/Sun relationships contribute to natural and anthropogenic (human-caused) modification of atmospheric composition. (DOK 2)

d. Summarize how past and present actions of ice, wind, and water contributed to the types and distributions of erosional and depositional features in landscapes. (DOK 1)

e. Research and explain how external forces affect Earth’s topography. (DOK 2)
   - How surface water and groundwater act as the major agents of physical and chemical weathering
   - How soil results from weathering and biological processes
   - Processes and hazards associated with both sudden and gradual mass wasting

5. Apply an understanding of ecological factors to explain relationships between Earth systems.

a. Draw conclusions about how life on Earth shapes Earth systems and responds to the interaction of Earth systems (lithosphere, hydrosphere, atmosphere, and biosphere). (DOK 3)
   - Nature and distribution of life on Earth, including humans, to the chemistry and availability of water
   - Distribution of biomes (e.g., terrestrial, freshwater, and marine) to climate regions through time
   - Geochemical and ecological processes (e.g., rock, hydrologic, carbon, nitrogen) that interact through time to cycle matter and energy, and how human activity alters the rates of these processes (e.g., fossil fuel formation and combustion, damming and channeling of rivers)
b. Interpret the record of shared ancestry (fossils), evolution, and extinction as related to natural selection. (DOK 2)

c. Identify the cause and effect relationships of the evolutionary innovations that most profoundly shaped Earth systems. (DOK 1)
   • Photosynthesis and the atmosphere
   • Multicellular animals and marine environments
   • Land plants and terrestrial environments

d. Cite evidence about how dramatic changes in Earth’s atmosphere influenced the evolution of life. (DOK 1)
GEOLOGY
- one half credit -

CONTENT STRANDS:

Inquiry
Earth and Space Science

COMPETENCIES AND OBJECTIVES:

INQUIRY

1. Apply inquiry-based and problem-solving processes and skills to scientific investigations.
   a. Conduct a scientific investigation demonstrating safe procedures and proper care of laboratory equipment. (DOK 2)
   b. Safety rules and symbols
   c. Proper use and care of the compound light microscope, slides, chemicals, etc.
   d. Accuracy and precision in using graduated cylinders, balances, beakers, thermometers, and rulers.
   e. Formulate questions that can be answered through research and experimental design. (DOK 3)
   f. Apply the components of scientific processes and methods in classroom and laboratory investigations (e.g., hypotheses, experimental design, observations, data analyses, interpretations, theory development). (DOK 3)
   g. Construct and analyze graphs (e.g., plotting points, labeling x-and y-axis, creating appropriate titles and legends for circle, bar, and line graphs). (DOK 2)
   h. Analyze procedures, data, and conclusions to determine the scientific validity of research. (DOK 3)
   i. Recognize and analyze alternative explanations for experimental results and to make predictions based on observations and prior knowledge. (DOK 3)

EARTH AND SPACE SCIENCE

2. Develop an understanding of plate tectonics and geochemical and ecological processes that affect Earth.
   a. Differentiate the components of the Earth's atmosphere and lithosphere. (DOK 1)
   b. Research and summarize explanations of how Earth acquired its initial
c. Compare the causes and effects of internal and external components that shape Earth's topography. (DOK 2)
   - Physical weathering (e.g., atmospheric, glacial, etc.)
   - Chemical weathering agents (e.g., acid precipitation, carbon dioxide, oxygen, water, etc.)

d. Develop an understanding of how plate tectonics create certain geologic features, materials, and hazards. (DOK 2)
   - Types of crustal movements and the resulting landforms (e.g., seafloor spreading, paleomagnetic measurements, and orogenesis)
   - Processes that create earthquakes and volcanoes
   - Asthenosphere

e. Summarize the theories of plate development and continental drift and describe the causes and effects involved in each. (DOK 2)

f. Develop a logical argument to explain how geochemical and ecological processes (e.g., rock, hydrologic, carbon, nitrogen) interact through time to cycle matter and energy, and how human activity alters the rates of these processes (e.g., fossil fuel formation and combustion, damming and channeling of rivers). (DOK 2)

Approved July 25, 2008
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<tr>
<th>Component</th>
<th>Grade Level</th>
<th>Standard</th>
<th>Performance Indicator</th>
<th>Academic Strand</th>
<th>Essential Question</th>
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<td>Earth and Space Science</td>
<td>3rd</td>
<td>Standard 1</td>
<td>I can describe the structure of the Earth and Sun.</td>
<td>Earth and Space Science</td>
<td>What are the major features of the Earth and Sun?</td>
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<td>Standard 2</td>
<td>I can explain the relationship between the Earth and the Sun.</td>
<td>Earth and Space Science</td>
<td>How does the Earth's rotation affect the seasons?</td>
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<td>Standard 3</td>
<td>I can describe the solar system.</td>
<td>Earth and Space Science</td>
<td>How many planets are in our solar system?</td>
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<td>Standard 4</td>
<td>I can explain the importance of Earth's orbit.</td>
<td>Earth and Space Science</td>
<td>Why is Earth's orbit important to life on Earth?</td>
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<td>Standard 5</td>
<td>I can describe the effects of tectonic plates moving.</td>
<td>Earth and Space Science</td>
<td>How do tectonic plates move?</td>
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<td>Standard 6</td>
<td>I can explain the significance of the Earth's magnetic field.</td>
<td>Earth and Space Science</td>
<td>What role does the Earth's magnetic field play in the magnetosphere?</td>
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*Note: This table represents a portion of the 2010 Mississippi Earth and Space Science Vertical Alignments.*
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APPENDIX C – Custom Research Instrument

Name ___________________________ Date ______________________

Background Information

I. Gender
   a) Male    b) Female    c) Other ______________________

II. Race
   a) Caucasian   d) African-American   g) Other _________________
   b) Hispanic    e) Asian               h) Pacific Islander
   c) Native-American

III. Age
    a) <18        c) 18-20      e) 21-23
    b) 24-26      d) 27-29      f) >30

IV. Academic Status
    a) Freshman   c) Sophomore   e) Junior
    b) Senior     d) Super-Senior (undergraduate in college for 5 or more years)

V. Academic Major:

VI. Primary K-12 Education
    a) Public    b) Private   c) Home School

VII. Have you taken any previous BIOLOGY content courses before taking Historical Geology?
    a) Yes    b) No

VIII. Have you taken any previous GEOLOGY content courses before taking Historical Geology?
     a) Yes    b) No

IX. Are you taking Historical Geology at the same time as your first college BIOLOGY course?
    a) Yes    b) No

X. Are you taking this course as a requirement for your degree?
   a) Yes    b) No

XI. Based on your current knowledge, how old is the Earth?

XII. Religious Affiliation, if any.
<table>
<thead>
<tr>
<th>Statement</th>
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<tbody>
<tr>
<td>1. I would enjoy studying science.</td>
<td>1 2 3 4 5</td>
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<td>2. Anything we need to know can be found out through science.</td>
<td>1 2 3 4 5</td>
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<td>3. It is useless to listen to a new idea unless everybody agrees with it.</td>
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<td>4. Scientists are always interested in better explanations of things.</td>
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<td>5. If one scientist says an idea is true, all other scientists will believe it.</td>
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<td>6. Only highly trained scientists can understand science.</td>
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<td>7. We can always get answers to our questions by asking a scientist.</td>
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<td>8. Most people are not able to understand science.</td>
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<td>9. Electronics are examples of the really valuable products of science.</td>
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<td>10. Scientists cannot always find the answers to their questions.</td>
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<td>11. When scientists have a good explanation, they do not try to make it better.</td>
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<td>12. Most people can understand science.</td>
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<td>13. The search for scientific knowledge would be boring.</td>
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<td>14. Scientific work would be too hard for me.</td>
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<td>15. Scientists discover laws which tell us exactly what is going on in nature.</td>
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<td>16. Scientific ideas can be changed.</td>
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<td>17. Scientific questions are answered by observing things.</td>
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<td>18. Good scientists are willing to change their ideas.</td>
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<td>19. Some questions cannot be answered by science.</td>
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<td>20. A scientist must have a good imagination to create new ideas.</td>
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<td>21. Ideas are the important result of science.</td>
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22. I do not want to be a scientist.
23. People must understand science because it affects their lives.
24. A major purpose of science is to produce new drugs and save lives.
25. Scientists must report exactly what they observe.
26. If a scientist cannot answer a question, another scientist can.
27. I would like to work with other scientists to solve scientific problems.
28. Science tries to explain how things happen.
29. Every citizen should understand science.
30. I may not make great discoveries, but working in science would be fun.
31. A major purpose of science is to help people live better.
32. Scientists should not criticize each other’s work.
33. The senses are one of the most important tools a scientist has.
34. Scientists believe that nothing is known to be true for sure.
35. Scientific laws have been proven beyond all possible doubt.
36. I would like to be a scientist.
37. Scientists do not have enough time for their families or for fun.
38. Scientific work is useful only to scientists.
39. Scientists have to study too much.
40. Working in a science laboratory would be fun.
Answer the following questions to the best of your ability by circling your response.

41. Scientists claim that they can determine when the Earth first formed as a planet. Which technique(s) do scientists use today to determine when the Earth first formed? Choose all that apply.

(A) Comparison of fossils found in rocks  
(B) Comparison of layers found in rocks  
(C) Analysis of uranium found in rocks  
(D) Analysis of carbon found in rocks  
(E) Scientists cannot calculate the age of the Earth

42. What did the Earth's surface look like when it first formed?

(A) One large landmass surrounded  
(B) All water and no land  
(C) Similar to today  
(D) Mostly molten rock and no water  
(E) We have no way of knowing
43. Which of the following statements about the age of rocks is most likely true?

   (A) Rocks found in the ocean are about the same age as rocks found on continents
   (B) Rocks found on continents are generally older than rocks found in the ocean
   (C) Rocks found in the ocean are generally older than rocks found on continents
   (D) Ages of rocks are not precise enough to determine which rock type is older

44. Which of the following statements about radioactivity and half-life do you think are true?

   Choose all that apply.

   (A) Radioactivity only occurs if carbon is present in an object
   (B) Radioactivity can occur in the atmosphere, but not at the Earth’s surface
   (C) Radioactivity only occurs when created by people
   (D) Half-life is a measure of how quickly radioactivity decreases
   (E) Half-life and radioactivity decrease and eventually disappear

45. If you could travel back in time to when the Earth first formed as a planet, what type(s) of life do you think you might encounter?

   (A) No life would exist in water or on land
   (B) One-celled organisms in water
   (C) Animal and plant life in water
   (D) All types of life in water and on land, except people
   (E) All types of life in water and on land, including people

46. Which of the following are sources of heat inside the Earth? Choose all that apply.

   (A) Gravitational energy from the Sun
   (B) Energy from the Earth’s formation
   (C) Heat energy from the Sun
   (D) Energy from radioactivity

47. The continents we see today were once a single continent. How long did it take for the single continent to break apart and form the arrangement of continents we see today?

   (A) Hundreds of years
   (B) Thousands of years
   (C) Millions of years
   (D) Billions of years
   (E) It is impossible to tell how long the break up would have taken
48. A scientist collects all of the fossils ever discovered into one room. This room now contains:

(A) Fossils of a few of the plants and animals that ever lived
(B) Fossils of most of the plants and animals that ever lived
(C) Fossils of all of the types of plants and animals that ever lived
(D) Fossils of all of the plants and animals that ever lived
(E) Fossils of all of the types of plants and animals that ever lived

49. Which of the figures below do you think most closely represents changes in life on Earth over time?
50. The figure below is a view of one-half of the Earth’s surface as seen from space today. The gray areas represent land, and the white represents water. Which of the other figures do you think most closely represents this half of the Earth’s surface when humans first appeared on Earth?

