

PILOT STUDY ON EDUCATING THE PUBLIC  
ABOUT CONTROVERSIAL ISSUES IN  
THE GEOSCIENCES

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## ABSTRACT

Scientists who are involved in educating the public about various scientific topics frequently encounter difficulty or opposition when they must deal with topics concerning origins. Whether the setting is a classroom, a courtroom, or a field interpretive situation, members of the target audience come to the discussion with a variety of inherent biases that dictate how they will receive information about the origin and formation of a particular rock, fossil, or living specimen. The preconceptions that I will specifically be examining in this paper center around the interpretation of geologic time and how an individual's own scientific and religious background influence the acceptance or rejection of various methods of dating geologic events. A conclusion by the Biological Science Curriculum Study regarding a recent People for the American Way Foundation poll is that an individual's rejection of the teaching of evolution, and the associated geologic time scale, is dependent on the individual's level of scientific literacy and education. It is my hypothesis, however, that the level of scientific literacy is not the major determinant in a person's acceptance or rejection of geologic time. It is a person's philosophical worldview, as developed through his or her own personal religious education and beliefs, which has more influence on how he or she accepts or rejects any scientific arguments with regard to time and origins.

Many professional organizations have issued policy or position statements concerning the teaching of evolutionary principles and the teaching of creationism. Usually these statements are worded in such a way as to completely discourage the discussion of creationist concepts in an educational situation. Unfortunately, this may be having the effect of causing educators in many different situations to miss the opportunity to facilitate an open discussion and critical analysis of creationist ideas.

At some point, most scientists will find themselves in the role of educators with respect to their particular field of expertise, and when this role leads to discussions of origins, it would benefit the scientist to understand the typical philosophical worldviews that people will be bringing with them to the discussion. This understanding will enable the scientist to select the data and educational technique that will best lead their particular “students” to a clearer understanding and/or acceptance of the model of origins and development that they advocate. Considering someone else’s point of reference will also enable scientists to look more objectively at the data they are presenting. This will serve to either confirm the strength of the particular scientific model or bring about refinements in the model. This thesis is intended to develop the basis for an educational model for dealing with controversial topics in the geosciences that can be successfully utilized in any given educational situation, including, but not limited to, public schools, universities, government and professional public education endeavors, and policy development surrounding these issues.

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Public Sentiment about Science and Religious Education

According to a Gallup poll published on August 30, 1999, 68% of Americans favored the teaching of creationism in the public schools along with evolution. It indicated that 47% believe God created human beings within the past 10,000 years, while 49% believe that humans have developed over several millions of years from lower forms of life. There were also 40% of respondents who believe that God guided the process of evolution. This means that 87% of the people polled believe that God played some part in the creation of humans. These are essentially the same percentages that have been reported since the Gallup organization began asking these particular questions in 1982 (Brooks 2001). In another poll sponsored by the National Science Foundation (2000), questions were asked to assess the level of scientific literacy in the United States. Only 33% of the adults polled indicated knowledge of the Big Bang origin of the Universe. While 80% acknowledged that continents have moved their locations during the previous millions of years, only 51% acknowledged that humans and dinosaurs have never coexisted. Forty-five percent said that humans have developed from earlier species of animals and 72% correctly identified the Earth as orbiting the sun instead of the sun orbiting the Earth. In yet

another poll, one that was conducted by the People for the American Way Foundation and was based on interviews with 1,500 Americans, 83% support the teaching of evolution in public schools. However, the poll also found that 79% of Americans think creationism has a place in the public school curriculum. Rodger Bybee, executive director of the Biological Sciences Curriculum Study pronounced

The results of this poll clarify the crying need for improving the public's scientific literacy. It is clear that most Americans misunderstand the scientific definition of the word 'theory' and the processes of scientific inquiry. As science educators, we must do a better job of communicating messages about the nature of science (BSCS 2000).

The implication here is that the primary cause of rejection of scientific models is the level of education of the public involved. Yet it does not seem to take into account that there may be other factors besides scientific literacy that determine whether people will accept or reject certain scientific conclusions.

There continues to be significant pressure placed on local school boards and legislatures to ensure that a "balanced" approach, with regard to topics of origins, is given in science education. Two recent articles in local newspapers describe court cases pending in Tennessee (Rocky Mountain News, 02/09/02) and Ohio (The Denver Post, 02/11/02) that both deal with public school districts seeking to teach views on origins of life and the Earth that are in addition to a naturalistic or materialistic view of evolution. Attacks on the teaching of evolution frequently go hand in hand with attacks on the teaching of uniformitarian geologic principles and an Earth-age of billions of years. As a result, many major professional geologic organizations have made public statements or published

position papers supporting the teaching of evolution and against the teaching of creationism in the public schools.

The purpose of this thesis is to explore the hypothesis that the science of origins that is being taught is not as much of the problem as the way in which it is being presented.

Rodger Bybee said

Schools may teach about various explanations of life on Earth, including religious ones such as creationism, in comparative religion, social studies or other classes-but not science classes. . . . Science does not accept or reject explanations based on votes or public opinion polls. . . . Acceptance of scientific explanations is not based on the idea of equal time-that any explanation has similar value. Scientists judge the weight of evidence supporting a proposed explanation. Regardless of public opinion, we don't owe it to our students to present creationism in science class any more than we are obligated to teach alchemy as an alternative to chemistry or astrology because some people believe in it (BSCS 2000).

This statement does not acknowledge the way students, especially those with religious predispositions, will respond to our teaching. In the same way, policy statements that strictly forbid the presentation of creationist ideas without consideration of learning theory and human cognition encourages educators at all levels to ignore the sentiments of the public they are teaching and thereby erect a barrier to the effective teaching of geologic principles. Unless we take the time to understand preconceptions about science and the source of those preconceptions, we are not likely to enable students to incorporate scientific theory in their psyche.

## 1.2 Overview of Thesis

This thesis explores a proposed methodology for addressing controversial issues in geoscience educational settings. After clarifying a number of terms in the remainder of this chapter, I discuss the historical ways that some scientists have chosen to address religious-based controversies. Next, I examine the educational theories that were developed during the latter part of the twentieth century concerning the way that learners tend to respond to new scientific information. The primary part of my research involves a pilot study group of preservice science teachers. I designed a research method to address the question, “What factors determine whether or not an educator would be willing to address religious-based controversies in a science educational setting?” An analysis of the data I collected concludes the paper.

## 1.3 Discussion of Terms

Anytime a document addresses the viewpoints of various groups, it must be careful to identify the specific ways in which these groups are defined. Here are some terms that will be used frequently in this paper to refer to groups of people.

### 1.3.1 Educators

A common definition of the term “educator” is “a person whose work is to educate others” (Webster’s Dictionary 1980). We usually think of an educator in the sense of an instructor associated with a classroom of students. However, in the various scientific disciplines, and particularly in the Earth Sciences, for the purpose of this treatment, any

time a scientist or agency must deliver scientific information with the intent to increase the audience's understanding of concepts, they are acting as an educator. For example, when the National Park Service places interpretive signs next to a natural feature offering an explanation of its formative origin, the Park Service is serving as an educator for the reader. Or, if a geologist testifies in front of a congressional committee about the environmental effects of a certain land use initiative, he serves as an educator. It is in this broader sense of the term that this paper is written.

### 1.3.2 Creationists

The term "creationist" is a politically charged term. In its simplest definition, it refers to anyone who attributes the existence of the physical universe to God. Unfortunately, the way in which it is frequently used connotes much more than that. Most frequently, the term "creationist" is used to refer to that group of people who maintain the premise that the Bible teaches, and science confirms, that the Earth is younger than the usual age given (4.5 billion years) and is in actuality an age closer to 10,000 years. However, Eugenie Scott of the National Center for Science Education has delineated various aspects of creationism (see Figure 1-1). She emphasizes that a more thorough understanding of the term "creationist" is essential to successfully working with them in an educational environment. A brief review of her descriptions follows (Scott 2000).



# THE CREATION/EVOLUTION CONTINUUM

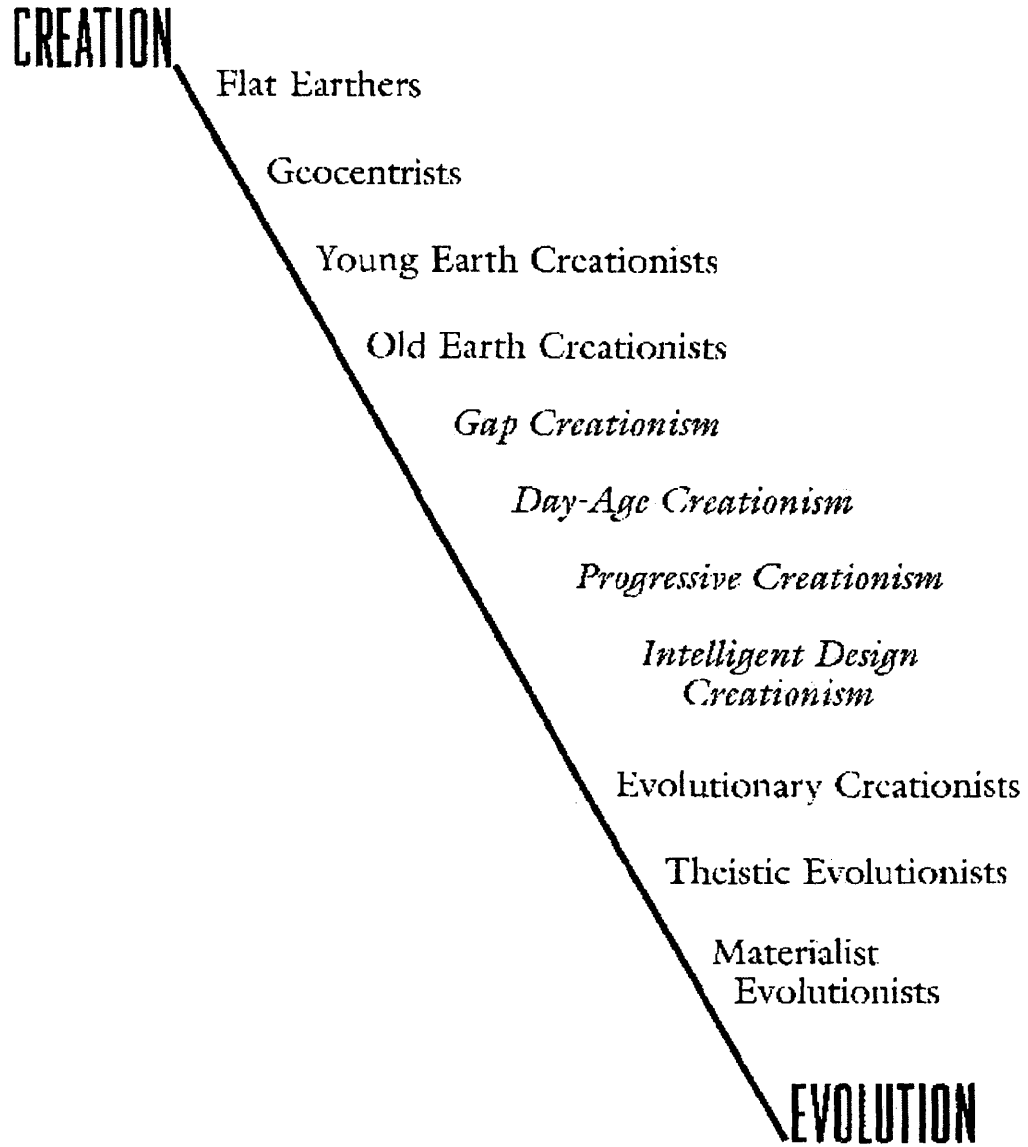


Figure 1-1 Eugenie Scott's Creation/Evolution Continuum

### 1.3.2.1 Flat Earthers

The Flat Earth Society is based in California and is a small but real group of people who claim to believe that the Earth is a circular disk shape. This belief is based on what they view as a literal interpretation of various references in the Bible to the “ends of the Earth”, the “four corners of the Earth” and the “circle of the Earth” (see also Schadewald 1980). This group believes in a recent or young age for the Earth.

### 1.3.2.2 Geocentrists

Geocentrists, like Flat Earthers, make up a very small minority within the modern-day creationist movement, but they do have a voice. Geocentrists believe that the Earth is the center of the solar system and is fixed in place. The sun and other bodies orbit the Earth. This is the classical geocentric model. They are also considered to be young-Earthers.

### 1.3.2.3 Young-Earth Creationism

A very vocal and politically active creationist group is simply called the “Young-Earth” Creationists. They are the primary promoters of “scientific creationism”, an attempt to use scientific methods to prove the assumed literal reading of the Bible that indicates the Earth is only 10,000 to 20,000 years old. This is the group that is most commonly associated with the “creationist” term in popular usage.

#### 1.3.2.4 Old-Earth Creationism

The “Old-Earth” Creationists encompass a variety of viewpoints of how science and the creation account in the Bible relate to each other. Generally speaking, they all accept the modern science view of an Earth that is approximately 4.6 billion years old. The differences that separate the various views of the “Old-Earth” Creationists lie in how they interpret science and scripture together.

##### 1.3.2.4.1 Gap Creationism

One way that “Old-Earth” Creationists harmonize science and scripture is by interpreting a “gap” in time between verses 1 and 2 of Genesis Chapter 1, e.g., “In the beginning God created the heavens and the Earth” [Billions of years GAP] “And the Earth was without form”. This gap was then followed by six literal days of “re-creation” of Earth in its present form.

##### 1.3.2.4.2 Day-Age Creationism

Day-Age Creationism loosely associates the geologic time scale divisions with the six days of creation recorded in Genesis 1. This allows for a more or less literal reading of Genesis while still accommodating the scientific evidence for an old Earth. In this view, the days of Genesis each represents a particular segment of the geologic time scale.

#### 1.3.2.4.3 Progressive Creationism

Progressive Creationists are “Old-Earth” Creationists who interpret much of current scientific theory about origins as compatible with a literal reading of Genesis. They are mixed in their views of the designation of the creation days as either 24-hour time periods occurring at the beginning of each segment of creation, happening in sequence, or separated by time, or as representations of long periods of time. They all share the view that God has actively worked (and continues to work) throughout geologic time to direct the formation of the Universe and Earth and its inhabitants. This view typically allows for some level of biological evolution as a process instituted by God to allow for the diversification of life on Earth as well.

#### 1.3.2.4.4 Intelligent Design Creationists

This is a relatively recent creationist title that strives to use modern scientific methods and theories to verify or prove that the order and intelligence visible in the natural world is indicative of a personal and identifiable Creator. The primary argument is based on the Anthropic Principal that the Universe and Earth are so finely tuned and irreducibly complex that chance events would have exceeded the mathematical probabilities for life and the physical universe as we know it to have developed without the direction of a Creator.