![TODAY](image)

A

B

C

D
51. Fossils are studied by scientists interested in learning about the past. Which of the following can become fossils? **Circle all that apply.**

(A) Bones  
(B) Plant material  
(C) Marks left by plants  
(D) Marks left by animals  
(E) Animal material

52. If you could travel millions of years into the future, how big would the planet Earth be?  

(A) Smaller than today  
(B) Larger than today  
(C) Same size as today  
(D) We have no way of knowing

53. Scientists have discovered fossils of four-legged creatures called dinosaurs. How much time passed between the appearance and extinction of these creatures?  

(A) Hundreds of years  
(B) Thousands of years  
(C) Millions of years  
(D) Billions of years  
(E) Some of these creatures still exist

54. If you put a fist-sized rock in a room and left it alone for millions of years, what would happen to the rock?  

(A) The rock would almost completely turn into dirt  
(B) About half of the rock would turn into dirt  
(C) The top few inches of the rock would turn into dirt  
(D) The rock would be essentially unchanged

55. How far do you think continents move in a single year?  

(A) A few inches  
(B) A few hundred feet  
(C) A few miles  
(D) We have no way of knowing  
(E) Continents do not move
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.

Choose the one answer that best reflects how an evolutionary biologist would answer.

56. 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.

57. 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 get larger, then smaller each year.
(D) the population will get smaller, then larger each year.

58. How did the different beak types first appear in the finches?

(A) The 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).

Choose the one answer that best reflects how an evolutionary biologist would answer.

59. 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.

60. If food and space are abundant, and there are no predators, what will likely happen if a mating pair of guppies is placed in a large pond?

(A) The guppy population would grow slowly. The guppies would have only the number of offspring that are needed to replace those that have died.
(B) The guppy population would never become very large, because only organisms such as insects and bacteria reproduce that way.
(C) The guppy population will grow slowly at first, then will grow to a large number, and thousands of guppies will fill the pond.
(D) The guppy population will keep growing slowly over time.
61. 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.

62. What will probably happen in a guppy population when the amount of food is low?

(A) The guppies cooperate to find food and will probably share what they find.
(B) The guppies fight for the available food, and the stronger guppies will kill the weaker ones.
(C) Genetic changes that allow guppies to eat new types of food will appear.
(D) The guppies that cannot compete for food well will die from a lack of food.

Introduction to Canary Island Lizards

- The Canary Islands are seven islands just west of the African continent.
- The islands gradually became colonized with life: plants, lizards, birds, etc.
- Three different species of lizards are found on the islands.
- These three species are similar to one species found on the African continent.
- Scientists think that the lizards traveled from Africa to the Canary Islands by floating on tree trunks washed out to sea.

Choose the one answer that best reflects how an evolutionary biologist would answer.

63. A population of lizards is made up of hundreds of individual lizards. How similar are they to other lizards in the population?

(A) All lizards are the same.
(B) All lizards are the same on the outside, but have differences in their internal traits.
(C) All lizards are the same on the inside, but have differences in their external traits.
(D) All lizards share many similarities, but have some important differences in their traits.
64. How are traits in lizards inherited by their young?

(A) When a parent lizard learns to catch certain insects, its young can inherit the ability to catch those insects.
(B) When a parent lizard gets stronger claws through repeated use in catching prey, its young can inherit the stronger claw trait.
(C) When a parent lizard is born with an extra claw on each limb, its offspring can inherit the extra claw.
(D) When a parent lizard’s claws are weak because the available prey is easy to catch, its young can inherit the weakened claws.

65. What could have caused one species to change into three species over time?

(A) Groups of lizards lived on different islands. Over time, many genetic changes may have happened in each group so they could no longer breed with each other, and this made them different species.
(B) There are small variations between the lizards, but all lizards are mostly alike, and are all members of a single species.
(C) Groups of lizards needed to adapt to different islands, so the lizards in each group slowly changed over time to become a new lizard species.
(D) Groups of lizards found different island environments, so the lizards needed to become new species with different traits in order to survive over time.

Consider the proposed evolutionary tree below. Mammals originated on land, yet whales are adapted to life in the sea and can never come onto the land. The exact process of how land animals evolved into whales has been difficult to understand. However, new discoveries in India, Afghanistan and Pakistan are providing evidence for the transition of the whale family from ancient shore-dwelling ancestors.
66. The whales are classified with a group of mammals which are called even-toed ungulates. Whales have been classified as part of this group along with their closest relative the hippopotamus because:

(A) Whales and hippos are big, heavy, and have round bodies with large mouths.
(B) Whales and hippos share a more recent common ancestor.
(C) Whales and hippos have similar diets and need to live in water.
(D) Whales and hippos display similar social and parenting behaviors.

67. The chart above suggests that:

(A) The animals in this classification tree have four legs.
(B) Baleen Whales are not related to camels.
(C) Whales are more closely related to giraffes than to bison.
(D) Whales are more closely related to deer than to pigs.

68. According to evolutionary theory, whales have evolved from land animal ancestors over time. How much time do you think the evolution process might have taken?

(A) Fifty million years.
(B) Five million years.
(C) Five hundred thousand years
(D) Five hundred million years

69. The fossils that are being examined to determine the ancestor in the evolutionary pathway of whales have been found in areas of Pakistan, Afghanistan, and India, places that are now well above sea level. The most scientifically reasonable explanation for the location of the fossils being examined is:

(A) Predators of whale ancestors carried their prey to this area to eat them.
(B) When the whales died their skeletons floated to the top of the ocean where they drifted ashore and became fossils.
(C) This area was most likely once covered with water and the shore-dwelling ancestors of whales once lived in these areas, died, and their skeletons were fossilized.
(D) The great meteor impact caused tidal wave that forced these animals into these areas trapping them causing them to die, and their skeletons were fossilized.
70. The evolutionary history and development of whales has been hotly debated. Recently there
has been a major shift in our understanding of the processes used to detail whale evolution.
This indicates that:

(A) Gaps in the fossil records will never allow us to fully understand evolution.
(B) Scientists studying evolution typically present ideas with very little evidence, leaving it
to others to find proof of their ideas.
(C) Aspects of evolution are constantly being challenged and explored in light of new
evidence.
(D) Much of the science of evolution is based on speculation that can easily be changed when
scientists think of new ideas.

71. The origins of the transformation from land animal to sea creature may be observed among
some wild sheep who have lived on the coast for hundreds of years. These sheep like to eat
seaweed and kelp so much that they are often observed swimming into the water to eat it. If
we returned millions of years later to observe these animals, what might you see?

(A) Sheep who wanted to be better swimmers and so developed the ability to swim great
distanced to eat kelp.
(B) Two distinct but related sheep like organisms, one that lives in the water and eats kelp,
the other lives on land and eats plants.
(C) These sheep will become extinct because they will not be able to find other food and only
their fossil will remain.
(D) There are so many possible outcomes that there is really no way to predict what will be
seen.
The graphic below 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.

72. 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.

73. The African Great Apes are theorized to have evolved from a common ancestor. Given that this process took place over time, how much time do you think the process of evolution in this group of organisms might take?

(A) Thirty million years.
(B) Three billion years.
(C) Thirty thousand years.
(D) Three million years.
74. The fossil record for early humans is very sparse compared to many other organisms. In the context of the Great Ape tree this means:

(A) Much of the evolutionary relationships of humans and the other Great Apes is opinion and based on guess.
(B) Analysis of genetic codes and anatomy are used to derive such relationships.
(C) The evolutionary relationships of humans are relative easy to determine based on the wide variety of humans alive today.
(D) Humans have not undergone many evolutionary changes and remain at the top of the tree.

75. In advanced discussions of the evolution of the Great Apes, one will see a number of different evolutionary pathways, each suggesting a different relationship between the different groups of Apes. These discrepancies suggest:

(A) Scientists remain uncertain if any of the Great Apes are really related and are continuing to try to prove this.
(B) Scientists remain uncertain why humans would want to evolve and are continued to be seen as the superior species.
(C) Anything aside from fossils is a weak form of evidence for the support of evolutionary theory.
(D) Processes and small differences in methods can produce very different evidence that can be interpreted in different ways.

76. What are your perceptions about evolution?
77. What are your perceptions about deep time?

78. Does the study of evolution conflict with your personal beliefs?
   a. If so, how do you deal with those conflicts when they arise?
79. Does the study of deep time conflict with your personal beliefs?
   a. If so, how do you deal with those conflicts when they arise?

80. What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?
APPENDIX D – Permission to Use the SAI II Instrument

Dr. Moore,

My name is Allan Nolan, and I am a PhD candidate at the University of Southern Mississippi in the Center for Science and Mathematics Education working towards my doctorate in Science Education with an emphasis in Earth Science. My proposed dissertation is titled, “The effects of an historical geology course on students’ attitudes towards science and their content knowledge of deep time as a mediator to understanding evolution.”

I would like to use the Scientific Attitude Inventory: A Revision, as one of the quantitative components of my research instrument. With your permission, may I use your instrument in my research? If you would like, I would be happy to explain my research methodology in more detail.

Thank you in advance for your time and consideration in this matter.

Sincerely,

Allan Nolan,
B.A. Biology Education
M.S. Geosciences
The University of Southern Mississippi
Center for Science and Mathematics Education

"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology." - Carl Sagan

Allan, I am attaching a copy of the SAI II, and a copy of SAI II Positions and Attitudes to this email. You can use the latter to develop a scoring system for the former. I regret that there is no currently useful scoring software available. However, one could easily score smaller groups using an Excel spreadsheet and the SAI II Positions and Attitudes document.

I hereby grant permission for your use of the attached materials for your current project.

Best wishes for your successful completion of the work.

Richard W. Moore
Professor Emeritus
Miami University
moorerw@miamioh.edu
APPENDIX E – Permission to Use the GCI Instrument

Dr. Libarkin,

My name is Allan Nolan, and I am a PhD candidate at the University of Southern Mississippi in the Center for Science and Mathematics Education working towards my doctorate in Science Education with an emphasis in Earth Science. My proposed dissertation is titled, “The effects of an historical geology course on students’ attitudes towards science and their content knowledge of deep time as a mediator to understanding evolution.”

I would like to use the Geoscience Concept Inventory, v.3, as one of the quantitative components of my research instrument. With your permission, may I use your instrument in my research? If you would like, I would be happy to explain my research methodology in more detail.

Thank you in advance for your time and consideration in this matter.

Sincerely,

Allan Nolan,
B.A. Biology Education
M.S. Geosciences
The University of Southern Mississippi
Center for Science and Mathematics Education

"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology." - Carl Sagan

Allan:

Nice not meet you! The GCI is freely accessible and anyone should use it as they see fit.

We have some new research and items that we aren’t quite ready to release - you can access the most recent items here in case you don’t have them:

https://geocognitionresearchlaboratory.wordpress.com/research-in-the-gri/research-related-to-understanding/

Cheers
Julie
Julie Libarkin
Professor
Director - Geocognition Research Lab
Michigan State University
288 Farm Lane, 206 Natural Science
East Lansing, MI 48824

Phone: 517-355-8369
https://www.msu.edu/~libarkin

Affiliations: Center for Integrative Studies in General Science, Department of Geological Sciences, Cognitive Science Program, Environmental Science and Policy Program, CREATEforSTEM
APPENDIX F – Permission to Use the CINS Instrument

Dr. Anderson,

My name is Allan Nolan, and I am a PhD candidate at the University of Southern Mississippi in the Center for Science and Mathematics Education working towards my doctorate in Science Education with an emphasis in Earth Science. My proposed dissertation is titled, “The effects of an historical geology course on students’ attitudes towards science and their content knowledge of deep time as a mediator to understanding evolution.”

I previously sent this email to the original address on the CINS publication, but I also found the email address above. I wanted to send it to both on the chance that one might be defunct.

I would like to use portions of the Conceptual Inventory of Natural Selection, as one of the quantitative components of my research instrument. With your permission, may I use questions from your instrument in my research? If you would like, I would be happy to explain my research methodology in more detail.

Thank you in advance for your time and consideration in this matter.

Sincerely,

Allan Nolan,
B.A. Biology Education
M.S. Geosciences
The University of Southern Mississippi
Center for Science and Mathematics Education
"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology." - Carl Sagan

Hi Nolan,

I am happy to share the CINS with you as well as the NARST paper that describes it. Since you do not say what age of students you are working with, I have attached both the middle school and high school/college versions.

Dianne
--
Dianne L. Anderson, Ph.D.
Professor of Biology
Point Loma Nazarene University
3900 Lomaland Drive
San Diego, CA  92106
619.849.2705

Dr. Anderson,

We spoke a few months ago concerning the use of the CINS for my dissertation. I have a quick question for you concerning the validity testing.

I was planning on using only a few questions from each of the subsets of items in the instrument (because I am combining the CINS with other instruments to create a composite college-level “evolution” instrument). My committee has said that to be able to do that, each item would need to be validated individually, otherwise I must use the instrument in its entirety or I would need to pilot my new instrument.

Do you have any data concerning the validity of the individual items? Or must they all be used together to be valid?

Thank you so much,

Allan Nolan,
B.A. Biology Education
M.S. Geosciences
The University of Southern Mississippi
Center for Science and Mathematics Education

"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology." - Carl Sagan

Hi Allen,

The gold standard in conceptual inventory development is comparing student answers on the CINS items with the student interview answers using a think-aloud protocol. We have done this with students from middle school to high school to college level and are confident that this validation is adequate to assure users that the individual items are assessing what they are intended to assess. I don't have data to share because we used an iterative process over a time span of two years to gradually fine tune the wording of each item based on our interviews. Not sure if a committee will accept this or not.

Dianne
Dr. Nadelson,

My name is Allan Nolan, and I am a PhD candidate at the University of Southern Mississippi in the Center for Science and Mathematics Education working towards my doctorate in Science Education with an emphasis in Earth Science. My proposed dissertation is titled, “The effects of an historical geology course on students’ attitudes towards science and their content knowledge of deep time as a mediator to understanding evolution.”

I would like to use portions of the Measure of Understanding of Macroevolution, as one of the quantitative components of my research instrument. With your permission, may I use questions from your instrument in my research? If you would like, I would be happy to explain my research methodology in more detail.

Thank you in advance for your time and consideration in this matter.

Sincerely,

Allan Nolan,
B.A. Biology Education
M.S. Geosciences
The University of Southern Mississippi
Center for Science and Mathematics Education

"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology." - Carl Sagan

Awesome project! Go for it! You may also be interested in my trust in science instrument.

Good luck with your research!

Louis

sent from my phone - thanks for your understanding

Dr. Nadelson,

We spoke a few months ago concerning the use of the MUM for my dissertation. I have a quick question for you concerning the validity testing.
I was planning on using only a few questions from each of the subsets of items in the instrument (because I am combining the MUM with other instruments to create a composite “evolution” instrument). My committee has said that to be able to do that, each item would need to be validated individually, otherwise I must use the instrument in its entirety or I would need to pilot my new instrument.

Do you have any data concerning the validity of the individual items? Or must they all be used together to be valid?

Thank you so much,

Allan Nolan,
B.A. Biology Education
M.S. Geosciences
The University of Southern Mississippi
Center for Science and Mathematics Education

"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology.” - Carl Sagan

Hi Allan,

WE validated each item as we sent the instrument to several experts in evolution education and asked them if each of the items would effectively measure some aspect of understanding macro-evolution.

I hope that helps.

Take care,

Louis

Louis S. Nadelson, Ph.D.
Director of Sponsored Programs and Academic Research
Colorado Mesa University
1100 North Street
Grand Junction, CO 81501
Office: 970-248-1424
Email: lnadelson@coloradomesa.edu
Alt email: Louisnadelson@gmail.com

“Extraordinary claims require extraordinary evidence.” — Carl Sagan
APPENDIX H – Permission to Use the Interview Questions

Dr. Woods,

My name is Allan Nolan, and I am a PhD candidate at the University of Southern Mississippi in the Center for Science and Mathematics Education working towards my doctorate in Science Education with an emphasis in Earth Science. My proposed dissertation is titled, “The effects of an historical geology course on students’ attitudes towards science and their content knowledge of deep time as a mediator to understanding evolution.”

I would like to use portions of the interview questions from your 2001 study, High School Students’ Perceptions of Evolutionary Theory, coauthored with Dr. Scharmann, as one of the qualitative components of my research instrument. With your permission, may I use questions from your interviews in my research? If you would like, I would be happy to explain my research methodology in more detail.

Thank you in advance for your time and consideration in this matter.

Sincerely,

Allan Nolan,
B.A. Biology Education
M.S. Geosciences
The University of Southern Mississippi
Center for Science and Mathematics Education

“We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology.” - Carl Sagan

You have my permission to use my interview questions.
APPENDIX I – Institutional Review Board Approval

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 20.111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

☐ The risks to subjects are minimized.
☐ The risks to subjects are reasonable in relation to the anticipated benefits.
☐ The selection of the subjects is equitable.
☐ Informed consent is adequate and appropriately documented.
☐ Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
☐ Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
☐ Appropriate additional safeguards have been included to protect vulnerable subjects.
☐ Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the “Adverse Effect Report Form”.
☐ If approved, the maximum period of approval is limited to twelve months.

Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: 17072501
PROJECT TITLE: The effect of an Historical Geology course on students’ attitudes towards science and their content knowledge of deep time as a mediator to understanding
PROJECT TYPE: Doctoral Dissertation
RESEARCHER(S): Allan Nolan
COLLEGE/DIVISION: College of Science and Technology
DEPARTMENT: Center for Science and Math Education
FUNDING AGENCY/SPONSOR: N/A
IRB COMMITTEE ACTION: Expedited Review Approval
PERIOD OF APPROVAL: 08/15/2017 to 08/14/2018

Lawrence A. Hosman, Ph.D.
Institutional Review Board
APPENDIX J – IRB Standard Informed Consent

ORI Office of Research Integrity

STANDARD INFORMED CONSENT

This completed document must be signed by each consenting research participant.
- The Project Information and Research Description sections of this form should be completed by the Principal Investigator before submitting this form for IRB approval.
- Signed copies of the long form consent should be provided to all participants.

Institutional Review Board

STANDARD INFORMED CONSENT PROCEDURES

Today’s date:

<table>
<thead>
<tr>
<th>PROJECT INFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Title: The effect of an Historical Geology course on students’ attitudes towards science and their content knowledge of deep time as a mediator to understanding.</td>
</tr>
<tr>
<td>Principal Investigator: Allan Nolan</td>
</tr>
<tr>
<td>College: College of Science and Technology</td>
</tr>
</tbody>
</table>

RESEARCH DESCRIPTION

1. Purpose:

As a member of this course, you are being invited to participate in the researcher’s study on deep time and evolution as part of the fulfillment of his dissertation requirements for his doctoral program.

2. Description of Study:

This research will involve pre- and post-test analysis of volunteers from both BSC 111 and GLY 103. The questionnaires seek to understand three different areas: (1) attitude towards science, (2) understanding of deep time (billions year old Earth), and (3) understanding of evolution. Some parts of the survey will be how much each student agrees or disagrees with a statement, and other parts of the survey will gauge their current understanding of specific paleontological topics. This questionnaire will be given twice per semester - once on the first day of class, and once again with the final exam. Each questionnaire should take less than an hour to complete.

The goal of this research is to determine the differences (if any) in student understanding of evolution, when evolution is presented in these two different contexts.

3. Benefits:

There are no direct benefits from participation in this research other than any benefits you may acquire from contemplating the questions for the study.

4. Risks:

There are no foreseeable risk to you for participating, other than the inconvenience of losing a little lab time, or any discomfort you may experience while answering these questions.

5. Confidentiality:
If you are enrolled as a student in BSC 111, although your participation in this research is not anonymous, your name will only be used to match your pre-test and post-test answers for analysis. Only the researcher will have access to the questionnaires, and all surveys will be shredded at that completion of the research. Any participants who would like to see the results of the research may do so after the conclusion of the study.

If you are enrolled in GLY 103, all information above applies, BUT your name and scores (no demographic data) will be provided to the instructor of record for submission to the university in completion of GEC requirements.

6. Alternative Procedures:

Participation in this research is completely voluntary and you have the option to withdraw at any time without penalty or prejudice.

7. Participant’s Assurance:

This project has been reviewed by the Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations.

Any questions or concerns about rights as a research participant should be directed to the Chair of the IRB at 601-266-5997. Participation in this project is completely voluntary, and participants may withdraw from this study at any time without penalty, prejudice, or loss of benefits. Any questions about the research should be directed to the Principal Investigator using the contact information provided in Project Information Section above.

CONSENT TO PARTICIPATE IN RESEARCH

Participant’s Name: 

Consent is hereby given to participate in this research project. All procedures and/or investigations to be followed and their purpose, including any experimental procedures, were explained to me. Information was given about all benefits, risks, inconveniences, or discomforts that might be expected.

The opportunity to ask questions regarding the research and procedures was given. Participation in the project is completely voluntary, and participants may withdraw at any time without penalty, prejudice, or loss of benefits. Unless described above and agreed to by the participant, all personal information is strictly confidential, and no names will be disclosed. Any new information that develops during the project will be provided if that information may affect the willingness to continue participation in the project.

Questions concerning the research, at any time during or after the project, should be directed to the Principal Investigator with the contact information provided above. This project and this consent form have been reviewed by the Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research participant should be directed to the Chair of the Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5147, Hattiesburg, MS 39406-0001, (601) 266-5997.

Include the following information only if applicable. Otherwise delete this entire paragraph before submitting for IRB approval: The University of Southern Mississippi has no mechanism to provide compensation for participants who may incur injuries as a result of participation in research projects. However, efforts will be made to make available the facilities and professional staff at the University. Participants may incur charges as a result of treatment related to research injuries. Information regarding treatment or the absence of treatment has been given above.

Research Participant ___________________________ Person Explaining the Study ___________________________
1. **Course Description:**

Welcome to BSC 111, Principles of Biological Sciences II. I hope you enjoy this course, which is designed to explore an introduction to the biological sciences, emphasizing the systematics, diversity, form and function of biological organisms, their evolution, and ecology. This course is required for all Biological Sciences majors. This course is part of the General Education Curriculum (GEC) of the University. As a consequence, the course fulfills the following GEC Student Learning Outcomes.

2. **Course Objectives:**

a. demonstrate the ability to develop and focus on one topic in writing assignments and present ideas in an organized, logical, and coherent form,

b. demonstrate the ability to develop and focus on one topic in speaking assignments and present ideas in an organized, logical, and coherent form,

c. demonstrate the ability to use Standard English grammar, punctuation, spelling, and usage,

d. understand the evolutionary history of major groups of organisms

e. understand the ecology of major groups of organisms

f. introduce concepts within the biology of human anatomy and physiology

3. **Course Assessments:**

a. 5 Exams

b. Daily Clicker Grades

c. Pre-Chapter Readings

d. Post-Chapter Quizzes

4. **Required Texts:**

a. Principles of Biology by Brooker *et al.*

b. Reef App or i>Clicker 2 Remote

5. **Tentative Course Schedule:**

a. Week 1 – Week 3
i. Evolution & The History of Life on Earth
ii. Taxonomy and Systematics
iii. Microorganisms: The Achaea and Bacteria
iv. Exam 1

b. Week 4 – Week 6
   i. Microorganisms: Protists
   ii. Plant Evolution and Diversity
   iii. Fungi

c. Week 7 – Week 10
   i. Exam 2
   ii. Introduction to Animal Diversity
   iii. Invertebrates
   iv. Vertebrates

d. Week 11 – Week 13
   i. Exam 3
   ii. Homeostasis/Neuroscience
   iii. Excretory Systems & Fluid Homeostasis
   iv. Endocrine Systems
   v. Immune Systems

e. Week 14 – Week 17
   i. Exam 4
   ii. Ecology & The Physical Environment
   iii. Population Ecology
   iv. Community Ecology
   v. Biodiversity and Conservation Biology
   vi. Final Exam
1. **Course Description:**

   BSC 111L is the corequisite laboratory for Principles of Biological Science II, the second biology course for science majors. This laboratory is designed to complement the lecture course rather than present parallel information, and, so, the topics presented may not be the same topics as in lecture. BSC 111L is part of the General Education Curriculum (GEC) of the University.