“Old-Earth” Creationists generally will not fall distinctly into one of these described viewpoints but will instead mix a number of aspects of each view as is deemed necessary to fit their personal knowledge of science and their interpretation of Scripture.

#### 1.3.2.4.5 Evolutionary Creationism and Theistic Evolution

Scott distinguishes between evolutionary creationism and theistic evolutionism solely on the basis of theology where evolutionary creationism is the view held by more conservative evangelicals. In both cases, God is viewed as using varying degrees of evolution to “create” life on Earth in all of its diversity. God is seen as intervening at critical stages in the development of life (and in other physical processes as well). The extent to which He intervenes defines the primary differences among the various theistic evolutionists.

#### 1.3.2.5 Materialist Evolutionism

Materialists are considered those who go beyond the realm of using science as a tool of study, but delve into the philosophical concept that science is the sole source of explanation for the physical and biological world. This group proposes that there is no room for supernatural intervention in the study of the world – that possibility simply does not exist.

### 1.3.3 Evolution

The term “evolution” is frequently associated with the term “creation” when discussions about the disagreements between the proponents occur. For the purposes of this thesis, the concepts and principles of evolutionary theory are not being addressed. However, the term is used periodically as a more general way of identifying viewpoints that are in opposition to young-Earth creationism.

CHAPTER 2  
OBJECTIVITY IN SCIENCE/RELIGION  
RELATED TOPICS

2.1 Is It Possible to be "Purely" Objective?

In their text Tectonics, Eldridge M. Moores and Robert J. Twiss (1995) have written an excellent essay about the scientific process. They outline the various aspects of formulating scientific theory, from the collection of data through the development of a testable scientific model. As they compare the inductive (Baconian) methodology and the model-deductive (Darwinian) methodology, they point out that both methods “rely on the non-rational and non-logical creativity, imagination, and intuition of the scientist, and that therefore these ‘scientific methods’ are not entirely an objective and rational approach to understanding our surroundings.” They point out that this creative aspect of science is difficult, if not impossible, to teach to students and that the rational, objective, fact gathering part of science is what teachers tend to focus on almost exclusively.

Unfortunately, in their words, “this part of the scientific process is only the part that comes after the fundamental insight, and it is really the insight that is the core of the process.”

The Truth (as capitalized by Moores and Twiss) of nature is beyond the scope of science. Science can develop models (paradigms) to explain observations, but the models are driven not only by factual data, but also by the creativity and intuition of the scientists developing

the models. This is summed up in the statement quoted by Moores and Twiss (source unknown), “The eye seldom sees what the mind does not anticipate.”

The tendency toward some form of bias needs to be emphasized when educators approach the teaching of science. My use of the term “bias” here is chosen with reference to the studies done by Clark A. Chinn and William F. Brewer, whose work will be discussed in chapter three. “Bias” is defined as “a mental leaning or inclination” (Webster’s Dictionary 1980). As we engage an audience with explanations of scientific concepts, we need to acknowledge not only our own bias, but the bias of the audience we are addressing. Acknowledging another’s bias does not imply agreement with it, but rather indicates awareness and willingness to deal with any conceptual difficulties that may arise.

## 2.2 Acknowledging Religious Bias in Scientific Work

We in the geosciences tend to look at books with titles such as The Religion of Geology and Christianity and the Age of the Earth with disdain. Why would someone waste the time writing a book that is obviously linked to religious beliefs and yet purports itself to be scientifically based as well? After all, as Claude Allègre points out, “they should stay separate. Nothing is to be gained by mixing the issues” (Allègre 1992). Stephen Jay Gould says that “People of good will wish to see science and religion at peace. . . . I do not see how science and religion could be unified, or even synthesized, under any common scheme of explanation or analysis; but I also do not understand why the two enterprises should experience any conflict” (Gould 1999).



There are, however, some scientific professionals who feel that there is something to be gained by mixing the issues. Why do they do this? What possible value is there in it? The following sections look at historical examples of scientists who have spoken out on religious issues as they relate to the scientific work they are doing.

### 2.2.1 Historical Approaches

Carl Sagan, a well-known contemporary popularizer of the sciences, often expressed his feelings about religious beliefs. In his book Cosmos, Sagan said,

In many cultures it is customary to answer that God created the universe out of nothing. But this is mere temporizing. If we wish courageously to pursue the question, we must, of course ask next where God comes from? And if we decide this to be unanswerable, why not save a step and conclude that the universe has always existed (Sagan 1980)?

This implies that God is an imagination of the human brain and nothing more. In contrast, modern creationist writings often include statements that reflect an effort to make their “science” a point of doctrine that must be adhered to if one is to profess belief in God and the Bible. John Morris, a chief author and founder for the Institute for Creation Research said,

I still am uncertain about young-Earth creationism being a requirement for church membership; perhaps it would be proper to give new members time to grow and mature under good teaching. But I do know one thing: Creationism should be a requirement for Christian leadership! No church should sanction a pastor, Sunday school teacher, deacon, elder, or Bible-study leader who knowledgeably and purposefully errs on this crucial doctrine (Morris 1992).

The implication here is that if one is to believe in God, he/she must accept as truth the version of science that is being proposed by young-Earth creationists.

There are many scientists (and others), however, who trust the discoveries of modern science but also believe the Bible. They generally maintain the following beliefs (as printed in the end notes of the journal of the American Scientific Affiliation, *Perspectives on Science and Christian Faith*), which are foundational beliefs of the Christian religion:

- The Holy Scriptures (the sixty-six books of the Holy Bible) are the inspired Word of God, the only unerring guide of faith and conduct.
- Jesus Christ is the Son of God and through His Atonement is the one and only Mediator between God and human beings.
- God is the Creator of the physical universe. Certain laws are discernable in the manner in which God upholds the universe. The scientific approach is capable of giving reliable information about the natural world.

There are, of course, those in the sciences who have religious inclinations, but have not chosen to write specifically on the subject of harmonization between Scripture and science. They simply wish to go about their work of scientific investigation and discovery. In the same way, there are Christians who may be knowledgeable of various scientific disciplines, but they are fairly silent about their beliefs as they relate to current scientific thought. However, since some scientists and theologians have consistently chosen, over the years, to verbally assault the ideas and beliefs of each other, there continues to be a

group who has seen the need to express their views of the existence of harmony between science and Scripture. Their motivation has been to explain the reason for their theology to scientists while simultaneously explaining the evidence for scientific conclusions to fellow believers. In this way they hope to dissipate the fears that seem to exist between both groups that the beliefs and conclusions being espoused are a threat to the strength of their own beliefs.

Another possible reason that authors in the sciences choose to address both the concepts of science and theology in their writings may have more to do with public sentiment than with their own personal beliefs. Realizing that the implications of their discoveries or commentary may clash with popular theological views, some authors offer explanations within their writings of how the science can fit with doctrinal statements without conflict. Their motivation may be to help the general populace understand that the science need not clash with their theology, or they may be making the statements more out of self-preservation in an antagonistic environment. While it is not always easy to determine the motivation of the author, either motivation is understandable.

The following subsections are a survey of the history of those who have tried to “stand in the gap” between Scripture and science. It is not intended to be complete, but only illustrative. In order to maintain the integrity of the writings of the authors cited, I have chosen to rely heavily on quotations. I also have chosen to focus most of my attention on those who have written on topics related to the Earth Sciences because it is Earth Scientists who are my primary intended audience.

### 2.2.1.1 Luke

In the New Testament, a physician (Luke) wrote the Gospel of Luke. He had a Greek education and tended to approach matters in a manner consistent with other highly educated people of his day. He opens his Gospel with the statement

Many have undertaken to draw up an account of the things that have been fulfilled among us, just as they were handed down to us by those who from the first were eyewitnesses and servants of the word. Therefore, since I myself have carefully investigated everything from the beginning, it seemed good also to me to write an orderly account for you, most excellent Theophilus, so that you may know the certainty of the things you have been taught” (Luke 1:1-4, NIV 1984).

In this passage Luke used a style of Classical Greek that indicates his formal education. It was written in a manner typical of the prefaces to the equivalent of professional papers of the times. He states his purpose for writing, identifies the recipient, acknowledges previous work and the need for a new treatise on the subject, and outlines his methodology. I choose this example to begin with because it represents a person who has an obvious Christian faith, but who approaches his work, as a “scientist” of his day would, with a planned data collection system and intent of objectivity. I believe that Luke’s purpose in writing in this manner was to show the educated (“scientific”) community that he has applied his faith in a manner that is consistent with current scholarly procedures.

### 2.2.1.2 Roger Bacon (1214?-1294)

Roger Bacon was an early proponent of scientific experimentation and deductive reasoning. Apparently, there were some in his acquaintance that were using illusions to

generate miraculous-appearing events in the name of some religion. Bacon defended the use of experimental science as a means to reveal the illusory nature of these “miracles”. He said,

This science, moreover, knows how to separate the illusions of magic and to detect all their errors in incantations, invocations, conjurations, sacrifices, and cults. But unbelievers busy themselves in these mad acts and trust in them, and have believed that the Christians used such means in working their miracles” (Ross and McLaughlin 1977).

Bacon saw the use of science as a means of disproving false superstitions and so-called magic that were being used to argue against Christianity.

#### 2.2.1.3 Bernard Palissy (1510-1590)

Bernard Palissy was a student of soils. He also commented on the origin of fossils and sedimentary rock. He explained them as originating from soft muds and mud-dwelling creatures that simultaneously hardened into rock (Young 1995). In his Admirable Discourses (1580), he argued against the theological dogma of the day, attributing the origin of fossils to Noah’s flood. However, he still credited his faith in God as the instrument through which he was able to come to this conclusion. He wrote, "It is, therefore, just as reasonable that each one should seek to multiply the talents it has pleased God to make me understand, according to the measure with which it has pleased him to endow me, in order to benefit posterity" (La Rocque 1957). Even though he appeared to some to be arguing against Scripture, he chose to give God the credit for his ability to acquire the understanding that he did.

#### 2.2.1.4 Francis Bacon (1561-1626)

Francis Bacon is often credited with introducing inductive reasoning into the scientific method. He had a definite belief, though, that scientific study, when developed properly, tends to enhance one's religious faith. This belief is shown in Meditationes Sacrae Works V-VII (1597) where he says, "A little natural philosophy and the first entrance into it inclines men's opinions to Atheism; but on the other hand much natural philosophy and a deeper progress into it brings men's minds about again to religion" (Martin 1992). He cautions that incomplete knowledge of scientific discovery may influence one to disbelieve in God's existence and that further study is necessary to regain an appreciation for Him.

#### 2.2.1.5 Johannes Kepler (1571-1630)

Johannes Kepler and Galileo Galilei were both involved with trying to harmonize the recently proposed Copernican model of the Solar System with Scripture. Yet they were both criticized by some in the religious community for heresy (Butterfield 1957). In a letter to Johann Herwart, Kepler wrote, "But I think in this way: since we astronomers are priests of the most high God with respect to the book of nature, it behooves us not to think of the praise of our abilities, but above all of the glory of God. . . . Enough for me is the honor of guarding, with my discovery, the door of God's temple, in which Copernicus serves before the high altar" – Dec. 16, 1598 (Ross and McLaughlin 1981). Kepler saw the workings of

nature as perfectly in line with faith in God and was willing to address the issue in his writings.

#### 2.2.1.6 Galileo Galilei (1564-1642)

Galileo is well known for his work in astronomy and physics and is frequently remembered for his statement about how Scripture tells us “how to go to heaven, not how the heavens go” (Seeger 1966). He believed in a dual revelation of God’s work – that the Bible tells us about God’s work with humans, whereas nature tells us about God’s creative work. Since both are representative of the same God, they should both be in harmony. In a letter to Madame Christine of Lorraine, Grand Duchess of Tuscany, Galileo said, “I do not mean to infer that we need not have an extraordinary esteem for the passages of Holy Scripture. On the contrary, having arrived at any certainties in physics, we ought to utilize these as the most appropriate aids in the true exposition of the Bible and in the investigation of those meanings which are necessarily contained therein, for these must be concordant with demonstrated truths” (Seeger 1966). The Roman Catholic Church charged him with heresy during the Inquisition. Nevertheless, his views represent a subtle shift in thought about the relationship between nature and Scripture. Both were seen as valid, compatible, yet separate revelations of the workings of God.

#### 2.2.1.7 Rene Descartes (1596-1650)

Descartes is sometimes referred to as the father of modern philosophy. He proposed that scientific hypothesizing does not have to interfere with one's Christian faith. In the Principia Philosophiae Part IV – “The Earth”, he expressed the belief that our investigations of the origins of the Earth may lead to some initially false conclusions, but that persistence will allow scientific investigation to correct itself and determine the truth. Whatever this truth may be, it does not deny the Creator or his workings in nature. We need not be fearful of discovering something that will damage our faith (Scott 1976).

#### 2.2.1.8 Robert Boyle (1627-1691)

Robert Boyle is not considered a major contributor to the field of the Earth Sciences, but he did write a book called An Essay about the Origine and Virtues of Gems, published in 1672. He was a Christian who also trusted science with the ability to accurately describe nature. His religious beliefs, though, had such a strong place in his life that he placed them in priority above his scientific work. He showed the importance and personal value of his faith in The Usefulness of Experimental Natural Philosophy (1663). He said,

For I, that had much rather have men not philosophers than not Christians, should be better content to see you ignore the mysteries of nature, than deny the author of it. . . . It seems to detract from the honor of the great author and governor of the world, that men should ascribe most of the admirable things, that are to be met within it, not to him but to a certain nature, which themselves do not well know what to make of (Hall 1966).



He was critical of those who would try to explain nature as if it all happened of its own accord without the creative work of God. He was also critical, though, of those associated with the church that refuted scientific investigation as being godless and unnecessary. He wrote, “I forget not, that there are several divines (and some of them eminent ones) that out of a holy jealousy (as they think) for religion, labor to deter men from addicting themselves to serious and thorough inquiries into nature, as from a study unsafe for a Christian, and likely to end in atheism” (Hall 1966). Robert Boyle was a man who most definitely had strong opinions on both sides of the issue.

#### 2.2.1.9 Niels Steenson or Steno (1638-1686)

Steno is credited with laying the foundation for modern stratigraphic interpretation through the principals of superposition, original horizontality, and lateral continuity (Dott 1981). Modern authors often criticize him, though, for attempting to accommodate Earth’s history to a time period of a few thousand years. Yet it is important to understand that he was working within the context of the common thought of his day – that God’s book of nature and His book of Scripture (the Bible) were equally valid and true revelations of Him. Steno simply addressed nature as either in total agreement with Scripture, or if it was not in agreement, he attributed the conflicting reports to misinterpretation of either the truth of Scripture or the truth of Nature (Rudwick 1976).