2. **General Education Curriculum Objectives:**

   a. demonstrate the ability to develop and focus on one topic in speaking and writing assignments and present ideas in an organized, logical, and coherent form,

   b. demonstrate the ability to use Standard English grammar, punctuation, spelling, and usage,

   c. have a good understanding of the scientific method,

   d. be able to interpret scientific data and reach a plausible conclusion,

   e. have a good understanding of the techniques used in science, and

   f. demonstrate the ability to find and use (and cite) relevant sources.

3. **Course Assessments:**

   a. Weekly Quizzes

   b. Weekly Lab Assignments

4. **Required Texts:**

   a. Principles of Biological Science II Lab Manual by J. Michael Sellers

   b. A Short Guide to Writing About Biology by Pechenick

5. **Tentative Course Schedule:**

   a. Week 1 – Course Introduction & Review

   b. Week 2 – The Classification & Diversity of Life

   c. Week 3 - Bacteriology

   d. Week 4 – The Protists

   e. Week 5 – Plant Diversity I
f. Week 6 – Plant Diversity II  
g. Week 7 – Kingdom Fungi  
h. Week 8 – Animal Diversity I  
i. Week 9 – Animal Diversity II  
j. Week 10 – Vertebrate Anatomy I: The Skin, Digestive, Circulatory, Respiratory, Excretory, and Reproductive Systems  
k. Week 11 – Vertebrate Anatomy II: Fetal Pig Dissection  
l. Week 12 – The Distribution of Organisms: An Introduction to Ecological Interactions  
m. Week 13 – Lab Practical
APPENDIX M – Abbreviated GLY 103 Lecture Syllabus

1. **Course Description:**

   This course serves as a broad introduction to the history of Earth and its past inhabitants. We will discuss plate tectonics and how it relates to mountain-building, environmental changes, changes in sea levels, and how it drove evolutionary changes to life on Earth. We will also look at ancient life, how it adapted and evolved to a dynamic Earth, how they were preserved, and what they can teach us about our world today.

   Not only should this introductory course foster an appreciation for Earth science but, for some, it will be a foundation to embark on an educational focus in the geosciences. Finally, it will serve as a background to better understand the dynamic nature of Earth and its inhabitants.

2. **Course Objectives:**

   a. Describe the general composition and structure of Earth.
   b. Classify and describe general groups of minerals and rocks.
   c. Associate the theory of plate tectonics with the development of continents and oceans.
   d. Understand the Geologic Timescale.
   e. Classify and describe Sedimentary Rocks and the Fossils they contain.
   f. Understand the Theory of Evolution and how it works.
   g. Understand the tectonic evolution of Earth through Geologic Time.
   h. Understand the biological evolution of Life through Geologic Time.

3. **General Education Curriculum Objectives:**

   a. Students will develop a topic and present ideas through writing in an organized, logical, and coherent form and in a style that is appropriate for the discipline and the situation.
   b. Students will use Standard English grammar, punctuation, spelling, and usage.
   c. Students will differentiate the basic concepts in a discipline of science.
d. Students will employ the scientific method, interpret scientific data, and reach a plausible conclusion.

e. Students will write a minimum of 2500 words.

4. **Course Assessments:**
   a. 4 Exams
   b. 16 Online Quizzes
   c. 12 Online Discussions
      i. Scientific Method (4)
      ii. Story of Life Readings (4)
      iii. Climate Change (4)
   d. 8 Attendance Quizzes

5. **Tentative Course Schedule:**
   a. Week 1 – Week 4
      i. Textbook Chapters 1-4
      ii. Scientific Method Online Discussion 1 & 2
      iii. Exam 1
   b. Week 5 – Week 7
      i. Textbook Chapters 5-7
      ii. Scientific Method Online Discussion 3 & 4
      iii. Story of Life Readings Online Discussion 1
   c. Week 8 – Week 12
      i. Exam 2
      ii. Textbook Chapters 8-13
      iii. Story of Life Readings Online Discussion 2-4
      iv. Climate Change Online Discussion 1
   d. Week 13 – Week 18
      i. Exam 3
      ii. Textbook Chapters 14-18
      iii. Climate Change Online Discussion 2-4
      iv. Final Exam
1. **Course Description:**
   This lab serves as a participatory, “hands on” complement to GLY 103: Historical Geology. Lab exercises will be a mixture of: (i) geologic sample identification, (ii) map competency and spatial cognition, (iii) fossil identification, (iv) understand biological evolution over geologic time, and (v) correlation, among others.

2. **General Education Curriculum Objectives:**
   a. Students will develop a topic and present ideas through writing in an organized, logical, and coherent form and in a style that is appropriate for the discipline and the situation.
   b. Students will use Standard English grammar, punctuation, spelling, and usage.
   c. Students will differentiate the basic concepts in a discipline of science.
   d. Students will employ the scientific method, interpret scientific data, and reach a plausible conclusion.

3. **Tentative Course Schedule:**
   a. Week 1 – Lab Manual Chapter 1
   b. Week 2 – Lab Manual Chapter 2
   c. Week 3 – Lab Manual Chapter 3
   d. Week 4 – Lab Manual Chapter 4
   e. Week 5 – Lab Manual Chapter 5
   f. Week 6 – Lab Manual Chapter 8
   g. Week 7 – Lab Manual Chapter 9
   h. Week 8 – Lab Manual Chapter 10
   i. Week 9 – Lab Manual Chapter 11
   j. Week 10 – Lab Manual Chapter 12
   k. Week 11 – Lab Manual Chapter 14
   l. Week 12 – Lab Manual Chapter 15
   m. Week 13 – Lab Manual Chapter 16
# APPENDIX O – Historical Geology: Evolution of Earth & Life Through Time:

## Abbreviated Chapter and Header Listings

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Sections</th>
</tr>
</thead>
</table>
d. James Hutton and the Recognition of Geologic Time

5. Rocks, Fossils, and Time: Making Sense of the Geologic Record
   a. Introduction
   b. Stratigraphy
   c. Fossils and Fossilization
   d. The Relative Geologic Time Scale
   e. Stratigraphic Terminology
   f. Correlation
   g. Numerical Dates and the Relative Geologic Time Scale
   h. Summary

6. Sedimentary Rocks: The Archives of Earth History
   a. Introduction
   b. Sedimentary Rock Properties
   c. Depositional Environments
   d. Interpreting Depositional Environments
   e. Paleogeography
   f. Summary

   a. Introduction
   b. Evolution: What Does It Mean?
   c. Mendel and the Birth of Genetics
   d. The Modern View of Evolution
   e. What Kinds of Evidence Support Evolutionary Theory?
   f. Fossils: What Do We Learn From Them?
   g. Summary

8. Precambrian Earth and Life History: The Hadean and the Archean Eon
   a. Introduction
   b. What Happened During the Hadean?
   c. Archean Earth History
   d. The Atmosphere and Hydrosphere
   e. Life – Its Origin and Early History
   f. Archean Mineral Resources
   g. Summary

9. Precambrian Earth and Life History: The Proterozoic Eon
   a. Introduction
   b. Proterozoic History of Laurentia
   c. Proterozoic Supercontinents
   d. Ancient Glaciers and Their Deposits
   e. The Evolving Atmosphere
   f. Proterozoic Life
   g. Proterozoic Mineral Resources
   h. Summary

10. Early Paleozoic Earth History
a. Introduction  

b. Continental Architecture: Cratons and Mobile Belts  

c. Paleozoic Paleogeography  

d. Early Paleozoic Evolution of North America  

e. The Sauk Sequence  

f. The Tippecanoe Sequence  

g. The Appalachian Mobile Belt and the Taconic Orogeny  

h. Early Paleozoic Mineral Resources  

i. Summary  

11. Late Paleozoic Earth History  

a. Introduction  

b. Late Paleozoic Paleogeography  

12. Paleozoic Life History: Invertebrates  

a. Introduction  

b. The Emergence of a Shelly Fauna  

13. Paleozoic Life History: Vertebrates and Plants  

a. Introduction  

b. Vertebrate Evolution  

c. Fish  

d. Amphibians – Vertebrates Invade the Land  

e. Evolution of the Reptiles – The Land is Conquered  

f. Plant Evolution  

14. Mesozoic Earth History  

a. Introduction  

b. The Breakup of Pangaea  

15. Life of the Mesozoic Era  

a. Introduction  

b. Marine Invertebrates and Phytoplankton  

c. Aquatic and Semiaquatic Vertebrates  

d. Plants – Primary Producers on Land
e. The Diversification of Reptiles
f. The Origin and Evolution of Birds
g. The Origin and Evolution of Mammals
h. Mesozoic Climates and Paleogeography
i. Mass Extinctions – A Crisis in Life History
j. Summary

16. Cenozoic Earth History: The Paleogene and Neogene Periods
   a. Introduction
   b. Cenozoic Plate Tectonics – An Overview
   c. Cenozoic Orogenic Belts
   d. North American Cordilleran
   e. The Continental Interior
   f. Cenozoic History of the Appalachian Mountains
   g. North America’s Southern and Eastern Continental Margins
   h. Paleogene and Neogene Mineral Resources
   i. Summary

17. Cenozoic Earth History: The Quaternary Period
   a. Introduction
   b. Pleistocene and Holocene Tectonism and Volcanism
   c. Pleistocene Stratigraphy
   d. Onset of the Ice Age
   e. Glaciation and Its Effect
   f. What Caused Pleistocene Glaciation?
   g. Glaciers Today
   h. Quaternary Mineral Resources
   i. Summary

18. Life of the Cenozoic Era
   a. Introduction
   b. Marine Invertebrates and Phytoplankton
   c. Cenozoic Vegetation and Climate
   d. Cenozoic Birds
   e. The Age of Mammals Begins
   f. Paleogene and Neogene Mammals
   g. Pleistocene Faunas
   h. Intercontinental Migrations

19. Primate and Human Evolution
   (not covered in Historical Geology)
   a. Introduction
   b. What are Primates?
   c. Prosimians
   d. Anthropoids
   e. Hominids and Hominins
   f. Summary

20. Epilogue

21. Appendices
   a. Epilogue
   b. English-Metric Conversion Chart
   c. Classification of Organisms
   d. Mineral Identification
   e. A Refresher on Structural Geology
1. Planet of the Scum: The First Fossils: Cryptozoon
2. Garden of the Ediacara: The First Multicellular Life: Charnia
3. “Little Shellies”: The First Shells: Cloudina
4. Oh, Give Me A Home, Where the Trilobites Roamed: The First Large Shelled Animals: Olenellus
5. Is It A Worm or An Arthropod?: The Origin of Arthropods: Hallucigenia
6. Is It A Worm or A Mollusc?: The Origin of Molluscs: Pilina
7. Growing from the Sea: The Origin of Land Plants: Cooksonia
9. Mega-Jaws: The Largest Fish: Carcharocles
10. Fish Out of Water: The Origin of Amphibians: Tiktaalik
11. “Frogamander”: The Origin of Frogs: Gerobatrachus
12. Turtles on the Half-Shell: The Origin of Turtles: Odontochelys
15. Terror of the Seas: The Largest Sea Monster: Kronosaurus
19. Not Quite a Mammal: The Origin of Mammals: Thrinaxodon
20. Walking into the Water: The Origin of Whales: Ambulocetus
22. Dawn Horses: The Origin of Horses: Eohippus
23. Rhinoceros Giants: The Largest Land Mammal: Paraceratherium
24. The Ape’s Reflection?: The Oldest Human Fossil: Sahelanthropus
25. Lucy in the Sky With Diamonds: The Oldest Human Skeleton: Australopithecus afarensis
26. Appendix: The Best Natural History Museums
27. Index
APPENDIX Q – Chapter Listing for Deciphering Earth History: Exercises in Historical Geology

1. Description and Classification of Sedimentary Rocks
2. Interpretation of Sedimentary Rocks
3. Relative Time and Sequence of Events
4. Lithostratigraphy
5. Biostratigraphy
6. Radioisotopic Dating Techniques
7. Geophysical Applications in Stratigraphy
8. Fossil Preservation and Taphonomy
9. Evolution
10. Early Paleozoic Life: The Cambrian Fauna
11. Later Paleozoic Life
13. Paleoecology
14. Paleoclimatology
15. Geologic Maps and Interpretation of Earth History in Selected Regions
16. Plate Tectonics
17. Appendix: Systematic Paleontology
APPENDIX R – Chapter Listing for Principles of Biology

1.  An Introduction to Biology
   a.  Principles of Biology and the Levels of Biological Organization
   b.  Unity and Diversity of Life
   c.  Biology as a Scientific Discipline

2.  The Chemical Basis of Life I: Atoms, Molecules, and Water
   a.  Atoms
   b.  Chemical Bonds and Molecules
   c.  Chemical Reactions
   d.  Properties of Water
   e.  pH and Buffers

3.  The Chemical Basis of Life II: Organic Molecules
   a.  The Carbon Atom and Carbon-Containing Molecules
   b.  Synthesis and Breakdown of Organic Molecules
   c.  Carbohydrates
   d.  Lipids
   e.  Proteins
   f.  Nucleic Acids

4.  General Features of Cells
   a.  Microscopy
   b.  Overview of Cell Structure and Function
   c.  The Cytosol
   d.  The Nucleus and Endomembrane System
   e.  Semiautonomous Organelles
   f.  Protein Sorting to Organelles
   g.  Extracellular Matrix and Plant Cell Walls
   h.  Systems Biology of Cells: A Summary

5.  Membrane Structure, Transport, and Cell Junctions
   a.  Membrane Structure
   b.  Fluidity of Membranes
   c.  Overview of Membrane Transport
   d.  Transport Proteins
   e.  Intercellular Channels
   f.  Exocytosis and Endocytosis
   g.  Cell Junctions

6.  Energy, Enzymes, and Cellular Respiration
   a.  Energy and Chemical Reactions
   b.  Enzymes
   c.  Overview of Metabolism and Cellular Respiration
   d.  Glycolysis
   e.  Breakdown of Pyruvate
   f.  Citric Acid Cycle
   g.  Oxidative Phosphorylation
   h.  Connections Among Carbohydrate, Protein, and Fat Metabolism
7. Photosynthesis
   a. Overview of Photosynthesis
   b. Reactions That Harness the Light
   c. Molecular Features of Photosynthesis
   d. Synthesizing Carbohydrates via the Calvin Cycle
   e. Variations in Photosynthesis

8. Cell Communication
   a. General Features of Cell Communication
   b. Receptor Activation
   c. Cell Surface Receptors
   d. Intracellular Receptors
   e. Signal Transduction and Cellular Response via an Enzyme-Linked Receptor
   f. Signal Transduction and Cellular Response via a G-Protein-Coupled Receptor

9. Nucleic Acid Structure, DNA Replication, and Chromosome Structure
   a. Properties and Identification of the Genetic Material
   b. Nucleic Acid Structure
   c. Discovery of the Double-Helix Structure of DNA
   d. An Overview of DNA Replication
   e. Molecular Mechanism of DNA Replication
   f. Molecular Structure of Eukaryotic Chromosomes

10. Gene Expression at the Molecular Level
    a. Overview of Gene Expression
    b. Transcription
    c. RNA Processing in Eukaryotes
    d. Translation and the Genetic Code
    e. The Machinery of Translation
    f. The Stages of Translation

11. Gene Regulation
    a. Overview of Gene Regulation
    b. Regulation of Transcription in Bacteria
    c. Regulation of Transcription in Eukaryotes: Roles of Transcription Factors
    d. Regulation of Transcription in Eukaryotes: Changes in Chromatin Structure and DNA Methylation
    e. Regulation of RNA Processing and
Translation in Eukaryotes

12. Mutation, DNA Repair, and Cancer
   a. Types of Mutations
   b. Causes of Mutations
   c. DNA Repair
   d. Cancer

13. The Eukaryotic Cell Cycle, Mitosis, and Meiosis
   a. The Eukaryotic Cell Cycle
   b. Mitotic Cell Division
   c. Meiosis and Sexual Reproduction
   d. Variation in Chromosome Structure and Number

14. Patterns of Inheritance
   a. Mendel’s Laws of Inheritance
   b. Chromosome Theory of Inheritance
   c. Pedigree Analysis of Human Traits
   d. Variations in Inheritance Patterns and Their Molecular Basis
   e. Sex Chromosomes and X-Linked Inheritance Patterns
   f. Epigenetic Inheritance: X Inactivation
   g. Linkage of Genes on the Same Chromosome
   h. Extraneural Inheritance: Organelle Genomes

15. Genetics of Viruses and Bacteria
   a. Genetic Properties of Viruses
   b. Genetic Properties of Bacteria
   c. Gene Transfer Between Bacteria

16. Genetic Technology
   a. Gene Cloning
   b. Genomics: Techniques for Studying Genomes
   c. Biotechnology

17. Genomes, Repetitive Sequences, and Bioinformatics
   a. Bacterial and Archaeal Genomes
   b. Eukaryotic Genomes
   c. Repetitive Sequences and Transposable Elements
   d. Bioinformatics

18. The Origin and History of Life on Earth
   a. Origin of Life on Earth
   b. The Fossil Record
   c. History of Life on Earth

19. An Introduction to Evolution and Population Genetics
   a. Overview of Evolution
   b. Evidence of Evolutionary Change
c. Genes in Populations  

d. Natural Selection  

e. Genetic Drift  

f. Migration and Nonrandom Mating  

20. Origin of Species and Macroevolution  

a. Identification of Species  

b. Reproductive Isolation  

c. Mechanisms of Speciation  

d. Evo-Devo: Evolutionary Developmental Biology  

21. Taxonomy and Systematics  

a. Taxonomy  

b. Phylogenetic Trees  

c. Cladistics  

d. Molecular Clocks  

e. Horizontal Gene Transfer  

22. Microorganisms: The Archaea, Bacteria, and Protists  

a. Introduction to Microorganisms  

b. Archaea  

c. Diversity of Bacterial Phyla  

d. Diversity of Bacterial Cell Structure  

e. Ecological And Medical Importance of Bacteria  

f. Protist Classification by Habitat, Size, Motility  

g. Eukaryotic Supergroups: Ecological and Medical Importance of Protists  

h. Technological Applications of Bacteria and Protists  

23. Plant Evolution and Diversity  

a. Ancestry and Diversity of Land Plants  

b. An Evolutionary History of Land Plants  

c. Diversity of Modern Gymnosperms  

d. Diversity of Modern Angiosperms  

e. Human Influences on Angiosperm Diversification  

24. Fungi  

a. Evolutionary Relationships of the Kingdom Fungi  

b. Fungal Bodies and Feeding  

c. Fungal Asexual and Sexual Reproduction  

d. The Importance of Fungi in Ecology and Medicine  

e. Biotechnology Applications of Fungi  

25. Animal Diversity: Invertebrates  

a. Characteristics of Animals  

b. Animal Classification
c. Parazoa: Sponges, the First Multicellular Animals
d. Radiata: Jellyfish and Other Radially Symmetric Animals
e. Lophotrochozoa: The Flatworms, Rotifers, Bryozoans, Brachiopods, Mollusks, and Annelids
f. Ecdysozoa: The Nematodes and Arthropods
g. Deuterostomia: The Echinoderms and Chordates

26. Animal Diversity: The Vertebrates
   a. Vertebrates: Chordates with a Backbone
   b. Gnathostomes: Jawed Vertebrates
   c. Tetrapods: Gnathostomes with Four Limbs
d. Amniotes: Tetrapods with a Desiccation-Resistant Egg
e. Mammals: Milk-Producing Amniotes

27. An Introduction to Flowering Plant Form and Function
   a. From Seed to Seed: the Life of a Flowering Plant
   b. Plant Growth and Development
   c. The Shoot System: Stem and Leaf Adaptations
   d. Root System Adaptations

28. Flowering Plants: Behavior
   a. Overview of Plant Behavioral Responses
   b. Plant Hormones
   c. Plant Responses to Light
   d. Plant Responses to Gravity and Touch
   e. Plant Responses to Attack

29. Flowering Plants: Nutrition and Transport
   a. Plant Nutritional Requirements
   b. The Roles of Soil in Plant Nutrition
   c. Transport at the Cellular Level
   d. Plant Transport at the Tissue Level
   e. Long-Distance Transport in Plants

30. Flowering Plants: Reproduction
   a. An Overview of Flowering Plant Reproduction
   b. Flower Production, Structure, and Development
   c. Male and Female Gametophytes and Double Fertilization
d. Embryo, Seed, Fruit, and Seedling Development

31. Animal Bodies and Homeostasis
   a. Organization of Animal Bodies
   b. The Relationship Between Form and Function
   c. Homeostasis
   d. Regulation of Body Temperature

32. Neuroscience I: Structure, Function, and Evolution of Nervous Systems
   a. Cellular Components of Nervous Systems
   b. Electrical Properties of Neurons and the Resting Membrane Potential
   c. Generation and Transmission of Electrical Signals Along Neurons
   d. Communication at Synapses
   e. The Evolution and Development of Nervous Systems of Humans and Other Vertebrates
   f. Impact on Public Health

33. Neuroscience II: Sensory Systems
   a. Introduction to Sensation
   b. Mechanoreception
   c. Thermoreception and Nociception
   d. Photoreception
   e. Chemoreception
   f. Impact on Public Health

34. Muscular-Skeletal System
   a. Types of Animal Skeletons
   b. Skeletal Musculy Structure and the Mechanism of Force Generation
   c. Types of Skeletal Muscle Fibers and Their Functions
   d. Impact on Public Health

35. Digestive Systems and Nutrition
   a. Overview of Animal Nutrition
   b. Principles of Food Digestions and Absorption
   c. Vertebrate Digestive Systems
   d. Nutrient Use and Storage
   e. Regulation of the Absorptive and Postabsorptive States
   f. Impact on Public Health

36. Circulatory Systems
a. Types of Circulatory Systems
b. The Composition of Blood
c. The Vertebrate Heart and Its Function
d. Blood Vessels
e. Relationship Among Blood Pressure, Blood Flow, and Resistance
f. Impact on Public Health

37. Respiratory Systems
a. Physical Properties of Gases
b. Types of Respiratory Systems
c. Structure and Function of the Mammalian Respiratory System
d. Mechanisms of Gas Transport in Blood
e. Control of Ventilation
f. Impact on Public Health

d. Blood Vessels

38. Excretory Systems and the Homeostasis of Internal Fluids
a. Principles of Homeostasis of Internal Fluids
b. Comparative Excretory Systems
c. Structure and Function of the Mammalian Kidneys
d. Impact on Public Health