#### 2.2.1.10 Thomas Burnet (1635-1715)

Geology was still not a well-developed science in the seventeenth and eighteenth centuries. However, more scientists were dealing with the issues of Earth processes and origins. Theoretical Earth scientists in Europe were typically basing much of their musings about ‘catastrophism’ and ‘neptunism’ on the basic outline of creation given in Genesis, the first book in the Bible. Thomas Burnet sought to address some of the apparent difficulties in reconciling the Genesis account of creation and the flood by writing his Sacred Theory of the Earth. In this work, Burnet recognizes the problem of the amount of water that would be necessary for a global flood. He takes some ideas from Descartes and proposes a formation of the Earth that differentiates it into a series of layers. The layers, from the center outward, would have included a subterranean abyss of water covered by the crust. This is the source, he proposed, of the water for the flood (Young 1995). In the preface to the book he says,

We are not to suppose that any truth concerning the Natural World can be an Enemy to Religion; for Truth cannot be an Enemy to Truth, God is not divided against Himself. . . . But for every new Theory that is propos'd, to be alarum'd, as if all Religion was falling about our Ears, is to make the World suspect that we are very ill assur'd of the foundation it stands upon (Burnet 1684).

Burnet is proposing here that whatever is discovered about the Earth, the Christian’s faith is (or should be) able to coexist with that new information. Regardless of what is discovered, the Christian’s faith will be able to stand firm.

#### 2.2.1.11 Isaac Newton (1642-1727)

Burnet consulted Newton for advice before he published his Sacred Theory.

Though Newton offered some suggestions for changes, he told Burnet that he found his theory “most plausible” and even more probable in some counts than his own theories (Turnbull 1960). Newton recognized the grandeur of a Creator in the workings of the Universe and saw fit to declare it in some of his own writings. In reference to the solar system, Newton says,

This most beautiful system of the sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent and powerful Being. And if the fixed stars are the centres of other like systems, these, being formed by the like wise counsel, must be all subject to the dominion of One. . . . This Being governs all things, not as the soul of the world, but as Lord over all; and on account of his dominion he is wont to be called Lord God, or Universal Ruler (Newton 1934 edition).

Some may question Newton’s religious views, but regardless of that, he still felt it important to acknowledge religious views in conjunction with the discoveries he was making.

#### 2.2.1.12 William Buckland (1784-1856)

Buckland was a staunch supporter of diluvial catastrophism. However, he was also beginning to recognize that science could interpret the world without necessarily relying on Scripture for its timeframe or methodology. He said,

The grand fact of an universal deluge at no very remote period is proved on grounds so decisive and incontrovertible, that, had we never heard of such an event from Scripture, or any other, authority, Geology of itself must have called in the assistance of some such catastrophe, to explain the phenomena

of diluvian action which are universally presented to us, and which are unintelligible without recourse to a deluge exerting its ravages at a period not more ancient than that announced in the Book of Genesis (Buckland 1820).

Here Buckland is trying to emphasize that science will recognize truth in nature and can come to a valid conclusion separate from, but complementary to, Scripture. This is another subtle shift in science-theology thinking. Proponents are saying that not only do we have two complementary revelations from God (nature and Scripture), but they both contain sufficient information so as to make each a complete description of an aspect of God's work.

#### 2.2.1.13 William Conybeare (1787-1857) and William Phillips (1775-1828)

William Conybeare and William Phillips were both ministers of the Church in England who also happened to study geology. They proposed that it is possible for a variety of interpretations of Genesis to be reconciled to current theories of Earth origins and processes. In the introduction to one of their books, Rev. Conybeare comments,

It does not become us to propose hypotheses of such a nature (reconciling Genesis with antiquity of the Earth) with any feeling of confidence. It is amply sufficient for our purpose to show that there exists more than one mode by which the appearances presented by the structure of the globe may be satisfactorily reconciled to the facts recorded by Moses, in order to remove the objection which has been drawn from them (Conybeare 1822).

This is an important step in showing the breadth of thought that can exist. While there can be multiple interpretations of the fit between science and Scripture, they can all coexist with faith in God.

#### 2.2.1.14 Benjamin Silliman (1779-1864)

Silliman was a mineralogist and chemist, professor at Yale University, and founder of the *American Journal of Science*. He was influenced greatly by the work of Buckland.

James Dwight Dana, a contemporary of Silliman's, wrote,

Geology, from the first, encountered opposition. Its very essence . . . involved the idea of secondary causes in the progress of the creation of the world - whilst Moses had seemingly reduced each step of progress to a *fiat*, a word of command. The champions of the Bible seemed called upon, therefore, to defend it against scientific innovations; and they labored zealously and honestly, not knowing that Science may also be of God. Professor Silliman, being an example of Christian character beyond reproach, with boldness and power . . . stood by both the Bible and the Science, until now there were few to question his faith (Fulton 1947).

Silliman was able to reconcile current geologic theory with his faith and was a popular lecturer who could inspire his audiences with his fervor and enthusiasm. His ability to explain geologic theory as well as his faith succeeded in encouraging many to accept the truth of both (Fulton 1947). Silliman published an American edition of Robert Bakewell's Introduction to Geology. In a supplement to the second edition Silliman addressed apparent conflict between geology and Scripture, saying, "these changes [geologic processes] have arisen from the action of those physical laws which the Creator established, and which are as truly his work as the materials upon which they operate. The amount of time is the only difficulty, and this will vanish before an enlarged and reasonable view of the whole subject, taken both in its geological and historical bearings" (Fulton 1947).

One of the critics of Silliman, Thomas Cooper of South Carolina College at Columbia, said, "It is well for Professor Silliman that his useful services to science have placed his reputation on a more stable foundation than his absolute unconditional surrender of his common sense to clerical orthodoxy." Silliman later said,

In the last letter which I received from him [Cooper] he reviled the Scripture, especially the Old Testament, pronouncing it in all respects an unsupported and in some respects a most detestable book. To this letter I made no reply, feeling that it was such a violation of gentlemanly courtesy when writing to one whose sentiments he knew to be so opposed to his own, that I thought it better to drop the correspondence and I never heard from him again (Fulton 1947).

Whether or not Silliman's geological ideas were correct, it seems that many of his critics were critical as much for his willingness to share his faith as they were of his science. This is one of the difficulties with being willing to address both scientific and theological issues together.

#### 2.2.1.15 Hugh Miller (1802-1856)

Hugh Miller was a primary author in the field of science and Scripture in the nineteenth century. He was a student of geology and wrote several geological descriptions such as The Old Red Sandstone, which described a stratigraphic sequence in England. One of his primary aims as an author was to address Christian critics of science, and scientist critics of Christianity. He was appointed as President of the Royal Physical Society of Edinburgh on January 7, 1852. At his opening address to the Society he presented a paper entitled "Geological Evidences in Favor of Revealed Religion." In it he said,

When it was first ascertained by the father of English geology, William Smith, . . . that this uniformity is attended by a certain equally uniform succession of groups of fossils, could it be once inferred that he was laying hold of a principle which, in the course of a single age, was destined marvelously to unlock the past history of our planet, and to acquaint us with God's doings upon it, as the Creator of all (Miller 1858).

Miller was a proponent of the idea that the Bible's primary purpose for revelation was on a moral basis. It was never intended by God to be a treatise on physical processes. On the other hand, his writings illustrate how Christians are to acknowledge God's involvement and design in the natural world.

#### 2.2.1.16 John Pye Smith (1774-1851)

Smith was a divinity tutor in London who was well read on topics related to geology (Young 1995). He felt it necessary to encourage Christians to not fear scientific endeavors. He wrote,

Let us, for a moment, suppose that there are some religious difficulties in the conclusions of geology: how, then are we to solve them? Not by shutting our eyes to facts, or denying the evidence of our senses; but by patient investigation carried on in the sincere love of truth, and by learning to reject every consequence not warranted by direct physical evidence. Pursued in this spirit, geology can neither lead to any false conclusions nor offend against any religious truth (Smith 1852).

He also blasted the "creation scientists" of his day for preying on the fears of Christians regarding science, and teaching erroneous ideas as fact. These people were publishing books that attempted to fit all of geology within the context of their version of a literal interpretation of Genesis. They were going against the established methodology of science by starting with a conclusion and trying to make the data fit that conclusion even

though it was in direct opposition to established laws of nature. Later in the same passage quoted above he said,

But there is another class of men, who pursue geology by a nearer road and are guided by a different light. Well-intentioned they may be; but they have betrayed no small self-sufficiency, along with a shameful want of knowledge of the fundamental facts they presume to write about. Hence, they have dishonored the literature of this country by ‘Mosaic Geology,’ ‘Scripture Geology,’ and other works of cosmogony with kindred titles. . . . Authors such as these ought to have first considered, that book-learning (in whatsoever degree they may be gifted with it), is but a pitiful excuse for writing mischievous nonsense (Smith 1852).

In a letter to Smith, commending him for his writings on the subject, Sir John Herschel (son of William Herschel) said,

Abstractedly, one might have thought that such wild and ‘vehement denunciations’ as those you cite . . . were hardly worth very serious handling. Yet, in effect, I am disposed to regard it as doing good service, not only to science, but to religion and moral feeling, to put down, as you have done, with a strong (though not a cruel) hand, that sort of barking and yelping. There cannot be two truths in contradiction to one another: and a man must have a mind fitted neither for scientific nor for religious truth, whose religion can be disturbed by geology, or whose geology can be distorted from its character of an inductive science, by a determination to accommodate its results to preconceived interpretations of the Mosaic cosmogony (Smith 1852).

I have not researched the status of Herschel’s faith, but he clearly recognized the need for Christian scientists to set the record straight when it comes to false teachings about science done in the name of religion.



### 2.2.1.17 Edward Hitchcock (1793-1864)

Hitchcock was a student of Silliman's, a founding member of the National Academy of Sciences, and well versed in the geology of New England (Young 1995). There are those today who may be inclined to scoff at the idea of writing a book, as Hitchcock did, entitled The Religion of Geology. But I emphasize that before we judge too harshly the work of such scientists, let us consider their purpose. Hitchcock was addressing the increasing level of conflict between Christianity and science and attempting to serve as a mediator between the two sides. In the preface to his book, he wrote,

I beg the intelligent Christian, however, before he condemns my views, to settle it in his mind what he can substitute for them that will be more honorable to religion. It is much easier to find fault with a mode of defending the truth than to invent a better method. We may not be pleased with certain views in vindication of religion, and yet the alternative of rejecting them may be so much worse as to lead us to be silent. Would that Christian critics had always kept this fact in mind when writing upon the views of geologists! They would find often that they are straining at a gnat and must swallow a camel (Hitchcock 1855).

His contention is that as a scientist who understands the workings of nature and yet has faith in the inerrancy of Scripture, he must do his best to show how current scientific thought can be shown to fit with an appropriate interpretation of Scripture. His warning is that Christians who refuse to allow for reinterpretation of Scripture in the light of discoveries in nature are jeopardizing the strength of the foundation of their faith. If at some point they become convinced about the facts of science and it still conflicts with their interpretation of Scripture, their Bible-based beliefs will be damaged. What they don't realize is that while Scripture is true and inerrant, an interpretation of Scripture may falter.

### 2.2.1.18 Joseph LeConte (1823-1901)

LeConte was a Professor of Geology at the College of South Carolina and then at the University of California. He was also an associate of John Muir. LeConte was persuaded by some of his friends to present a series of Sunday lectures on the relation between science and Scripture. He said,

I wish to compare the two divine books, and to show that the God revealed in the one is the same as the God revealed in the other. I find sufficient justification for this course of lectures in the existence of a constantly-growing feeling among intelligent people, that there is an irreconcilable antagonism between science and revelation; and that the unbiased and earnest study of the former is inconsistent with a belief in the latter (LeConte 1884).

In his lectures, he addressed what were currently regarded as the most significant sources of conflict between science and Scripture – the antiquity of the Earth, the duration of the creation days, and the existence of death prior to Adam. He felt very strongly that those who trust science and also have faith in the inerrancy of God’s Word must take a stand on the issue and help their fellow believers to be strengthened in their faith as well. He said,

We never can expect the conflict to cease, so long as science continues to advance. The conflict must be perpetual, and the distress and doubt occasioned thereby to the religious mind must also be perpetual, unless we rise to a higher and more philosophical point of view. . . I do believe that we cannot do a man a greater and a more irreparable injury than to unsettle in any way his religious faith (Le Conte 1884).

He went on to encourage scientists to be aware of how their discoveries relate to the Scriptures and to endeavor to help their fellow humans to understand that relationship.

Finally, he also believed that ultimately there really is no conflict and that such conflict is due to simple misinterpretation of science or Scripture and usually represents a fairly trivial dispute. He said,

Now, I have long come to the conclusion that much of the difficulty and distress which many feel in regard to the discordance between science and religious belief is wholly factitious, having its origin, not in the nature of the subject itself, but in the irrelevant matter, the rubbish which has been gathered about the subject by bigotry on the one side, by conceit and vanity on the other, and by misconceptions on both sides. We are so blinded by the smoke and the dust of the conflict that the true question is scarcely seen at all. Remove the rubbish, clear away the smoke so that we can see the question in its naked simplicity, and nearly the whole difficulty disappears (Le Conte 1884).

#### 2.2.1.19 Arnold Guyot (1807-1884) and J. William Dawson (1820-1899)

Guyot was a professor of geology at Princeton for thirty years. Dawson was professor of geology at Canada's McGill University. They both chose to write on the subject of geology and Scripture. Each in his own way were proponents of the idea that a scientist who is a Christian has an advantage over his peers in having the ability to appreciate his discoveries by attributing them to God as Creator. Through better understanding and study of Scripture, one can apply to their scientific work an identification and intimate knowledge of the Author of nature. Dawson wrote,

The ordinary Christian who believes his Bible is thus so far on his way toward a rational geology and archaeology, and cannot say with truth that he is absolutely ignorant of the pre-human history of the Earth. His notions, it is true, may be imperfect, either by reason of the brevity of the record to which he trusts, or of his own imperfect knowledge of its contents, but they give to historical and archaeological inquiry an interest and importance which they could not otherwise possess (Dawson 1894).

This idea of attributing a specific value to nature by acknowledging its Creator can be illustrated with the following example. If one were to be given a gift of \$1,000 by a friend, contrasted with finding \$1,000 abandoned on the street, he could make equal use of either amount. However, as he uses it, he will feel a connection with the giver of the gift that would not otherwise be felt. This is the sense of appreciation that Dawson was talking about.

### 2.2.2 Recent Work

The ultimate goal of Christianity is to share its beliefs about God as Creator and Savior. The ultimate goal of science is to share its discoveries of the workings of nature. While it seems to some that there are fewer and fewer people who work to do both, there are still those who see both endeavors as simultaneously valuable and necessary to humanity. Here are a few examples of modern authors and groups.