39. Endocrine Systems
a. Types of Hormones and Their Mechanisms of Action
b. Links Between Endocrine and Nervous Systems
c. Hormonal Control of Metabolism and Energy Balance
d. Hormonal Control of Mineral Balance
e. Hormonal Control of Growth and Development
f. Hormonal Control of Reproduction
g. Impact on Public Health

40. Animal Reproduction and Development
a. Overview of Sexual and Asexual Reproduction
b. Gametogenesis and Fertilization
c. Human Reproductive Structure and Function
d. Pregnancy and Birth in Mammals
e. General Events of Embryonic Development
f. Impact on Public Health

41. Immune Systems
a. Types of Pathogens
b. Innate Immunity
c. Acquired Immunity
d. Impact on Public Health
42. Animal Behavior
   a. The Influence of Genetics and Learning on Behavior
   b. Communication
   c. Living in Groups and Optimality Theory
d. Altruism
e. Mating Behavior
43. Ecology and the Physical Environment
   a. The Environment’s Effect on the Distribution of Organisms
   b. Climate and Biomes
44. Population Ecology
   a. Measuring Population Size and Density
   b. Demography
c. How Populations Grow
d. Species Interactions
e. Human Population Growth
45. Community Ecology
   a. Patterns of Species Richness and Species Diversity
   b. Species Diversity and Community Stability
c. Succession: Community Change
d. Island Biogeography
46. Ecosystem Ecology
   a. Food Webs and Energy Flow
   b. Biomass Production in Ecosystems
c. Biogeochemical Cycles
47. Biodiversity and Conservation Biology
   a. Biodiversity Concerns Genetic, Species, and Ecosystem Diversity
   b. Biodiversity Is of Great Value to Human Welfare
c. The Causes of Extinction and Loss of Biodiversity
d. Conservation Strategies
1. Topic 1: The Classification and Diversity of Life
2. Topic 2: Bacteriology
3. Topic 3: The Protists
4. Topic 4: Plant Diversity I: Nonvascular Plants and Seedless Vascular Plants
5. Topic 5: Plant Diversity II: Seed Plants
6. Topic 6: The Kingdom Fungi
7. Topic 7: Animal Diversity I
8. Topic 8: Animal Diversity II
9. Topic 9: The Distribution of Organisms: An Introduction to Ecological Interactions
10. Topic 10: Vertebrate Anatomy I
11. Topic 11: Vertebrate Anatomy II: Fetal Pig Dissection
APPENDIX T – Chapter Listing for A Short Guide to Writing About Biology

1. Introduction and General Rules
2. Locating Useful Sources
3. General Advice on Reading and Note Taking
4. Reading and Writing About Statistical Analyses
5. Citing Sources and Listing References
6. Revising
7. Writing Summaries, Critiques, Essays, and Review Papers
8. Answering Essay Questions
9. Writing Laboratory and Other Research Reports
10. Writing Research Proposals
11. Presenting Research Findings: Preparing Talks and Poster Presentations
12. Writing Letters of Application
APPENDIX U – Evolution Category Exemplars

No Knowledge

ID 171221 – BSC 111 – Pre-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: I believe evolution happens but I can't say I believe it all

Instrument Question: What are your perceptions about deep time?
Participant Answer: I don't know a lot about deep time or have study it.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Sometimes I feel it does but I try not to believe all or nothing from each

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Sometimes I feel it conflicts with my beliefs but I try not to believe all of one or the other

ID 171250 – BSC 111 – Post-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: - Evolution is the way things evolve.

- I believe evolution plays a big part in todays [sic] time.

- Without evolution the world would be out of date.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Really unsure about what Deep Time is.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No
**Participant Answer:** When we discussed dopamine [*sic*]. Ex. If you are with your boyfriend for years and yall [*sic*] break up, you will be sad, which is the effect of the dopamine [*sic*].

**Participant Answer:** It took a long time for the evolution to form.

**Participant Answer:** I'm not sure

**Participant Answer:** CO$_2$ gases in environment can affect the planet

**Participant Answer:** N/A

**Participant Answer:** N/A

**Participant Answer:** No, it does not.
Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: [blank]

Instrument Question: What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: [blank]

Atheistic Evolution

ID 171105 – BSC 111 – Pre-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: We don't understand it fully, but as of the 21st century, this is the most true theory we have come up with, and until compelling evidence shows otherwise, it will continue to be so.

Instrument Question: What are your perceptions about deep time?
Participant Answer: The earth is billions of years old according to modern evidence. The Universe works very slowly.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No.

ID 171105 – BSC 111 – Post-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: It's true.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Also true
Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No

Instrument Question: What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: Relatively unchanged.

Instrument Question: What are your perceptions about evolution?
Participant Answer: It works, and it explains how all organisms became that organism very well. Unless some evidence comes forth that contradicts it, it seems fine to me.

Instrument Question: What are your perceptions about deep time?
Participant Answer: The Universe is an old place. The Earth, on that scale, is young. The Earth is like 4 billion years old. To humans that's a long time. It's hard to imagine, so I suppose that's why people have trouble believing that. I think that a lot of sciences, not including evolutionary biology, have things that only work on that time scale. Our ways of measuring that far back aren't the most accurate, but it gives us a good enough idea that the Earth and Universe are way older than, say, 4,000 years.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: None, I've already seen plenty of evidence that shows me that evolution, excluding the case of new evidence, is the most likely theory.

ID 181125 – GLY 103 – Post-test

**Instrument Question: What are your perceptions about evolution?**
Participant Answer: Positive, I believe what general science has to say about it, not religion

**Instrument Question: What are your perceptions about deep time?**

**Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**
Participant Answer: No

**Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**
Participant Answer: No.

**Instrument Question: What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?**
Participant Answer: [blank]

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Nontheistic Evolution

ID 171232 – BSC 111 – Pre-test

**Instrument Question: What are your perceptions about evolution?**
Participant Answer: Evolution is a thing that always gone [sic] happen.

**Instrument Question: What are your perceptions about deep time?**
Participant Answer: deep time we will evolve just like something evolve to us [sic].

**Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**
Participant Answer: Nope
Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Nope

ID 181121 – GLY 103 – Pre-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution is always happening in every species based on where they are from.

Instrument Question: What are your perceptions about deep time?
Participant Answer: What is this?

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No. I believe in it.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: What is deep time?

ID 182131 – BSC 111 – Pre-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: I believe that evolution is the result/an indicator that the Earth is constantly shifting and its inhabitants shift with it.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I’m not entirely sure what this means; however, I think that the Earth operates on a scale and time frame that is difficult to completely comprehend.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No
Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: [blank]

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution occurs different ways [sic].
- A DNA mutation may occur [sic] gives them an advantage in certain climers [sic] helps them survive the climate they are in. Like brown bears couldn’t hunt will in the snow. A genetic mutation occurred [sic] making some white which makes them have a [sic] easier time hunting.
- Females may pick and choose certain characteristic [sic] for male maybe strength, color, etc. So they [sic] group may become more colorful, stronger, etc.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Don’t know what it is.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: no

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: whatever it is probably not.
Participant Answer: Deep Time is a very confusing concept to think about, but I always wonder where everything came from.

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: Evolution doesn’t conflict with my personal beliefs, however some parts of evolution are questionable.

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: Again, I just want to know what started it all.

**Instrument Question:** What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?

Participant Answer: The chapters on Animal and Plant diversity have showed me just how much the complexity of organisms has [sic] changed over time.

**Instrument Question:** What are your perceptions about evolution?

Participant Answer: I feel as though evolution in [sic] very real, but [sic] there is still much more to be studied and found out about the evolution of species (humans in particular). I also feel like some things will never be exact or for certain simply because we weren’t there to witness [sic] the change over time.

**Instrument Question:** What are your perceptions about deep time?

Participant Answer: I’m not very aware of the concept “deep time” but I hope to learn more about it.

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: The study of evolution does conflict with my personal beliefs and I try to keep an open mind, but I’m a strong believer that there are certain things that humans don’t know and will never fully understand. I think some things are just beyond us and certain things will be revealed in its own time.
Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Again, I’m not familiar with the concept, but I hope to become aware in the near future

ID 181123 – GLY 103 – Pre-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution is primarily composed of theories & scientific guesses that have become “law” over time.

Instrument Question: What are your perceptions about deep time?
Participant Answer: N/A

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No necessarily, but I tend to read with a serene mind & not allowing [sic] any swaying of my own personal perception.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: N/A

ID 182139 – BSC 111 – Post-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: I am conflicted with whether or not to agree with it because I was raised in a Catholic home.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Still don’t think I know that this is.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes. I usually keep my opinions to myself because it is a controversial topic
Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I don’t know because I don’t know what it is

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: Phylogenetic trees to show which organisms evolved from what.

Casual Creation

ID 171123 – BSC 111 – Pre-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution is very real. When you are able to see the common physical characteristics among two living organisms, it shows that evolution is true and forever ongoing.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Not really sure what deep time means but I hope to learn. 😊

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Kind of conflicts, kind of doesn’t. Yes, I believe in God, but evolution makes more sense than thinking God snapped his fingers and everything appeared.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I don’t know what deep time means and can’t wait to find out.
**Instrument Question: What are your perceptions about evolution?**
Participant Answer: Even though I am a Christian, evolution seems like the correct answer as to how we came about. It is easier to understand science and believe in evolution.

**Instrument Question: What are your perceptions about deep time?**
Participant Answer: Not sure what deep time is.

**Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**
Participant Answer: Yes, I just choose to ignore it. I believe in both in which they somehow correlate.

**Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**
Participant Answer: Don’t know what this means

**Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?**
Participant Answer: This class has broken down the upcoming of organisms on Earth and it really is much easier to understand and believe in Evolution, especially by knowing how everything comes from.

**Instrument Question: What are your perceptions about evolution?**
Participant Answer: It obviously occurs, that doesn’t mean it isn’t also divinely guided (or at least initiated or intended)

**Instrument Question: What are your perceptions about deep time?**
Participant Answer: I don’t know what deep time refers to.

**Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**
Participant Answer: No
Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Still don’t know what deep time is.

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: The more I see how organisms connect together, develop from one another, evolve to survive, and balance each other ecologically; the more convinced I become that the entire system was intended by a divine creator to function exactly thus.

ID 182130 – BSC 111 – Post-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: it [sic] is an ongoing process among all living things.

Instrument Question: What are your perceptions about deep time?
Participant Answer: i [sic] don’t really have any, to be honest i [sic] don’t think about it very often.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: no

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: no

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: The chapter about evolution (duh) because it taught me a lot about evolution.

*[Researcher Note: Follow up email confirmed Casual Creation viewpoint]*
Follow up Question: Do you still hold the same beliefs now as you did at the
time of the semester, or have any of your views changed? If they have changed,
how would you state your current viewpoint now?
Participant Response: No, my views have not changed. I just didn’t write anything on the
post test because I already wrote it on the pre test.

Instrument Question: What are your perceptions about evolution?
Participant Answer: Without evolution and natural selection there wouldn’t be anything
living the environment constantly changes and if every organism stayed the same they
would all become extinct.

Instrument Question: Does the study of evolution conflict with your personal
beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No, I believe evolution is the reason we are still alive, However I do
have difficulty believing [sic] we evolved from apes.

Instrument Question: Does the study of deep time conflict with your personal
beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Honestly, couldn’t tell you yet.

Instrument Question: What are your perceptions about evolution?
Participant Answer: I don’t agree with evolution, but I can see similarities.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Don’t really have an opinion

Instrument Question: Does the study of evolution conflict with your personal
beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes. I am always willing to listen.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Honestly don’t know enough about it.