#### 2.2.2.1 Bernard Ramm (1916-1992)

Ramm was a professor of Theology at American Baptist Seminary. He wrote,

We are to pay due respect to both science and Scripture. Neither adoration of one nor bigoted condemnation of the other is correct. We must be ready to hear the voice of science and the voice of Scripture on common matters. The spirit of mutual respect for both science and Scripture preserves us from any charge of being anti-scientific or blindly dogmatic or religiously bigoted; and from being gullible, or credulous or superstitious in our religious beliefs as they pertain to Nature (Ramm 1954).

Ramm's work predated the modern rise of the "Creation Science" movement by several years. However, he became an immediate target of leaders in this movement and received much criticism for compromising his faith to accept the so-called heresies of science and thereby leading weak Christians away from what is touted as an uncompromising belief in the Bible.

#### 2.2.2.2 Davis A. Young

Davis A. Young is a professor of geology at Calvin College. He is a frequent lecturer and author on the subject of harmonization of science and Scripture. He is also a critic of the modern creationist movement and is a common target of their criticisms. He addresses the issue of misleading pseudo-science that is being taught under the name of "Creation Science." He points out that this teaching has as much potential for damage to the faith of a Christian as the teaching of a science that blatantly excludes the possibility of God's existence. He says, "What is much more likely to undermine Christian faith [than acceptance of an old Earth] is the dogmatic and persistent effort of creationists to present their theory before the public, Christian and non-Christian, as in accord with Scripture and nature, especially when the evidence to the contrary has been presented again and again by competent Christian scientists" (Young 1982). He points out that it is better for the Christian to accept that there may appear to be disharmony between science and Scripture for a time, but further study and discovery will only show that this is not truly the case. He wrote,

The facts of the Bible and the facts of nature . . . do not disagree but form one comprehensive, unified expression of the character and will of our Creator and Redeemer. Nature and Scripture form a unity, for God is one. Although man, because of his sinful nature, reveals himself in inconsistent and contradictory ways, God cannot do so. But the fact that God's words and works are a perfect unity does not by any means indicate that we can always see how they agree or fit together (Young 1982).

#### 2.2.2.3 Alan Hayward

Alan Hayward is a British physicist who retired early in order to allow him more time to write on the issues of science and faith. He says,

It is a pity that the term ‘Creation Science’ was ever invented. Creation is not a branch of science, and never can be. Creation is a matter of faith, one of the fundamental beliefs of Christianity. . . [Creationists] claim that their version of creationism is a scientific model that can compete on equal terms with Darwinism. Then, when atheists shoot the so-called ‘creation science’ full of holes, the result is tragic: it looks as if atheism has triumphed over Bible-based Christianity. . . . To redress the balance, a great deal of new creationist literature is urgently needed. There are still many creationists who respect both the Bible and the physical sciences. But their voices have been muted for too long. . . . If we can but present it with moderation and good sense, the world may yet come to see the truth of physicist Sir William Bragg’s famous dictum: ‘Religion and science are opposed . . . but only in the same sense as that in which my thumb and forefinger are opposed – and between the two, one can grasp everything’ (Hayward 1995).

#### 2.2.2.4 Hugh Ross

Hugh Ross is an astrophysicist who has founded an organization called *Reasons to Believe*. This group has as its primary purpose the goal of “research and teaching on the harmony of God’s revelation in the words of the Bible and in the facts of nature” (Ross

1994). This group maintains that the geological and astronomical record depicted in nature is a valid representation of God's creative work and this record is not in conflict with God's revelation in Scripture.

There also currently exist organizations of professionals that encourage their members to publish works dealing with harmonization of science and Scripture. Some of these include the *American Scientific Affiliation* and the *Affiliation of Christian Geologists*. These organizations provide a forum in which authors can publish papers in response to some of the misinformation about science and Scripture that is being presented from both sides of the issue.

It is unfortunate that some authors in the scientific community take a very antagonistic view to the mixing of science and Christian theology. For example, regarding the development of uniformitarian principles, Claude Allègre says, "The scientific arguments were so convincing, however, that despite the religious status of most of the professors, Hutton's theory was accepted by almost everyone in the geologic community" (Allègre 1994). The implication here is that many geologists were able to overcome the hindrances of their faith in order to accept Hutton's theory of cyclical events and uniformitarianism. I contend that they merely understood the scientific evidence and realized that it could be harmonized quite sufficiently with their or others' faith. Allègre also writes that

Science and religion are two separate aspects of human activity. They should stay separate. Nothing is to be gained by mixing the issues (Allègre 1994).

This statement does not reflect an acknowledgement of the great scientists who have used their faith as additional motivation to study nature.



## CHAPTER 3

### LEARNING THEORY

#### 3.1 Position Statements of Professional Organizations

The Geological Society of America has published a very clear statement regarding the teaching of creationism in public schools. It says,

The immensity of geologic time and the evolutionary origin of species are concepts that pervade modern geology and biology. These concepts must therefore be central themes of science courses in public schools; creationist ideas have no place in these courses because they are based on religion rather than science. Without knowledge of deep time and the evolution of life, students will not understand where they and their world have come from, and they will lack valuable insight for making decisions about the future of their species and its environment (GSA 2002).

Similarly, the American Geophysical Union has said, “AGU opposes all efforts to require or promote teaching creationism or any other religious tenets as science. AGU supports the National Science Education Standards, which incorporate well-established scientific theories including the origin of the universe, the age of Earth, and the evolution of life” (AGU 2002).

Both of these statements are obviously very strong in opposition to the teaching of creationism in public schools. Unfortunately, this explicitly hard-line stance fails to acknowledge that there may be students who are already in the classroom who have sympathies or opinions in support of creationism, specifically in this case referring to

young-Earth creationism. By encouraging schools to not discuss creationism, I believe these statements are also discouraging educators from engaging their students in the open and critical examination of some of the science preconceptions they are bringing with them to the classroom. If followed literally, the GSA and AGU positions might well keep science teachers from being the good teachers that they really need to be.

### 3.2 Cognitive Dissonance

This paper deals not only with scientists and their task of educating the public about their work, but with the public that receives that information. When people learn about anything new, they do so within the context of their previous experiences and knowledge. These foundational learnings form the basis for making judgments about the validity and application of new information. The next task is to come to an understanding of what influence these preconceptions have on the way that people learn.

Learning theorists of the twentieth century such as Jean Piaget, B.F. Skinner, and Benjamin Bloom have identified a number of factors that influence how humans learn. Some of the major factors include age, motivation, prior experience and intelligence. There has also been much written on cognitive consistency, which is the tendency for a person to exhibit beliefs and actions that are logically consistent with one another. When he/she experiences cognitive dissonance, the person unconsciously seeks to restore consistency by changing his or her behavior, beliefs, or perceptions (Festinger 1957). The role of the

influence of preconceptions in the learning of scientific material has been the subject of a very interesting series of studies by Clark A. Chinn and Walter S. Brewer.

### 3.3 Chinn and Brewer's Research

Clark A. Chinn and William F. Brewer have jointly published several papers on the relationship between bias and the ways that people learn scientific concepts. Their use of the word "bias" is in the sense that preconceptions play a significant role in how we respond to new scientific material. They have proposed a methodology with which to present ideas to people with various scientific preconceptions. They especially advocate the judicious use of anomalous data in the presentation and development of new ideas. The purpose of focusing on anomalous data is to force the examination of the data in the light of theories that may have difficulty explaining it. Before designing a lesson to present, an educator needs to be aware of the various ways that people may deal with this anomalous data. These ways range all the way from ignoring data to changing a theory as a result of the data.

#### 3.3.1 Ignoring the Data

This is the most extreme way that people may deal with new data. By ignoring the implications of the data to their currently held theory, they are able to choose to keep their theory intact. This is not something that is limited to the general public. There have been

times that the scientific community as a whole has chosen to ignore anomalous data for a time rather than try to alter currently held theories (Chinn and Brewer 1993).

### 3.3.2 Rejecting the Data

This goes beyond ignoring the data in that the person will try to discount data for a number of reasons. The most frequent arguments against anomalous data are that the data is erroneous due to some error or flaw in data collection. Another argument is that the data can be explained as a fluke or random fluctuation of nature.

### 3.3.3 Questioning the Validity of the Data

In a follow-up study, Chinn and Brewer tested their taxonomy and concluded that one additional response needed to be added. They said that individuals faced with anomalous data will sometimes dismiss the data as being falsified or purposely deceptive (Chinn and Brewer 1998). This is different than the previous category in that the source of the data is what is being rejected, in addition to the data itself.

### 3.3.4 Excluding the Data

Instead of rejecting the data, or its source, the student may acknowledge (to a certain degree) the validity of the data but excuse the data as being outside the constraints of their particular theory. In this way, the student does not need to explain the data because, in their opinion, the data does not apply to their theory and does not need explanation.

### 3.3.5 Holding the Data in Abeyance

Another way to forestall the explanation of an anomaly is to hold it in abeyance. This means that the student acknowledges the anomaly and proposes that his theory does not have an explanation only because no one has thought of it yet. This essentially accepts the data as anomalous, but with the expectation that it will likely be explained by their theory at some point in the future.

### 3.3.6 Reinterpreting

A student may also choose to reject the data indirectly by offering a “reinterpretation” of the data that will allow it to fit into their current theory. At this point, proponents of different theories can agree that the data, as interpreted by them, poses a problem for the other. This has the potential to open an initial line of communication between proponents of differing theories by forcing them to understand something of how the data fits into both theories.

### 3.3.7 Peripheral Change

Depending on the strength and abundance of the data, the student may choose to alter his or her theory in order to explain the anomalous data without throwing the theory out altogether. This encourages refinement of a model or theory and pushes the student closer to the scientific process of model testing.

### 3.3.8 Theory Change

If the data is sufficiently convincing, the student may reject his theory altogether. Before adopting a new theory, the student will make sure the data is credible and can be explained. Lastly, the student will begin work on their own beliefs, adjusting them to fit both the new theory and the problematic data. The new theory must have two main characteristics in order for the student to accept it. It must be of good quality, which has the inherent elements of accuracy, breadth, consistency and simplicity, and it must be able to lead to further research. It must also be plausible, being easily understood and containing reasonable mechanisms of operation. This gets back to the idea of cognitive consistency.

## 3.4 Ways Science Is Typically Presented

I propose that there are four perspectives from which science education materials are being presented that relate specifically to students' preconceptions or bias. There may be more that I have not addressed, but these four approaches are keyed to the way a religious person may be approached.

### 3.4.1 Perspective I - Christian to Christian

Science materials written by Christians specifically for Christians usually state this openly (acknowledgement of bias). The materials refer to a basic belief in God and usually have some sort of Biblical reference or support for their science statements. The biased voice is usually very apparent in the author. Sometimes this bias is dogmatic in terms of

biblical or scientific interpretation. For example, the author might blatantly say, “the Bible says . . . , and that’s what it means,” or “the scientific evidence fits this way with Scripture and therefore must mean this one thing.” Other times, the bias is somewhat more objective, with the author saying “the Bible can be interpreted this way and therefore could fit with this scientific observation” or “in my opinion, this is the way things are.”

Young-Earth creationists have written many volumes of literature that have been circulated among the Christian community that sound "scientific." These publications have led many people to the conclusion that science educators are out to compromise the religious beliefs of their students. Frequently, science education in private schools is less than exemplary because of the proliferation of creationist publications (Young 2002). There are a number of old-Earth creationist publications out as well, but many of the conservative Christian groups have not yet embraced them.

#### 3.4.2 Approach II - General Acknowledgement of Varied Bias

Some authors choose to write in such a way that they offer explanations of various viewpoints, essentially summarizing and qualifying the bias in the authors they are quoting. Their purpose is to point out to the reader the apparent motivations or reasons behind the various viewpoints so the viewer can critically evaluate the viewpoints. It is my feeling that this is the approach that will be most effective in getting people to understand the scientific process. The interlude in the Moores and Twiss text Tectonics (discussed in section 2.1) is an example of this approach. They acknowledge the role of bias in scientific

interpretation and encourage the student to be aware of this as they delve deeper into a topic.

The need to acknowledge and critically examine various views is discussed by Hugh Ross in a 1999 issue of his organization's newsletter *Connections*. In regard to ways people respond to each other's ideas, he says,

Non-theistic evolutionists, theistic evolutionists, young-Earth creationists, and old-Earth creationists all hold different views on the constancy of physical laws. If we fail to understand each other's perspective, we debate the wrong issues. We frustrate and offend one another. At best, nothing gets clarified or resolved (Ross 1999).

I feel that the role of science educator should go beyond the mere dissemination of information to include an analysis of the viewpoints that are currently held by the community we serve. Unfortunately, by ignoring dissenting viewpoints, we are not encouraging people to critically examine them.

### 3.4.3 Approach III - Ignorance of Possible Belief Conflicts

Much material is written from the stance of "pure objectivity", failing to acknowledge the inherent bias of the author or the existence of a variety of biases in the potential reader. By writing from this perspective, the author leaves questions unanswered that a reader with preconceptions about a topic might have. For example, the facts that support the conclusions held by the author are usually comprehensive for that theory, but they don't address the ways others have responded to the data. In section 1.1 I quoted Rodger Bybee as saying, "Regardless of public opinion, we don't owe it to our students to



present creationism in science class any more than we are obligated to teach alchemy as an alternative to chemistry or astrology because some people believe in it” (BSCS 2000). The problem with this statement is that if there are people who we come into contact with who believe in alchemy or astrology, we are doing them a disservice to ignore that belief when we have access to data that might encourage them to critically evaluate their preconceptions. Acknowledging and addressing these preconceptions is not the same as teaching them.

#### 3.4.4 Approach IV - Attacking of Belief Structures

Some authors not only acknowledge their own bias and bias in others, but are bent on attacking or ridiculing any bias that does not match their own. Unfortunately, this approach tends to polarize those involved and does not encourage any critical analysis of preconceptions.

#### 3.5 Acknowledgement of My Own Personal Bias

Before proceeding with the quantitative and qualitative analysis of the impact of preconceptions in science education, I need to clearly establish for the reader my own bias. I am a Christian and have a vested interest in this topic. I have encountered teachers, both as a student and as a co-worker, who have been openly antagonistic toward belief in God and the Bible. I have had and known students who have struggled with the mixed messages they receive in school and at church about how science and faith do or do not fit

together. I know people in the Christian community who have learned the material presented as “creation science,” including the concepts of a young Earth and flood geology, who feel that “creation science” is a viable scientific explanation for the geological and biological record found in nature. I also know many Christians who have the same basic perspective of science and faith that I do. That perspective is that the Bible is the inerrant Word of God and can be trusted as an accurate account of God’s character and work. I also believe that His creation holds an accurate account of His work and can be trusted to clearly indicate His creative processes. I believe that this dual revelation of God (Scripture and Nature) is completely compatible and when there is apparent conflict, the conflict is only due to our current misinterpretation of one or the other. Finally, lest there be any question, I believe that the age of the Earth is well established at 4.6 billion years old.

### 3.6 Chinn and Brewers’ Approach to Promoting Reflective Theory Change

Not all anomalous data must force someone to reject a theory. However, students of science must be encouraged to be willing to face this data with the intent of seeking an explanation for it, either within the context of their current theory, or in the context of a new one. Chinn and Brewer (1993) propose the following instructional strategies for promoting the critical analysis of data and theories.

### 3.6.1 Influencing Prior Knowledge

A student's background knowledge is critical to the analysis of anomalous data. The educator must also develop sufficient background knowledge of the student's theories in order to understand where the students are coming from. This understanding on the educator's part will enable him to guide the students in acquiring sufficient background to deal with new data. The educator can also identify student misconceptions in the assigning of concepts to ontological categories (beliefs about the fundamental categories and properties of matter). As a final preparation for the presentation of anomalous data, the educator should attempt to foster an understanding in the students of epistemological commitments. This entails a discussion of what constitutes good scientific theory, knowledge and practice.

### 3.6.2 Introducing an Alternative Theory

As educators prepare to present an alternative to the students' preconceptions, they must make sure the alternative is plausible, of high quality, and intelligible. While students may be able to take data on their own and develop the theory themselves, they may still be so entrenched in their preconceptions that they will need some guidance. "Hands-on" learning is good, but students may lack the ability to synthesize a theory on their own without some directed activities or hints along the way.

### 3.6.3 Introducing Anomalous Data

Now that students have two theories with which to analyze data, present them with anomalous data that will confront their preconceptions. The data must meet three primary criteria. It must first of all be credible. The data itself and the source of the data must be shown to have a strong measure of validity to it. Again, students may not have the capacity to fully make this determination on their own, so the educator must make every effort to demonstrate the validity of the data for the students.

Next, the data needs to be unambiguous. Ambiguous data will encourage students to ignore it or explain it away. The educator must carefully select data that is as concrete as possible within the context of the students' background. If the learners don't understand the data, they will not be likely to make positive conclusions from it.

Third, anomalous data will be much more likely to drive new conclusions if it is presented in the context of multiple data sets. A student will not be as likely to be convinced of the validity of data if it represents an isolated example. Data that has multiple expressions in nature will require more analysis and incorporation into preconceptions than will rare examples.

### 3.6.4 Encourage Deep Processing

Deep processing of information involves the extensive reflection and study of the information by the student. This includes a focus on apparently contradictory information, attempts to understand related alternative theories, enunciating the relationships between

the accumulated data and the alternative theories, and the inclusion of all available data.

Chinn and Brewer suggest that two ways to encourage this depth of processing in students is to choose a topic that can be demonstrated to have direct personal impact on them, and to force the students to have to defend their conclusions to others.

## CHAPTER 4

### PILOT STUDY ON TEACHING ABOUT THE AGE OF THE EARTH

#### 4.1 Overview of Research Structure

Against the background provided in chapters two and three, I developed a plan to test my hypothesis that the public would be better served by an open discussion of creationist ideas. I decided to work with pre-service teachers enrolled in the Teacher Licensure Program at the University of Colorado at Denver. I gave them a survey to measure their beliefs about the appropriateness of discussions of differing opinions on the age of the Earth in science classes. A week after the initial survey, I met with them to present some information about the age controversy and learning theory, and concluded my work with them with a follow-up survey. I drew my conclusions based on the quantitative and qualitative analysis of both surveys.

#### 4.2 Survey Variables

It was my initial plan to take some of the survey questions from the polls mentioned in the introduction. By using these questions, I had hoped to draw comparisons between my research subjects and the participants in the national polls. I abandoned this idea because the poll questions were not aligned closely enough to my specific focus. Instead, I

brainstormed some variables that might be a factor in influencing the answer to the question, "What factors might determine whether or not a teacher will or will not address creationist ideas about the age of the Earth?" The following factors arose out of that brainstorming session.

#### 4.2.1 Knowledge of Age Dating Techniques

One factor that I thought might influence educators' willingness to address creationist ideas is their background on age dating techniques. This would, of course, include the principles of radiometric dating, but would also include familiarity with such non-radiometric age indicators as varve studies, ice core analyses, and carbonate development. Without some basic knowledge of these various techniques, science educators can articulate the conclusion that the Earth is approximately 4.5 billion years old, but they cannot explain how we in the scientific community have reached that conclusion.

#### 4.2.2 Educational Background

All of my research subjects are enrolled in a Master's degree program that includes their teacher licensure. However, I wanted to find out how their undergraduate science field of study might affect their views on addressing creationist ideas in the classroom. In addition to their own science training, I wanted to see if there was any indication that those who went through private or home school programs felt differently about this issue than

those educated through the United States public school system. Ultimately, though, I did not feel my study sample was heterogeneous enough to provide an answer to this question.

#### 4.2.3 Religious Background

The creation / evolution controversy is tied very closely to religion. Another variable I chose to look at is religious background and beliefs. I emphasized primarily the monotheistic religions of Christianity, Judaism, and Islam in the wording of my survey questions. I expected to see a direct correlation between religious viewpoints and the willingness to address creationist ideas in science education, but I wanted to test this variable to make sure.

#### 4.2.4 Fear Factor

The issue of creationism in the public schools continues to be a prominent issue in current news and in the courts. I wanted to find out if this influences the willingness of teachers to address creationist ideas in their teaching. In other words, since there are so many religious and community concerns with the teaching of origins of the Earth and life, are educators less likely to address the issues in their classes because of the threat of conflict?

#### 4.2.5 Policy Statements

Since many professional scientific and educational organizations have published position statements specifically addressing the teaching of creationism in the public



schools, and since the American court system continues to be faced with cases about the teaching of creationism in schools, I wanted to know what impact these things are having on the willingness of pre-service teachers to deal with creationist issues in the classroom. I expected to find that the position statements and court rulings are having the effect of discouraging teachers from even discussing the ideas in their classes.

#### 4.2.6 Pedagogical Knowledge

It is important to understand how students learn before you try to teach them new material. I wanted to find out what pedagogical understanding preservice teachers had, both from past experiences and from their current teacher licensure studies. My pedagogical questions focused most specifically on the relationship of prior knowledge to the learning of new science material.

#### 4.2.7 Awareness of the Creation/Evolution Controversy

The controversies surrounding creationism permeate various sectors of our society, but they do not occur heterogeneously. In other words, there are many people who don't even know that creationism or age of the Earth is an issue. I wanted to find out how familiar the preservice teachers are with the controversy and how that familiarity would affect their willingness to discuss the ideas with their classes. In other words, how willing are they to discuss an issue that may be important to their students if it is not an issue that they see any relevance in.

### 4.3 Survey Development

After brainstorming the variables, I wrote four to six statements for each variable that could be associated with a Likert type response system. Some of the questions were based on the Gallup poll mentioned in the introduction, some were based on policy statements of professional organizations, and some were original. I also included some demographic data collection questions to develop a clearer picture of the personal background of the individuals. Finally, I included some qualitative, free-response type questions dealing with the subjects of creationism, age of the Earth, and evolution in order to develop a portrait of the extent of the familiarity the respondents have with the subject matter. This initial survey was distributed to eighteen high school science teachers, of varying subject area backgrounds and teaching experience, for feedback on the structure of the questions. I also wanted to be able to have some test data to run some initial analysis with to see if I was likely to get any useable information. This phase of survey development happened to coincide with the Association of Teacher Educators conference held in Denver in February, 2002. I was scheduled to co-present at that conference with a few of my colleagues and was able to attend some presentations by other teacher researchers. The sessions that were most helpful were a session on survey development and analysis (Newman, Pullman, Pullman and Turner 2002) and one on preservice teachers' willingness to address controversial topics (Carroll 2002). The information I collected from the science teachers and the ATE conference was incorporated into the final draft of my survey (see Appendix A).

#### 4.4 Pilot Study Discussion with Preservice Teachers

The preservice teachers that participated in this study are all enrolled in the teacher licensure program at the University of Colorado at Denver. All but one have an undergraduate degree in the biological or physical sciences. They are studying to be secondary school science teachers. These particular preservice teachers were selected because they are enrolled in the UCD Initial Professional Teacher Education course IPTE 5351 - Secondary Science Methods. The instructor of the course is Dr. Michael P. Marlow, and the class meets once a week for three hours.

On February 11, 2002, Dr. Marlow distributed the survey to the class. I was not present. They were instructed to take the survey home and bring it back with them to the following Monday night's class in preparation for a discussion of dealing with controversial issues in the science classroom.

I came to the class on February 18, 2002, with a presentation prepared in Microsoft PowerPoint. Dr. Marlow introduced me to the class and reminded them that the purpose of the evening's session was to look at how various controversial topics might be handled in the science classroom. He pointed out that this discussion was applicable to topics such as AIDS, human cloning, sex education, evolution and even global warming, but that the focus of this session would be on the age of the Earth and the controversy associated with some creationist interpretations. I had prepared copies of the PowerPoint presentation and distributed these to the class members (see Appendix B). I told them that I wanted them to have the full text of the presentation because some of the slides were purposefully wordy

and were there primarily for illustration and background material. I did not want the presentation to last more than 45 minutes so that there would be time for follow-up questions and discussion. The following subsections are a narrative of the information that I delivered to the class. The section titles correspond to the titles of the slides that I presented. I purposely wrote it in the first-person present tense to convey a sense of how and what was said. I describe it in this much detail because those who wish to check my process or would like to continue the research need to know what common background the preservice teachers received during the presentation. While some of the material may be redundant with information discussed earlier in this document, I feel it is important for other researchers to know as much as possible about what was said in the context of this presentation. Within the text, I periodically shift to past-tense language to explain my purpose or reasons for saying what I did. These statements are enclosed in parentheses.

#### 4.4.1 My Purpose

My purpose in presenting this information is not to teach rock dating techniques. (I knew that most of the students were probably at least somewhat familiar with radiometric dating techniques. I planned to mention non-radiometric methods of establishing minimum ages for geologic processes as well, but my intent would be to only acknowledge their usefulness and not to present a discourse on the theory behind them.) My purpose is not to teach creationism, either. I am not an advocate for young-Earth creationism, but I want us to look at the types and format of arguments that are presented to support this viewpoint.

My primary purpose is to allow us to examine the thinking and methods that underlie the various approaches to the age issue and the motivations that may drive the responses of these viewpoints to each other.

#### 4.4.2 Personal Involvement

I have been teaching for nineteen years at Northglenn High School. During that time I have taught Earth Science, Geology, Astronomy, Meteorology, Biology, Physics and Advanced Placement Physics. For the past four years, in addition to teaching AP Physics, I have been a coordinator for the Initial Professional Teacher Education Program at the University of Colorado at Denver. This position has allowed me to work with the preservice teachers that are placed in our school. My responsibilities have ranged from assigning their placement with supervising teachers to coaching them on their teaching skills and working with them on the effective integration of technology into their teaching.

I am a Christian and have belonged to a local Southern Baptist Church since moving to Colorado in 1983. It is a typical conservative evangelical church. I have periodically served on staff as music director in between full-time music ministers. On a few occasions, I have been asked how I can teach science and still maintain my Christian beliefs. I have served with several church staff members and lay leaders who believe in a recent creation (young-Earth).

In my teaching experiences, I have periodically encountered students who come from religious backgrounds that taught them to mistrust the conclusions of the scientific

community about evolution and the age of the Earth. I have been especially aware of these students when I've taught Biology and the Earth Sciences. Since the topic of origins doesn't come as frequently in Physics, I don't encounter as much vocal opposition to science concepts.

My thesis is specifically focused on challenging the policies of major scientific organizations against the teaching of creation. While I am not an advocate for teaching creationism, I feel that the policies, as typically stated, encourage teachers at all levels to avoid the topic of creationism (as represented here by the age of the Earth) to the point that students aren't being challenged to critically think about what they learn in science when it comes to religious-based controversies.

One of the reasons I see this as a problem at all levels is my friendship with a graduate of the Geology Program at Mines. He is an employee with the USGS and is an advocate of the young-Earth position. Another reason is my acquaintance with a current student at Mines who is studying Geology and has come out of a young-Earth religious background. He has approached me to help him with some of the difficulties he feels he has encountered in reconciling his beliefs with the content presented in his Geology courses.

#### 4.4.3 Why Is This Topic Important?

Even though I am focusing on the age of the Earth, this topic is representative of multiple topics that are deemed controversial in science. For example, the studies of

evolution, the origin of life, and the age and origin of the Universe are influenced by the religious beliefs of those studying them. Even some basic geologic concepts such as sedimentation, uniformitarianism and plate tectonics cause some element of concern among young-Earth creationist circles because of their implications for Earth age.

(At this point, one of the preservice teachers asked for clarification of the term uniformitarianism. I explained that it could be summed up by saying that the record of events we see in the rocks can be explained by the types of geologic processes we see going on today. In other words, there are no events in the rock record that cannot be explained by processes that we know about and expect could occur due to natural forces. I continued my explanation by saying that this concept generates controversy in some circles because it is frequently and erroneously defined as being associated with slow geologic processes and not with rapid, cataclysmic types of processes.)

I am aware that my examples are tied with the Earth Sciences. I explained that this is because of the nature of my project and its association with a Geology degree. However, these are examples of controversial topics that any science educator needs to be prepared to discuss with classes of diverse opinions.

#### 4.4.4 Overview of Presentation

My presentation is divided into four parts. The purpose of the first part is to show typical approach used in geology texts. It is not intended to be a comprehensive survey of the most commonly used texts but only a representation of what I consider to be a common

approach to the topic of Earth age. The second part of the presentation is intended to show a typical Christian young-Earth response to the concepts of Earth age and the reasons behind that response. When I use the term “Christian”, I am also generally referring to the other major monotheistic religions, such as Judaism and Islam. Since my own personal religion is Christian, my examples focus more on that religion, but the other two also have the same holy books that we call the Old Testament. The third part is designed to show how the scientific community responds to creationist arguments. Finally, the fourth part will look at learning theories and how these theories might be incorporated into science classes during the discussion or topics that might generate controversy.

#### 4.4.5 Old-Earth Education as Presented in an Entry Level Geology Text

I chose the geology textbook that is used at Northglenn High School as my example text (Plummer, McGeary, and Carlson 1999). The topic of Earth age is presented by looking at a history of changing viewpoints. It also gives an overview of radiometric dating techniques and concludes with a presentation of the major sections of the geologic time scale.