**ID 182114 – BSC 111 – Pre-test**

**Instrument Question:** What are your perceptions about evolution?
Participant Answer: It happens over time based on the need for survival.

**Instrument Question:** What are your perceptions about deep time?
Participant Answer: Deep time is considered billions of years.

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes, we are told we come from God not apes.

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No, because it couldn’t possibly have happened its [sic] not discussed in the bible

**ID 182114 – BSC 111 – Post-test**

**Instrument Question:** What are your perceptions about evolution?
Participant Answer: That human evolved from monkey [sic], but if that were true why are there still monkeys?

**Instrument Question:** What are your perceptions about deep time?
Participant Answer: Over time, the earth changes which is true

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: It does, but I choose to not believe in evolution

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: It does not.

**Instrument Question:** What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?

Participant Answer: None

Graded Creation

**Instrument Question:** What are your perceptions about evolution?

Participant Answer: I believe in creation, that all things on Earth were created by God. I believe that animals & plants can change & adapt, but I don’t believe that they can change into a completely different species (ie. apes turning into humans).

**Instrument Question:** What are your perceptions about deep time?

Participant Answer: I have never heard of deep time

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: Yes, I simple [sic] state my beliefs and stand by them.

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: I don’t know about it.

**Instrument Question:** What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?

Participant Answer: No component changed the way I feel about evolution.
ID 181131 – GLY 103 – Pre-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: i [sic]believe the word adaptation is one i [sic] would prefer to use. I believe God created me and that those finches simply adapted and got better beaks.

Instrument Question: What are your perceptions about deep time?
Participant Answer: [blank]

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes. i [sic] view it as if im [sic] just learning.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: [blank]

ID 182101 – BSC 111 – Pre-test

Instrument Question: What are your perceptions about evolution?
Participant Answer: A lot of aspects of evolution are true. For example, the most fit individuals will be the ones to survive, which then can shift the way a population of a certain area looks. I’ve always been very skeptical of how true the idea that we all came from one species and evolved into different looking species. To say for certain the [sic] the evolution is real is impossible. Scientists want answers, but will have to settle for the best-looking answer, but we will never know for sure, and I’m find with that. The mystery is what makes life beautiful.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I’m not familiar with deep time, but if it’s talking about how old the Earth is, I do not believe the Earth is billions of years old, and we have discovered our ancestral [sic] roots by finding some bones in the ground.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: In some ways no. Survival of the fittest is a real and observable concept that we have witnessed during humans’ documented time. But to say we came from monkeys is extreme, and conflicts with my beliefs that the Earth and everything is and around it was created by God.

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: I do not know what deep time is; therefore, I cannot really comment on the issue.

**Instrument Question:** What are your perceptions about evolution?

Participant Answer: I believe in micro-evolution where species change over time in order to survive.

**Instrument Question:** What are your perceptions about deep time?

Participant Answer: I don’t know.

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: It depends on how it is presented.

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: I don’t know what deep time is.

**Instrument Question:** What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?

Participant Answer: I have opened my eyes to see a greater variety of evolution.
Instrument Question: What are your perceptions about evolution?
Participant Answer: I personally believe in microevolution, as it is apparent in every day animals/plants/etc. I do not believe in Macro theory, because it infers \textit{sic} that the creator of those animals didn’t do a “good enough job” when He created them.

Instrument Question: What are your perceptions about deep time?
Participant Answer: What? IDK what this is

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes, so I take in info pertinent \textit{sic} to tests/exams, but it doesn’t influence my beliefs.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: ? N/A

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: The phylogenetic tree is very compelling, and while there are truths to it, most evolutions of animal depicted are more than likely incorrect.

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evidence of evolution is undeniable. Organisms and species adapt to live in conditions that are best suited to sustain their life. I do not, however, believe that all life evolved from single-celled organisms. We were created.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I do have a problem believing in deep time. There is so little
evidence to support scientific guesses that suggest that the first life evolved billions of
years ago. Methods used to date fossils are flawed. Carbon dating is not accurate.

**Instrument Question:** Does the study of evolution conflict with your personal
beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: No

**Instrument Question:** Does the study of deep time conflict with your personal
beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: This is the crap that I have to go through to get my degree, so I just
humor the professor and nod.

**Instrument Question:** What component, if any, of this Principles of Biology II class
has the most influence on your perceptions of evolution this semester, and in what
way?

Participant Answer: I still see evolution in the same way that I saw it before: just a
theory. The wisdom of man is foolishness in the sight of God.

**Instrument Question:** What are your perceptions about evolution?

Participant Answer: Read the bible. Genesis.

**Instrument Question:** What are your perceptions about deep time?

Participant Answer: Read the bible. It gives time.

**Instrument Question:** Does the study of evolution conflict with your personal
beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: Yes. Read the Bible

**Instrument Question:** Does the study of deep time conflict with your personal
beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: I don’t really know what deep time is.
Instrument Question: What are your perceptions about evolution?
Participant Answer: I do not believe in evolution.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I still don’t know what deep time is.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes. Read Genesis chapter 1 KJV Bible.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: IDK What it is.

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: It was interesting, but did not change anything.
APPENDIX V – Student Responses Who Moved Within Creation-based or Scientific-based Categories

ID 171102 – BSC 111

Pre-test – Nontheistic Evolution

**Instrument Question:** What are your perceptions about evolution?
Participant Answer: Evolution has occurred for billions of years & has made us what we are today.

**Instrument Question:** What are your perceptions about deep time?
Participant Answer: [blank]

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: no

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: no

Post-test – Incomplete Evolution

**Instrument Question:** What are your perceptions about evolution?
Participant Answer: Evolution makes sense in many instances, but there are also many holes in which have not been filled, leaving room for doubt, as well as the fact that the idea of evolution clashes with religious beliefs.

**Instrument Question:** What are your perceptions about deep time?
Participant Answer: deep time?

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes & No. In both evolution and personall [sic] beliefs there are things that make sense & things that don't.

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: deep time?
Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: This class has positively influenced my perception of evolution in terms of how plants/animals have changed over time to adapt & survive.

ID 171106 – BSC 111

Instrument Question: What are your perceptions about evolution?
Participant Answer: I do not know enough about evolution to have an opinion. However, I do understand how species evolve.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I do not know what "deep time" is.

Pre-test – Incomplete Evolution

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes, but I am open to discussion of comparing what I believe & how it cooresponds [sic] to evolution.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I do not know, because I don't know what deep time is.

Post-test – Nontheistic Evolution

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution is needed to sustain life. All organisms adapt to their changing environment which leads to these organisms evolving.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I still do not know what deep time is, so I do not have a perception

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes & no; depending on the topic, I believe in evolution however my religious beliefs are rather strict on how life began mostly.

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: I do not know.

**Instrument Question:** What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?

Participant Answer: I do not feel there is a specific component from this class, but more of a better understanding from a less biased source. Overall, with the information provided I can now formulate my own opinion.

**Instrument Question:** What are your perceptions about evolution?

Participant Answer: Evolution gives us a better idea of how things happen & why they happen

**Instrument Question:** What are your perceptions about deep time?

Participant Answer: Deep time is from the beginning of Earth & evolution helps with knowing more about deep time

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: Evolution does conflict, but scientists were put here to help the future. My beliefs are how the Earth started, not how science can help Earth & it's inhabitants

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: [blank]
Instrument Question: What are your perceptions about evolution?
Participant Answer: Since there are ways to prove organisms go through evolution, then there must be some truth to it. If they share qualities & characteristics of extinct organisms evolution must've happened.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Deep time is very interesting in the aspect of how scientists have evidence of extinct organisms.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes, but I believe both because of the evidence that has been found.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: Finding out how organisms evolved and the proof. It has given me a new insight [sic] on science, biology mainly.

ID 171218 – BSC 111

Pre-test – Nontheistic Evolution
Instrument Question: What are your perceptions about evolution?
Participant Answer: I think that there is very solid information about it and adiquet [sic] evidence to support the observation.

Instrument Question: What are your perceptions about deep time?
Participant Answer: It was very thought provocking [sic] and interesting.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I answered this on the back page.
Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes, I see them as two separate [sic] things and have [sic] an understanding of its [sic] duality in my life and society as a whole.

Instrument Question: What are your perceptions about evolution?
Participant Answer: It may be real due to all the hard evidence found but some theories to support it are weak.

Instrument Question: What are your perceptions about deep time?
Participant Answer: It may be real.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes; I respect others beliefs in hopes they will do the same with mine.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: It does; I try to listen & get an understand [sic] of others thoughts on it.

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: It honestly hasn't changed my perceptions.

Instrument Question: What are your perceptions about evolution?
Participant Answer: There are some aspects of evolution that make sense to me, while others, I don't 100% agree with. Things like a population can just change based on
environmental issues makes sense but also arises questions for me. Also, I don't believe that organisms just appeared on this planet. There had to have been a creator.

**Instrument Question: What are your perceptions about deep time?**

Participant Answer: I don't really know much about deep time.

**Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: Yes, the study of evolution does conflict with my beliefs. I make sure to let the professor know about my beliefs and then I conduct research required for the class and do the necessary assignments to get the credit. Even if I don't agree, I still complete the task just like I am asked to.

**Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: I haven't studied deep time before, so I'm not 100% sure.

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**Post-test – Progressive Creation**

**Instrument Question: What are your perceptions about evolution?**

Participant Answer: Regarding evolution, I understand what the topic means and how it basically works. However, I don't really 100% agree with all the postulates of the topic itself.

**Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: Evolution does somewhat conflict with my beliefs. I don't really agree with humans and organisms evolving over time on their own. God made organisms the way they were for a reason. When these conflicts come up, I usually just study the topic as is and stick to what I believe and write/answer questions based on what professors want me to write.

**Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**
Participant Answer: N/A

**Instrument Question:** What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: [blank]

ID 172104 – GLY 103

**Pre-test – Quick Creation**

**Instrument Question:** What are your perceptions about evolution?
Participant Answer: God created us all

**Instrument Question:** What are your perceptions about deep time?
Participant Answer: I don't actually know what Deep Time is

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I practice my beliefs out of school but in school since I need the points I accept what the teacher have [*sic*] to say

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: [blank]

**Post-test – Casual Creation**

**Instrument Question:** What are your perceptions about evolution?
Participant Answer: It is a theory that is very hard to prove. And I also think evolution is interesting [*sic*] & this [*sic*] days evolution have [*sic*] more supporting documents to support its claims.

**Instrument Question:** What are your perceptions about deep time?
Participant Answer: [blank]

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes, I am a Christian & I believe that all humans was [sic] created by God. but science doesn't believe that & since I am a Science student & I need to get A's in my class I do what my teacher told me in class.

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: It doesn't conflict that much

**Instrument Question:** What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?

Participant Answer: The evolution of dianosaurs [sic] & how they became extinct [sic].

ID 172114 – GLY 103

**Pre-test – Quick Creation**

**Instrument Question:** What are your perceptions about evolution?

Participant Answer: I do not believe in evolution

**Instrument Question:** What are your perceptions about deep time?

Participant Answer: I currently don't have any.

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: Yes, I usually kindly state my opinion and move on from the subject. Everyone is entitled to their opinion.

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?

Participant Answer: I am unsure as to what deep time is so I am undecided.

**Post-test – Graded Creation**

**Instrument Question:** What are your perceptions about evolution?

Participant Answer: I believe more in adaption [sic] than evolution.