#### 4.4.6 Historical Views of Earth Age

In 1625 Archbishop James Ussher determined, using Biblical genealogies, an Earth origin date of 4004 B.C, making the Earth about 6,000 years old. This date was generally accepted in western civilization. The Hindus at that time dated the Earth around 2 billion



years. In the 1800's, uniformitarianism led to a belief in a multi-million year age for the Earth. Then, in 1866, Lord Kelvin limited the Earth's age to 20-40 million years, based on natural heat loss since its formation. In 1896, radioactivity was discovered as a heat source within the Earth. This allowed Kelvin's limit on cooling time to be lifted because of some heat gain that would have occurred since Earth's formation. In 1905, the first radiometric age was determined to be around two billion years. Currently, the age of the Earth is estimated to be 4.5 to 4.6 billion years. There is no mention in this discussion of any current controversy about this date.

#### 4.4.7 Textbook Presentation

The age of the Earth is commonly regarded as about 4.5 to 4.6 billion years. The oldest dated rocks are found in northwestern Canada. They have been dated as approximately 4.03 billion years old. In isotopic dating, radioactive elements that are sealed inside newly crystallized minerals decay at a measurable rate. By comparing parent to daughter element ratios, we can determine the actual age of the crystal. I pointed out that there is no mention in this discussion of Earth age determination of any non-radiometric methods of determining minimum ages for geologic events. These techniques are discussed later in section 4.4.51.

#### 4.4.8 Radioactive Decay

In a sidebar of the text, there is a discussion of the mathematical method of radiometric age determination. Radioactive decay is the spontaneous nuclear disintegration of isotopes with unstable nuclei. When protons are lost, the parent element changes into another daughter element. Parent atoms decay at a proportionally constant rate, apparently unaffected by chemistry or pressure and temperature changes. The time for one-half of the parent to decay is the element's half-life.

#### 4.4.9 Calculating a Rock's Age

If  $N$  represents the number of parent atoms left in a sample, then  $N_0$  represents the number of parent atoms initially present in the sample.  $N$  is associated with  $N_0$  by the equation  $N=N_0e^{-\lambda t}$ , where  $e$  is the mathematical constant 2.718 and  $\lambda$  is the decay constant (atoms decayed divided by time). Time  $t$  is the time elapsed since initial formation of the rock crystal being dated. The decay constant is related to the half-life of an element by the equation

$$\lambda = \frac{\ln 2}{t_{hl}} = \frac{0.693}{t_{hl}}$$

where  $t_{hl}$  represents the half-life of the element. The time since the formation of the rock that contains the radioactive element is found by the equation

$$t = \frac{t_{hl}}{0.693} \ln \frac{N_0}{N}$$

#### 4.4.10 Graphical Representation

In addition to the mathematical description of radiometric age determination, the text used graphical representation similar to the following (Figure 4-1).

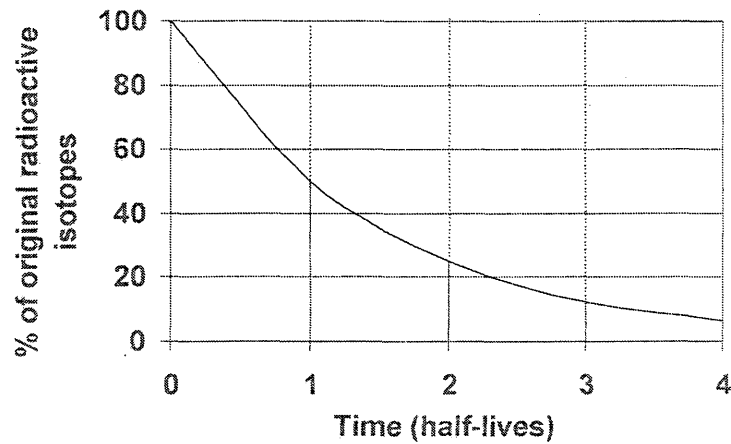


Figure 4-1 Graphical Representation of Radioactive Decay

In Figure 4-1, solid vertical lines represent the remaining parent element in a sample while the dotted vertical lines represent the daughter element found in the sample. By comparison, a candle burns at a linear rate (Figure 4-2).

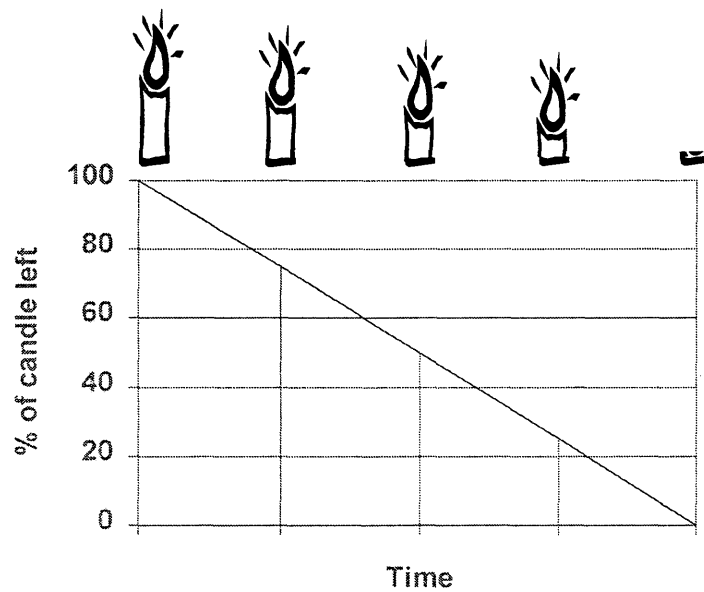


Figure 4-2 Linear Rate at Which a Candle Burns

#### 4.4.11 Modern Interpretation of Geologic Time

The subdivisions of geologic time had already been worked out through stratigraphic studies. The textbook presented a Geologic Time Scale (Figure 4-3) similar to this one from Microsoft Encarta (2002).

Eon	Era	Period	Epoch	Approx. time boundaries*	Life forms originating
Phanerozoic	Cenozoic	Quaternary	Holocene	10,000	
			Pleistocene	1,600,000	Human Beings
	Tertiary	Pliocene	Pliocene	5,000,000	
			Miocene	24,000,000	Grazing and Carnivorous
		Oligocene	Oligocene	38,000,000	
			Eocene	55,000,000	Mammals
		Paleocene	Paleocene	65,000,000	
	Mesozoic	Cretaceous	Cretaceous	138,000,000	Primates, Flowering Plants
			Jurassic	205,000,000	Birds
		Triassic	Triassic	240,000,000	Dinosaurs, Mammals
			Permian	290,000,000	
	Paleozoic	Carboniferous	Pennsylvanian	330,000,000	Reptiles
			Mississippian	360,000,000	Fern Forests
Devonian		Devonian	410,000,000	Amphibians, Insects	
		Silurian	435,000,000	Vascular Land Plants	
Ordovician	Ordovician	500,000,000	Fish, Chordates		
	Cambrian	570,000,000	Shellfish, Trilobites		
Proterozoic			900,000,000	Algae	
Archean				2,500,000,000	Eukaryotic Cells
				3,800,000,000	Prokaryotic Cells
				4,500,000,000+	Formation of the Earth

\* Beginning date for each period or epoch.

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Figure 4-3 Geologic Time Scale as Presented in Microsoft Encarta 2002

#### 4.4.12 Reasons for Christian Opposition

The second part of my presentation was focused generally on the Christian, and specifically on the young-Earth creationist, reaction to the determination of an old age for the Earth. I pointed out that the age issue has been a point of controversy off and on during the development of the study of geology and evolution, but it experienced a relatively recent resurgence in 1961 with the publication of the young-Earth book The Genesis Flood by Henry Morris and John Whitcomb (Ross 1994). One of the reasons that Earth age is of concern to some in the Christian community is that naturalistic theories of evolution require

long periods of time and tend to remove the activity of a Creator. The Morris and Whitcomb book is written like a technical scientific work and seemed to give the Christian community a scientific tool to combat the long period of time required by evolution.

#### 4.4.13 Relevant Biblical Texts – Inerrancy

Another reason that an old age for the Earth is a sticking point for some Christians stems from differing interpretations of the Bible and the doctrine of biblical inerrancy. The Bible claims to be directly inspired by God because it says, “all Scripture is God-breathed and is useful for teaching, rebuking, correcting and training in righteousness (2 Timothy 3:16 NIV). Elsewhere in the New Testament it says, “above all, you must understand that no prophecy of Scripture came about by the prophet's own interpretation. For prophecy never had its origin in the will of man, but men spoke from God as they were carried along by the Holy Spirit” (2 Peter 1:20-21 NIV). The Old Testament makes several claims of inerrancy through verses such as “the law of the Lord is perfect” (Psalm 19:7 NIV). There are also scriptures that warn against altering any of the text, such as, “I warn everyone who hears the words of the prophecy of this book: If anyone adds anything to them, God will add to him the plagues described in this book. And if anyone takes words away from this book of prophecy, God will take away from him his share in the tree of life and in the holy city, which are described in this book” (Revelation 22:18-19 NIV). It is texts such as these that make discussions of biblical interpretation contentious among Christians.

#### 4.4.14 Relevant Biblical Texts – Creation

Since this presentation is dealing with the age of the Earth, it is important to examine some of the biblical texts that address this issue in order to better understand the young-Earth creationist response to an old Earth. The first chapter of the first book of the Bible (Genesis) says, “In the beginning God created the heavens and the Earth. . . . and God said, ‘Let there be light,’ and there was light. . . . and there was evening, and there was morning-the first day. . . . and God said, ‘Let there be an expanse between the waters to separate water from water’ . . . . And there was evening, and there was morning-the second day. . . third day . . . fourth day . . . fifth day . . sixth day” (Genesis 1 NIV). It goes on to say “Thus the heavens and the Earth were completed in all their vast array. By the seventh day God had finished the work he had been doing; so on the seventh day he rested from all his work (Genesis 2:1-2 NIV). The use of the word day here seems, to some, to mean that all of the Earth and its life forms were created in six 24-hour days. Combining this view with the record of genealogies lead some to conclude that the Earth can’t be more than a relatively few thousand years old. Finally, another verse, stated in the context of the ten commandments, says, “for in six days the Lord made the heavens and the Earth, the sea, and all that is in them, but he rested on the seventh day (Exodus 20:11 NIV). This seems to add additional scriptural support to a six-day complete creation.

#### 4.4.15 Fundamentalism

From 1909 to 1915, a group of Christians who were increasingly disturbed by society's eroding view of the inerrancy and authority of scripture published a set of booklets on basic Christian doctrine called The Fundamentals: A Testimony of the Truth (Ross 1994). These books articulated five basic Christian doctrines regarding the Trinity, Jesus Christ's Deity, His second coming, salvation, and scripture. In the 1925 Scopes "Monkey Trial," William Jennings Bryan, a noted fundamentalist, admitted the possibility of "long" days of creation. This led many fundamentalists to add a doctrinal statement incorporating "recent" creation of the Earth.

#### 4.4.16 Biblical Inerrancy Doctrinal Statement

An example of one of these statements comes from the Special Committee Report of the Reformed Church of the United States, adopted in 1999. It says,

Our insistence upon the doctrine of six-day creation is a direct, and necessary, extension of our doctrine of Scripture. . . . To defend six-day creation is to defend the proposition that the Bible means what it says, and that it's meaning is clear. If our Bibles mean whatever we want them to mean in Genesis 1, then why not at every other juncture where God's Word offends the sensibilities of man's reason. . . . Is six-day creation a stumbling block to would-be believers? If so, let them also stumble at the offense of the cross. Let them scoff at swimming axe heads, manna from heaven and, most unbelievable of all, the resurrection of the dead (RCUS 1999).

This demonstrates the willingness of some Christians to take a young-Earth stance no matter what the outcome.



#### 4.4.17 Young-Earth Arguments

Young-Earth Creationists tend to support their position in one of two ways. They watch for errors in methodologies and evidences for old Earth age. They also seek new evidences that they feel provide indications of a youthful Earth. Sections 4.4.18 – 4.4.22 are evidences that are proposed on the Scientific Evidence for Creation website. Similar to my choice for a geology text, I selected this website as a representative of what I consider to be typical young-Earth materials. It is not intended to represent all views of young-Earth creationists. During the presentation, I showed some of the images from that website, but I have refrained from including them here because of copyright issues.

#### 4.4.18 Radiocarbon Dating

The terms “radiocarbon” and “radiometric” are often treated as being entirely synonymous with each other in young-Earth materials. Sometimes the distinction is not made clear between them. This particular gives three examples of radiometric dates that don’t agree with standard interpretation of the specimens.

The first example discusses the dacite dome from Mount St. Helens that was formed in 1986. In 1997 five specimens were taken from this dome at five different locations and subjected to conventional Potassium-Argon dating. The results indicated ages of less than one half to almost three million years old, all from eleven-year-old rock. The second example indicates that an Illium bone from an Acrocanthosarus was

radiocarbon dated at 19,000 years old. Of course, this is much younger than the standard interpretation of a Mesozoic age for this species.

The third example I chose from this website shows a carbonized stick embedded in 110 million year old limestone that is radiocarbon dated at 12,900 years old. I have not included any references to the location of any of these specimens because they were not listed on the website.

#### 4.4.19 Fossilized Hammer

The same website showed a hammer with its wood handle being partially coalified with quartz and calcite crystalline inclusions. Tests performed at Battelle Laboratory document the hammer's unusual metallurgy, 96% iron, 2.6% chlorine and .74% sulfur (no carbon). Density test indicate casting of exceptional quality. A unique coating of FeO, which does not readily form under present atmospheric conditions, appears to inhibit rusting. The enclosing rock contains Lower Cretaceous fossils. It is a concretionary sandstone nodule from the nearby cliff which is made up of concretionary sandstone nodules.

#### 4.4.20 Rapid Petrification

This website also questioned standard age interpretation by trying to show evidence that processes that are supposed to take very lengthy amounts of time can actually take much shorter time to happen. The website showed a

rubber-soled boot with petrified cowboy (human) leg, bones and all [that] was found in a dry creek bed near the West Texas town of Iraan, about 1980 by Mr. Jerry Stone, an employee of Corvett oil company. Only the contents of the boot are fossilized, not the boot itself, demonstrating that some materials fossilize more readily than others. The bones of the partial leg and foot within the boot were revealed by an elaborate set of C.T. Scans performed at Harris Methodist Hospital in Bedford, Texas on July 24, 1997.

The site went on to mention that the manufacturer of the boot had been contacted to establish the actual age of the boot.

#### 4.4.21 Malachite Man

Another similar example to the previous one stated that

skeletons of ten perfectly modern humans have been excavated from fifty eight feet down in the Dakota Sandstone, over an area spanning about 50 by 100 feet. This formation is a member of the Lower Cretaceous, supposedly 140 million years old. It is known for its dinosaurs and is the same formation found at Dinosaur National Monument. The bones are partially replaced with malachite (a green mineral) and turquoise, thus appropriately named "Malachite Man".

The site never stated which outcrop of the Dakota Sandstone these bones were found in, only that it was the same formation as the one in Dinosaur N.M.

#### 4.4.22 Evidence for Human coexistence with Dinosaurs

One of the continuing arguments for a young-Earth is the coexistence of dinosaurs and humans. The Paluxy River in Glen Rose, Texas is frequently used as evidence for this coexistence. Concerning an apparent human footprint, the website says,

the Burdick Track is in Cretaceous limestone, found near Glen Rose, Texas (famous for its dinosaur tracks). Evolutionary theory claims that humans were separated from these dinosaurs by over 100 million years, so [evolutionists] just say, "It is carved." This assumption has been disproved by cross-sectioning. Carving would randomly cut across the internal rock structures. However, if those structures follow the contours of the impression, the carving theory would be falsified. Internal structures dramatically conform to the shape of both the heel impression and the great toe impression.

#### 4.4.23 Earth's Magnetic Field

Another common young-Earth argument concerns the Earth's magnetic field. Referencing a published study (McDonald and Gunst 1967), Thomas Barnes says that the Earth's magnetic field is decreasing at a rate of 5% per 100 years. Comparing this to measured field strengths of typical stars, (which would exceed the maximum for Earth), indicate that Earth's field could have been at a maximum no more than 10,000 years ago (Barnes 1989).

#### 4.4.24 Comets

Harold Slusher uses the argument that comets lose material as they approach the sun in their orbit. Since there are short period comets whose orbits require that they should have lost their material by now, their calculated maximum age is less than 10,000 years old.

#### 4.4.25 Helium in Earth's Atmosphere

Another popular young-Earth argument concerns the helium content of Earth's atmosphere. In reference to a paper by Larry Vardiman, the argument can be summarized as follows. Helium is built up in the atmosphere from radioactive isotopes, volcanic eruptions and nitrogen interactions with cosmic ray neutrons. The average rate of thermal escape of  $^4\text{He}$  is about  $6 \times 10^4$  atoms/cm<sup>2</sup>·sec. The present abundance of  $^4\text{He}$  in the atmosphere would accumulate in about two million years. The rate of thermal escape of  $^3\text{He}$  has been estimated to be about 4 atoms/cm<sup>2</sup>·sec, also much less than its estimated

influx. Using these estimated fluxes of helium, the present abundance of  $^4\text{He}$  would accumulate in 1.8 million years. Only 370 thousand years would be required to supply the atmosphere with its present content of  $^3\text{He}$ .

The helium must be escaping from the atmosphere in some way for the evolutionary model to be true. Otherwise, there would be a great deal more helium today (Vardiman 1989). This argument does not indicate an Earth age as young as the young-Earth creationist viewpoint would expect, but their reliance on the argument is for its indication of an atmosphere much younger than is commonly thought.

#### 4.4.26 Granite Crystal Halos

Dr. Robert V. Gentry claims to have radiometric evidence that the basement rock of the Earth was formed in a cool state, not in a molten condition. A cool initial state of the Earth gives support to a young age for the Earth. His research involves the study of pleochroic halos (colored spheres) produced by the radioactive decay of Polonium-218. He analyzed over one hundred thousand of these halos in granitic rocks which had been taken from considerable depths below land surface and in all parts of the world.

He had two conclusions. First, the Polonium 218 was primordial, or an original component of the granite. His second conclusion was that, because the halos can only be formed in the crystals of the granite, and the Polonium 218 half-life is only 3 minutes, the granite had to be cool and crystallize very quickly. The Polonium 218 would have been gone before molten granite could have cooled and it would take a very long time for a

molten Earth to cool. Therefore, our current model for the time necessary for the basement granitic rocks of the Earth to cool is erroneous (Gentry 1986).

#### 4.4.27 Colleges

I did a brief Internet search for colleges that offer science classes that have a young-Earth focus. The first one I found was Ozark Christian College. I selected it primarily because it was the first one I came across. I do not mean to imply that it is representative of all Christian schools and their science programs. This particular college is a Bible school that primarily trains people who will be serving in the ministry and working in Christian organizations. They offer a course called Creation and Science. This course is required for three of their Bible Education degrees. Usually this course is taken during a student's first year at OCC. The course description in the catalog says,

the Christian of today lives in a world where science dominates much of life. In such a world it is essential for the Christian to know how his faith is to be related to science. This is especially true in light of the fact that much of what is considered to be scientific is permeated with evolutionary thinking. The Christian must be able to distinguish true science from false. He must also be aware of the real challenge the theory of evolution presents to evangelizing today.

This description is vague regarding the course's stance on the age of the Earth, but I found a course syllabus at the same website that describes the class as giving the participants the tools to refute the old-Earth arguments (OCC 2002).

#### 4.4.28 Institute for Creation Research

The Institute for Creation Research is one of the leading organizations for the young-Earth creationist stance. They have a graduate school, accredited by the State of California, that offers Master's degrees in Biology, Geology and Physics. Two of their advanced geology courses are Advanced Sedimentary Geology and Geochronology. The course description of Advanced Sedimentary Geology says it is the "study of modern and ancient sedimentary processes; evaluation of uniformitarian and catastrophist models for origin of sedimentary rocks; analysis of sedimentary deposits by statistical methods; case studies of some of the classic deposits alleged to indicate great age within strata." The Geochronology course description says it is "a study of decay mechanisms of radioactive atoms, measurement methods for radiogenic atoms, and the application of radioactive isotopes to the problem of the chronology of Earth history. Special emphasis is given to radiocarbon, potassium-argon, lead-lead, and rubidium-strontium dating." Both of these courses are taught from the perspective of a young-Earth (ICR).

I mention these colleges because they are some of the ones that are producing the educators that teach that many of modern scientific conclusions are not trustworthy. These educators are influencing many of the people in our churches and private schools.

At this point, one of the participants in the class I was speaking to reminded me that I had said that my examples were associated with the Christian religion, but that Judaism and Islam also shared some of the same holy book texts. The preservice teacher asked if there were any materials advocating a young-Earth viewpoint that have been written from

the Judaic or Islamic perspective. I said that I am aware of a printed work written from the Judaic perspective and had found a website from the Islamic perspective, but that I had chosen to focus my research on the Christian perspective.

#### 4.4.29 Response of the Scientific Community

Many in the scientific community either ignore the age controversy, or are not even aware that it exists. There are many young-Earth creationist websites available on the Internet, and there are also many anti-creationist websites. Many prominent scientists and professional organizations have also chosen to speak out against the creationist viewpoints. This is the topic of the third part of the presentation.

#### 4.4.30 Anti-Creationist Page

Another general Internet search revealed several websites that are definitely antagonistic toward creationists. One such site, simply called “Anti-Creationist” has this as its opening statement: “As the summer of 1999 Kansas incident shows, the creationists have some sway in our society. They publish books and papers that convince people that evolution is not a reasonable explanation of life, but those works are deeply flawed. I am collecting here arguments that show their egregious errors.” The term “egregious” means “outstandingly bad; flagrant” (Webster’s Dictionary 1980). This seems typical of many of the websites and printed materials I’ve seen. They are openly hostile toward creationist thinking.



#### 4.4.31 Carl Sagan

Regarding the origin of the universe, one of the statements made by the late Carl Sagan in his book and television production Cosmos is

in many cultures it is customary to answer that God created the universe out of nothing. But this is mere temporizing. If we wish courageously to pursue the question, we must, of course ask next where God comes from? And if we decide this to be unanswerable, why not save a step and conclude that the universe has always existed (Sagan 1980)?

This represents an example of a prominent scientist voicing his opinion that there is no reason to allow for the possibility of a Creator.

#### 4.4.32 Claude Allègre

Claude Allègre is the Minister of Education for France and the author of one of the texts I used in a course at Colorado School of Mines. In this book, Allègre states, “Science and religion are two separate aspects of human activity. They should stay separate. Nothing is to be gained by mixing the issues” (Allègre 1994). Again, an influential scientist is taking a strong stand to keep science and religion separated.

#### 4.4.33 Stephen Jay Gould I

Stephen Jay Gould is one of the better-known scientists in America. He has a very strong interest in the science/theology debate. He says,

No . . . conflict should exist because each subject has a legitimate magisterium, or domain of teaching authority--and these magisteria do not overlap (the principle that I would like to designate as NOMA, or

"nonoverlapping magisteria"). The net of science covers the empirical universe: what is it made of (fact) and why does it work this way (theory). The net of religion extends over questions of moral meaning and value. These two magisteria do not overlap, nor do they encompass all inquiry (Gould 1997).

#### 4.4.34 Stephen Jay Gould II

Gould goes on to relate a story of one of his visits to Rome. He was approached by a group of Jesuit priests.

At lunch, the priests . . . wanted to know, [what] was going on in America with all this talk about "scientific creationism"? One asked me: "Is evolution really in some kind of trouble. And if so, what could such trouble be? I have always been taught that no doctrinal conflict exists between evolution and Catholic faith, and the evidence for evolution seems both entirely satisfactory and utterly overwhelming. Have I missed something?" . . .the priests all seemed reassured by my general answer: Evolution has encountered no intellectual trouble; no new arguments have been offered. Creationism is a homegrown phenomenon of American sociocultural history--a splinter movement (unfortunately rather more of a beam these days) of Protestant fundamentalists who believe that every word of the Bible must be literally true, whatever such a claim might mean (Gould 1997).

This particular statement is difficult because it casts a shadow on the truth of the Bible, and this is something that many Christians will take offense at.

#### 4.4.35 Stephen Jay Gould III

Gould continues his position in another text by saying, "People of good will wish to see science and religion at peace. . . . I do not see how science and religion could be unified, or even synthesized, under any common scheme of explanation or analysis; but I

also do not understand why the two enterprises should experience any conflict" (Gould 1999). This fails to acknowledge a primary learning theory that I am about to address.

#### 4.4.36 American Geophysical Union

The American Geophysical Union has published a position statement regarding the teaching of creationist ideas in the public schools. It says "AGU opposes all efforts to require or promote teaching creationism or any other religious tenets as science. AGU supports the National Science Education Standards, which incorporate well-established scientific theories including the origin of the universe, the age of Earth, and the evolution of life" (AGU, 2002)

#### 4.4.37 Geological Society of America

The Geological Society of America has published a similar statement.

The immensity of geologic time and the evolutionary origin of species are concepts that pervade modern geology and biology. These concepts must therefore be central themes of science courses in public schools; creationist ideas have no place in these courses because they are based on religion rather than science. Without knowledge of deep time and the evolution of life, students will not understand where they and their world have come from, and they will lack valuable insight for making decisions about the future of their species and its environment (GSA, 2002).

Statements such as the one's by GSA and AGU imply that teachers should not address creationist ideas at all in their classrooms.

#### 4.4.38 National Science Teachers Association

The National Science Teachers Association published a booklet called The Creation Controversy and the Science Classroom (Skehan and Nelson 2000). It has a position statement in the back that includes the following statements:

Policy makers and administrators should not mandate policies requiring the teaching of creation science or related concepts. Science teachers should not advocate any religious view about creation, nor advocate the converse. Publishers should not be required or volunteer to include disclaimers in textbooks concerning the nature and study of evolution.

The language here is slightly different than that of AGU and GSA. Instead of “opposing all efforts” like AGU or saying “creationist ideas have no place” like GSA, NSTA reminds science educators that they should not advocate a particular religious viewpoint in the public school science classroom.

#### 4.4.39 NSTA Guidelines

The NSTA booklet also suggests methods that teachers should use when dealing with ideas that spark creation/evolution types of debates. They suggest that educators should

Discuss the strength of support of the issues. Don’t only present conclusions – teach thinking and development as well. The education of science teachers who will likely face these topics should include something about the premises and procedures of modern biblical interpretation and the distinct roles of scientific knowledge and religious faith.

I will incorporate some of these ideas in the model I’ll be presenting shortly.

#### 4.4.40 American Scientific Affiliation Guidelines

Another group that is committed to maintaining integrity in science education and in modern scientific theory is the American Scientific Affiliation. This is a group of scientists who are Christians who hold to a view of the Bible as being trustworthy and divinely inspired, but who also feel that God's work is accurately measured and revealed through scientific investigation. They published a booklet somewhat similar to the NSTA one in 1986, with a reprint in 1993. In it, they propose that science educators should "present well-established data and conclusions forcefully. Distinguish clearly between evidence and inference. Discuss unsolved problems and open questions candidly" (ASA 1993).

#### 4.4.41 Learning Research

The final section of the presentation is focused on learning research that spans across the last four decades of the twentieth century. Topics will include a look at how people tend to assimilate new information and ways that students respond to new learning. Finally a model developed by one group of theorists will be presented along with my suggested modifications.

#### 4.4.42 How People Learn - 1999

There is a booklet published by National Academy Press called How People Learn: Bridging Research and Practice that begins by addressing how students' preconceptions affect their learning. It says, "students come to the classroom with preconceptions about

how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom” (Donovon, Bransford, and Pellegrino 1999). This is a basic concept that any educator needs to understand and acknowledge if they want to successfully engage their students in learning new material.

#### 4.4.43 Cognitive Dissonance -1957

A whole branch of learning theory was started in 1957 by L. Festinger. He wrote about cognitive consistency, which is the tendency for a person to exhibit beliefs and actions that are logically consistent with one another. When he/she experiences cognitive dissonance, the person unconsciously seeks to restore consistency by changing his or her behavior, beliefs, or perceptions (Festinger 1957).

#### 4.4.44 Typical Student Responses 1993 - 1997

Learning researchers Clark A. Chinn and William F. Brewer have done a set of studies on the ways students acquire knowledge and respond to anomalous data in science. When students have preconceptions about how the world works they will tend to respond in one of eight ways. They will either ignore the anomalous data, reject the data, question the validity of data, exclude the data from the domain of their theory, hold the data in abeyance with the expectation that it will be explained at a later time, reinterpret the data, accept the data and make peripheral changes in their theory, or accept the data and alter

their theory (Chinn and Brewer 1993 and 1998). These responses represent a progression of increased learning with regard to the new theory the educator is trying to present to the student.

#### 4.4.45 Models

Chinn and Brewer say that in order to effectively get students to examine new theories, we should first influence their prior learning. This means that we must gain an understanding of the students' conceptions, which involves not only checking for prior learning, but also gaining an understanding of the source of that learning. Next, we should introduce the alternative theory that we are attempting to teach to the students. Assuming that this new theory is in some way in contradiction to their currently held preconceptions, the educator should introduce anomalous data for examination in the context of the multiple theories that the student now has to look at. We can encourage deep processing of the information by having students defend their position and by helping them to see relevance and application for the new information.

I added some additional parameters to Chinn and Brewers' model. As we begin to influence the prior learning, we must be careful to avoid ridicule of the students' prior learning. Anytime someone feels their beliefs are being personally attacked, they will tend to withdraw from the learning and become either unresponsive or belligerent.