**Instrument Question:** What are your perceptions about deep time?

Participant Answer: There are many learning tools that can be found there.
Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I believe we adapt, not evolve.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No it doesn't [sic]

Instrument Question: What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: things can definitely adapt to their surroundings

ID 181105 – GLY 103

Pre-test – Quick Creation

Instrument Question: What are your perceptions about evolution?
Participant Answer: I do not believe evolution.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I do not think the Earth is that old.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I know that we will never answer all the questions we have. God is too big and complex for us to understand.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: [blank]

Post-test – Casual Creation

Instrument Question: What are your perceptions about evolution?
Participant Answer: There is no doubt things evolve and adapt.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Think it is a little hard to know.
Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes, I think God made us in his image and things have evolved over time.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: [blank]

Instrument Question: What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: [blank]

ID 181106 – GLY 103

Pre-test – Progressive Creation

Instrument Question: What are your perceptions about evolution?
Participant Answer: I think it's an interesting idea, but no concrete evidence with humans though.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I'm not sure what deep time is.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: It does, I just try to keep an open mind and listen to everyone's ideas respectfully.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: [blank]

Post-test – Quick Creation

Instrument Question: What are your perceptions about evolution?
Participant Answer: I see evolution as gradual adaptation species use to live in different environments.
Instrument Question: What are your perceptions about deep time?
Participant Answer: That it is vast & unknowing.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: It does. I believe in the book of Genesis. I try to keep an open mind. I research & ask my Pastor about this as he explained it's okay to ask scientific questions about religion.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Not really I don't believe

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: N/A

Instrument Question: What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: The lab component had the biggest influence because it was hands on.

ID 181107 – GLY 103

Pre-test – Atheistic Evolution

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution makes more sense about Earth's history rather than how religion explains it.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I'm not sure what that means

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No I believe in evolution

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: N/A
Post-test – Incomplete Evolution

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution best explains how life came to Earth and why our behaviors and anatomy is similar

Instrument Question: What are your perceptions about deep time?
Participant Answer: We cannot go back into time so we cannot know for sure what has occurred [sic] on our planet of the billions of years of its existence.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No

Instrument Question: What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: The amount of years it takes to see changes in a species, since we can't watch a species evolve in our lifetime

Pre-test – Nontheistic Evolution

Instrument Question: What are your perceptions about evolution?
Participant Answer: It is a long process with survival of the fittest. Slight changes are made in species over time. People say humans evolved from apes.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I have never heard this term. But it seems like a long time.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I am open to listening to new ideas and trying to make things work together. In a way evolution does conflict with my beliefs but I understand the science behind it.
Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I am unsure.

Post-test – Incomplete Evolution
Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution is a difficult task because the transition fossils can be hard to find in order to show exactly how one species became another. Evolution is still occurring.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Deep time is very long periods of time unlike how comparisons in the present are done by minutes to years. Deep time takes much more research and methods because of the large scale.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I don't think evolution necessarily conflicts with my beliefs.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I don't think deep time conflicts with my beliefs.

Instrument Question: What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: Seeing specific evolution examples and what they evolved to influenced how it really makes sense.

ID 181118 – GLY 103

Pre-test – Nontheistic Evolution
Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution although being a theory I believe now could actually be true do [sic] too [sic] recent studies and evidence found.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I'm really not even sure what deep time is. I guess it could be described as evolution over a long period. I'm not sure.

**Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: Yes. I look past what is being said, and really try to see all the factual evidence given.

**Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: I'm not sure. I really don't know what deep time is.

**Post-test – Incomplete Evolution**

**Instrument Question: What are your perceptions about evolution?**

Participant Answer: I really think evolution is complex, and it’s a matter of perceiving and analyzing to understand true facts of evolution.

**Instrument Question: What are your perceptions about deep time?**

Participant Answer: I still don't really understand deep time that well.

**Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: Yes. I look at it from more than one perspective, and really look into details of evolution.

**Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?**

Participant Answer: Yes and No. Analyze evidence more closely.

**Instrument Question: What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?**

Participant Answer: Learning evolution of dinosaurs, mammals, reptiles, and humans.
Pre-test – Atheistic Evolution

**Instrument Question:** What are your perceptions about evolution?
Participant Answer: I believe that we all share a common ancestor and that we are closely related to other types of primates.

**Instrument Question:** What are your perceptions about deep time?
Participant Answer: [blank]

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: It does not affect me at all. People should want to have for sure facts about where they came from.

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I'm not to [sic] familiar [sic] with deep time to understand it and its meaning.

Post-test – Nontheistic Evolution

**Instrument Question:** What are your perceptions about evolution?
Participant Answer: I believe in evolution I feel looking at how other organisms evolve theres [sic] no way humans didn't come from something previous

**Instrument Question:** What are your perceptions about deep time?
Participant Answer: [blank]

**Instrument Question:** Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: They don't conflict me at all.

**Instrument Question:** Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: [blank]
Instrument Question: What component, if any, of this Historical Geology class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: The discussion we went over in the Story of Our Life [sic]. That whole segment of the class really intet [sic] me.

ID 182105 – BSC 111

Instrument Question: What are your perceptions about evolution?
Participant Answer: I do not believe in the way many evolutionists think the earth was formed and everything has a single common ancestor. I do believe that evolution occurs though because it can be seen in adaptations and changes in species

Instrument Question: What are your perceptions about deep time?
Participant Answer: ? Not sure what deep time is but maybe how old the universe is??

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Origins of life do, still trying to find the balance and a firm way to look at it all

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Once again, not sure what this term means, but if it is as I mentioned early, still trying to find the more correct way of viewing things

Post-test – Casual Creation

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution is the gradual change in a species over time that may lead to new species, whether that be one, or many.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Not sure what this is referring to but maybe the idea that the universe is expanding and not sure if it will ever reach an end.
Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Sort of, yes I do believe evolution occurs. I don't agree with the time scale and some theories. I am still working on how to confront these issues and find a "scientific" idea that aligns with my personal views.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I cannot really answer this question because I am not sure what the term "deep time" refers to. Sorry.

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: I suppose some of the theories in general just don't add up to me, but the most profound was that birds are descendants of dinosaurs. I still have a little trouble making this connection.

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution happens when a species needs to change to survive. Different species are created through evolution & often come from a common ancestor.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Not sure what deep time is.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: This topic has always [sic] been a hard subject to discuss. I believe there are many theories to evolution and many things we still don't [sic] know. I deal with conflicts from this topic by having discussions.
Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I am not sure what deep time is and what it relates to so I don’t have conflicts about it or with my beliefs.

Post-test – Nontheistic Evolution

Instrument Question: What are your perceptions about evolution?
Participant Answer: We evolved from a common ancestor over a long period of time.
Instrument Question: What are your perceptions about deep time?
Participant Answer: not sure what deep time is

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: The study of evolution doesn’t conflict with my personal beliefs.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: Studying evolution this semester has taught me more about evolution than I knew before. I’m not sure which component had the most influence.

ID 182133 – BSC 111

Pre-test – Casual Creation

Instrument Question: What are your perceptions about evolution?
Participant Answer: It is a process that is observed over millions of years
Instrument Question: What are your perceptions about deep time?
Participant Answer: Deep time is a very long time.
Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes. I think evolution happens today but after God made stuff

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I am not too sure what deep time is.

Post-test – Quick Creation

Instrument Question: What are your perceptions about evolution?
Participant Answer: It is real

Instrument Question: What are your perceptions about deep time?
Participant Answer: Not sure what that is

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes, Adam & Eve

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Not sure what it is

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: Our study of Evolutionary relationships.

ID 182137 – BSC 111

Pre-test – Incomplete Evolution

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution may explain the traits that humans have now. I am not a full believer of evolution, but I am willing to listen.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I'm not sure of what deep time is.
Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: They don't conflict w/ my beliefs. I just don't fully believe in evolution.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I am not sure of what deep time is.

Post-test – Nontheistic Evolution

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution is the gradual change of species over time.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I still don't fully understand deep time.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No, Evolution does not conflict w/ my personal beliefs.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No, deep time does not conflict w/ my personal beliefs.

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: The section on invertebrates and vertebrates had the most influence on my perception of evolution. The range of adaptations was astounding.
APPENDIX W – Student Responses Who Moved from Scientific-based Views to Creation-based Views

ID 171103 – BSC 111

Pre-test – Incomplete Evolution

Instrument Question: What are your perceptions about evolution?
Participant Answer: There have been missing pieces in the process.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I dont [sic] know enough about deep time to have an opinion.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes. Look at both possibilities instead of just one.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I dont [sic] know

Post-test – Casual Creation

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution occurs over time at a very slow rate.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I am not sure what deep time is.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Sometimes, I believe organisms do change over time, but, I believe God created the world.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Not sure
Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: My beliefs haven’t [sic] changed.

ID 171115 – BSC 111

Pre-test – Nontheistic Evolution

Instrument Question: What are your perceptions about evolution?
Participant Answer: We all came from somewhere and science has proven in order to survive [sic] we must continue to evolve [sic].

Instrument Question: What are your perceptions about deep time?
Participant Answer: Never heard of it.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No.

Post-test – Casual Creation

Instrument Question: What are your perceptions about evolution?
Participant Answer: Evolution is a never ending [sic] cycle of life, and theories [sic] associated with evolution continue to change.

Instrument Question: What are your perceptions about deep time?
Participant Answer: Before this Bio class I’d never heard of deep time.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No, believe that God created like he created the scientist who created science.
Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: Fossils and how we can trace back age based on fossilized materials.

ID 171208 – BSC 111

Pre-test – Nontheistic Evolution
Instrument Question: What are your perceptions about evolution?
Participant Answer: Ideal traits are passed on through survival and reproduction, which allow evolution over time.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I am unsure of the meaning of deep time other than maybe a great measure of time.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Sometimes some of the concepts do conflict with my beliefs. However, I respect all concepts and learn the material to pass classes

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: N/A, I don't know the meaning of deep time.

Post-test – Graded Creation
Instrument Question: What are your perceptions about evolution?
Participant Answer: I think organisms can undergo small changes over time to better adapt to their surroundings, but I don't think organisms completely change into completely different organisms.
Instrument Question: What are your perceptions about deep time?
Participant Answer: unknown

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Sometimes. I compare the two and try to take into consideration both sides. The evidence of evolution and my beliefs will always challenge each other, but sometimes there are similarities. For classes, I learn the necessary material to perform well on tests, but I do not always believe everything taught.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: unknown

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: none

ID 171224 – BSC 111

Pre-test – Nontheistic Evolution

Instrument Question: What are your perceptions about evolution?
Participant Answer: everything changed over time for better accomodation [sic]

Instrument Question: What are your perceptions about deep time?
Participant Answer: I don't know

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: No
Post-test – Progressive Creation

Instrument Question: What are your perceptions about evolution?
Participant Answer: Everyone was created from Adam & Eve

Instrument Question: What are your perceptions about deep time?
Participant Answer: I don't know

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: Yes, God created earth & everything created cannot be explained through Science. I choose to side with my religion if Science presents that interaction

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: [blank]

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: [blank]

ID 182120 – GLY 103

Pre-test – Nontheistic Evolution

Instrument Question: What are your perceptions about evolution?
Participant Answer: I think that evolution is a complicated process that occurs over time and can be proven w/ evidence.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I do not have any.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: They do not conflict w/ my beliefs.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I do not have any conflicts
Post-test – Casual Creation

Instrument Question: What are your perceptions about evolution?
Participant Answer: I think evolution does exist and species do evolve over time which is why we have so many various types of species.

Instrument Question: What are your perceptions about deep time?
Participant Answer: I am not familiar with deep time.

Instrument Question: Does the study of evolution conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: They do not necessarily conflict completely. I do believe in evolution and changing over time, but I also believe that we were created by God.

Instrument Question: Does the study of deep time conflict with your personal beliefs? If so, how do you deal with those conflicts when they arise?
Participant Answer: I am not sure what deep time is so no.

Instrument Question: What component, if any, of this Principles of Biology II class has the most influence on your perceptions of evolution this semester, and in what way?
Participant Answer: I would say phylogenetic trees may have influenced me the most since it was a new way of examining evolutionary relationships.
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