When checking for prior learning, the educator needs to learn enough about the various sides to argue their validity, whether he/she believes it or not. If we can understand

a concept well enough to argue in favor of it, we can begin to see the point of view of those who hold the concept and better understand what data would be considered anomalous for the concept.

Finally, as we seek to bring our students to a deeper understanding, we and they must openly acknowledge the limitations of science. There are simply some areas that are either beyond the scope of science or that science has not found sufficient explanations for. Ultimately, our goal, when teaching science concepts to others should not necessarily be to alter our students' theory but instead to get students to think critically about whatever theory they choose to hold. I have always held the philosophy in my teaching experience that what my students know and believe about science is not as important as why they believe it. I am not nearly as successful at teaching if my students believe everything I tell them without understanding how the information can be discovered and checked out for themselves. Finally, deal with controversial material only as your class warrants it. As you check for prior learning, don't push an issue and try to present anomalous data if no one holds a theory for which the data is anomalous.

#### 4.4.46 Ideas Specific to this Topic

To complete the model, I addressed how the topic of Earth age might be handled in a class. I encouraged the preservice teachers to discuss the eight previously mentioned learning responses to anomalous data with their students. Chinn and Brewer mentioned



case study examples from the history of science of scientists exhibiting each of the eight responses as new anomalies in current theory became evident.

#### 4.4.47 Continuum of Viewpoints

I also encouraged them to review Eugenie Scott's Continuum of Viewpoints with students in the context of a discussion of the current age controversy. I did not go into much detail of the definitions of the viewpoints other than to point out their existence.

#### 4.4.48 Timeline (1600 – 1700 A.D.)

A few years ago I did a presentation on a similar topic. In it, I outlined the way that a number of Earth Scientists have taken the opportunity to address the religious and scientific community about the compatibility of science and religion. For this time period, I mentioned that Galileo Galilei, Rene Descartes, Robert Boyle, Niels Steenson, Thomas Burnet and Isaac Newton all chose to address this compatibility in their writing. I chose to elaborate on Boyle and Burnet.

Robert Boyle said, "I, that had much rather have men not philosophers than not Christians, should be better content to see you ignore the mysteries of nature, than deny the author of it" (Hall 1966). Thomas Burnet said, "We are not to suppose that any truth concerning the Natural World can be an Enemy to Religion; for Truth cannot be an Enemy to Truth, God is not divided against himself" (Burnet 1684).

#### 4.4.49 Timeline (1800 – 1900 A.D.)

I also mentioned William Buckland, William Conybeare, Benjamin Silliman, Hugh Miller, John Pye Smith, Edward Hitchcock, Joseph LeConte, Arnold Guyot, and J. William Dawson. I focused specifically on a comment by LeConte, who was an associate of John Muir. He said, “I do believe that we cannot do a man a greater and a more irreparable injury than to unsettle in any way his religious faith. I believe, therefore, it is the duty of every scientific man, who is also a lover of his fellow-men, to attempt to restore again the faith which he himself, perhaps, has helped to destroy” (LeConte 1884). My point to the preservice teachers is that they can use this type of historical approach to show that controversy is not new to the sciences and people have found ways to achieve cognitive consistency without compromising their role as a scientist or as a believer in God.

#### 4.4.50 Biblical Interpretation

I reminded the preservice teachers of the NSTA statement that a science teacher would be wise to become familiar with biblical texts and interpretation rules if they are going to deal with these topics. If we encounter individuals that struggle with understanding how science fits with scripture, we can direct them to resources that will help them see how others can deal with the subject while still maintaining their scientific and religious integrity. For example, there are at least 3 major ways to interpret the Genesis creation account and still allow it to maintain authority and inerrancy. One can interpret the days of creation as literal 24-hour days. However, it can be argued, equally

effectively, in my opinion, that the days represent long periods of time. There are also those who interpret the days as figurative, poetic language. People who hold any of these three viewpoints will argue that they are interpreting the Bible literally.

#### 4.4.51 Outside Resources

I concluded my presentation by pointing out that when we deal with controversial topics, we may do well to refer students with questions to others with more expertise in the areas. For example, the publisher of the geology text that I chose to use in my presentation (McGraw-Hill) has an online study guide that links viewers to the American Scientific Affiliation if they have questions dealing with faith and science issues. Other organizations that I mentioned to the preservice teachers are the Association of Christian Geologists and Reasons to Believe. I also mentioned that I am a current member of both ASA and ACG.

At this point, I would have liked to spend a little time discussing some of the non-radiometric indicators of an Earth age longer than a few thousand years, but I didn't feel that we had sufficient time. Had I to do it over, I would have given some examples such as those described on the God and Science website (2002). Some of these examples are shown in Table 4-1.

Table 4-1 Non-radiometric Indicators of Age

Age Indicator	Minimum time required
Length of days of coral fossils	370 million
Accumulation of sodium in the oceans	260 million
RATE OF CONTINENTAL DRIFT TO FORM THE ATLANTIC OCEAN	200 million
Reversals of the earth's magnetic pole recorded in the Atlantic Ocean sea bottom	80 million
Erosion of the Grand Canyon	25 million
Carbonate deposits: The Great Bahama Bank, off the coast of Florida, has multiple layers over 14,500 feet thick	12.4 million
Ooid (small spheroidal bodies) formation time	>7 million
The Green River annual layers (alternating Summer calcium carbonate and Winter organic layers)	4 million
Evaporites: The Delaware Basin formation is 1,300 feet thick, consisting of 200,000 layers, requiring at least 600,000 years to form. The Mediterranean Sea floor is underlain by about 7,000 feet of evaporites, requiring millions of years to form	>3 million
Length of time that surface rocks have been exposed to cosmic rays (extinct volcanoes in Nevada)	830,000
Huge stalactites, stalagmites, and columns in the Carlsbad Caverns in New Mexico	500,000
Vostok ice core in Antarctica	420,000
Thickness of coral reefs	130,000
Organic banks (The Capitan Reef of West Texas is 2,000 feet thick in places)	100,000

It would have been interesting to present this information to the group, because many of these examples provide anomalies that young-earth creationists have had to reinterpret in a variety of ways to fit with their interpretation of Earth age.

#### 4.5 Post Presentation Discussion

Most of the questions that followed the presentation were clarification questions. The preservice teachers asked me if I believed in evolution. I told them that my views concerning evolution have shifted over the years. I said that I acknowledge the fossil record depicts changing life forms over geologic time. I believe that there seems to be some evidence to support some level of evolution, but I don't believe that evolution alone can explain all the diversity of life that is present on Earth. I qualified my answer by saying that I have not had a chance to study the theory and evidences for evolution in great detail, so I don't feel like I can make a very strong statement either for or against it at this point, except that I believe that God had an active role throughout the geologic history of the Earth. I said that, in reference to the creation/evolution viewpoint continuum, I place myself with the progressive creation viewpoint. One of the students then asked me if I would answer the question the same way if a student in a public school had asked. I said that I have to be careful how I answer these kind of questions in a public school setting, but that if a student asks me directly what I believe, I would answer truthfully in as compact a statement as the question warrants. I would go so far as to acknowledge my alignment with the progressive creation stance. Next they wanted to know how I would answer the question at church. I explained that I would take more time with the theological and biblical interpretation aspects of my explanation, but the answer would be essentially the same.

One student referred to the acquaintances I mentioned who maintained the young-Earth stance while being students at CSM. I had said that even college professors need to understand the viewpoints of their students so they know whether they are really believing the material they learn. This preservice teacher said, “What does it matter what someone believes at that level (college)? The only important thing is that they learn the course material. A professor doesn’t need to be concerned about whether the student believes it.” I agreed that this is a valid point, but I would argue that a good teacher goes beyond teaching his or her students and seeks to understand how learning the new material is affecting their lives. I reiterated that my goal is not to change a student’s belief, but I do want to know how the student thinks and responds to what he/she is learning.

#### 4.6 Post-Discussion Survey

I was interested in finding out how this discussion might have influenced the thinking of these preservice teachers, so I brought a follow-up survey to the class. The survey had many of the same Likert-scale questions. I left the questions on it that I anticipated might register some change in attitude or feelings as a result of the presentation. I added some additional open-ended questions to find out what parts of the presentation had the most impact on the preservice teachers and also to find out what information they feel should have been included. The follow-up survey can be found in Appendix C.

## CHAPTER 5

### DATA SUMMARY, ANALYSIS AND CONCLUSIONS

#### 5.1 Methods of Analysis

The demographic and quantitative data that I collected in the pre- and post-lesson surveys was entered into the Statistical Package for the Social Sciences (SPSS) software program for PCs. Using this software, I was able to generate information about apparent changes in perception that occurred from the pre-lesson survey to the post-lesson survey. I also took some of my established variables and ran cross correlations on them. I chose to run both Pearson and Spearman correlations on the variables to obtain a comparison of significances.

#### 5.2 Participant Demographic Information

As mentioned in section 4.4, all participants in this study were enrolled in a Secondary Science Methods Course at the University of Colorado at Denver. There were twelve females and three males present at the time of the presentation. Two of the males were in the 31-40 year age range. One male did not identify his age. Five females were in the 21-30 year age range, three females were age 31-40, and two were 41-50. Two females declined to identify their ages. One female indicated that she had received two years of

elementary school education in a private school. The rest of her pre-college education, and the pre-college education of the rest of the group was in public schools.

All of the preservice teachers have Bachelor's degrees. The subject areas represented by the degrees are Biology (3), Material Science Engineering, Geophysical Engineering, Spanish, Medical Technology, Economics, Earth Science, Chemical Engineering, Physics, Fisheries, Soil and Crop Sciences and an unspecified science degree. One female has completed a Master's Degree in Materials Sciences.

### 5.3 Summary of the Survey Responses

Table 5-1 lists the 32 Likert scale questions that were on the two surveys. I had asked respondents to identify their surveys with a unique four-digit number so the responses to the two surveys could be matched. The responses to the questions are totaled in a four-column format. The first two columns represent responses to the pre-lesson survey. There were thirteen individuals that returned the pre-lesson survey, but one of the individuals only completed the first of the three pages. The last two columns represent responses to the post-lesson survey. There were fourteen individuals that returned this survey, but two of them could not be matched with the pre-lesson survey.



Table 5-1 Survey Question Responses

Pre-lesson survey (whole) n=13	Pre-lesson survey (part correlated) n=12	Post-lesson survey (whole) n=14	Post-lesson survey (part correlated) n=12
<b>5. I have encountered individuals who have preconceived notions that affect how they learn about science.</b>			
76.9 % agree 23.1 % disagree	75.0 % agree 25.0 % disagree	Question not present on post-survey	
<b>6. I am comfortable teaching controversial issues.</b>			
61.5 % agree 38.5 % disagree	58.3 % agree 41.7 % disagree	78.6 % agree 21.4 % disagree	75.0 % agree 25.0 % disagree
<b>7. I understand the arguments proposed for a young (less than 50,000 years old) Earth.</b>			
30.8 % agree 69.2 % disagree	33.3 % agree 66.7 % disagree	57.1 % agree 42.9 % disagree	58.3 % agree 41.7 % disagree
<b>8. I consider myself a religious person.</b>			
	50.0 % agree 50.0 % disagree	Question not present on post-survey	
<b>9. My pre-university education was primarily through the American Public School System.</b>			
	91.7 % agree 8.3 % disagree	Question not present on post-survey	
<b>10. I currently feel prepared to handle the topic of Earth age and origin in a classroom of diverse backgrounds and beliefs?</b>			
	83.3 % agree 16.7 % disagree	78.6 % agree 21.4 % disagree	75.0 % agree 25.0 % disagree
<b>11. I feel that multiple viewpoints about the origin of life should be discussed in the public school classrooms.</b>			
	83.3 % agree 16.7 % disagree	57.1 % agree 42.9 % disagree	50.0 % agree 50.0 % disagree
<b>12. I have encountered individuals who disagree with mainstream scientific theory based on their prior knowledge.</b>			
	83.3 % agree 83.3 % disagree	Question not present on post-survey	
<b>13. I am comfortable teaching multiple views on the age of the Earth.</b>			
	58.3 % agree 41.7 % disagree	42.9 % agree 57.1 % disagree	41.7 % agree 58.3 % disagree
<b>14. I feel that I am knowledgeable about the various theories of the evolution of life.</b>			

Pre-lesson survey (whole) n=13	Pre-lesson survey (part correlated) n=12	Post-lesson survey (whole) n=14	Post-lesson survey (part correlated) n=12
	66.7 % agree 33.3 % disagree	Question not present on post-survey	
<b>15. I consider myself familiar with some religious creation texts</b>			
	58.3 % agree 41.7 % disagree	64.3 % agree 35.7 % disagree	66.7 % agree 33.3 % disagree
<b>16. My pre-university education included some parochial or religious training.</b>			
	25.0 % agree 75.0 % disagree	Question not present on post-survey	
<b>17. I believe that there is ample evidence to indicate the Earth is approximately 4.5 billion years old.</b>			
	91.7 % agree 8.3 % disagree	64.3 % agree 35.7 % disagree	91.7 % agree 8.3 % disagree
<b>18. I feel that multiple viewpoints about the age of the Earth should be discussed in the public school classrooms.</b>			
	83.3 % agree 16.7 % disagree	64.3 % agree 35.7 % disagree	58.3 % agree 41.7 % disagree
<b>19. I believe it is important to understand my students' prior knowledge before teaching a concept.</b>			
	100.0 % agree 0 % disagree	100.0 % agree 0 % disagree	100.0 % agree 0 % disagree
<b>20. I would avoid the issue of Earth origin because of the religious overtones.</b>			
	33.3 % agree 66.7 % disagree	7.1 % agree 92.9 % disagree	8.3 % agree 91.7 % disagree
<b>21. I feel that I am knowledgeable about the various theories of creationism.</b>			
	50.0 % agree 50.0 % disagree	35.7 % agree 64.3 % disagree	33.3 % agree 66.7 % disagree
<b>22. I believe that modern scientific theory is compatible with the religion.</b>			
	50.0 % agree 50.0 % disagree	71.4 % agree 28.6 % disagree	66.7 % agree 33.3 % disagree
<b>23. My pre-university education included either home-schooling or private school.</b>			
	16.7 % agree 83.3 % disagree	Question not present on post-survey	
<b>24. I feel that there is no way to know for certain how old the Earth is.</b>			
	33.3 % agree 66.7 % disagree	35.7 % agree 64.3 % disagree	41.7 % agree 58.3 % disagree
<b>25. I feel that there is no place for a discussion of the ideas of creationism in a public school science classroom.</b>			

Pre-lesson survey (whole) n=13	Pre-lesson survey (part correlated) n=12	Post-lesson survey (whole) n=14	Post-lesson survey (part correlated) n=12
	33.3 % agree 66.7 % disagree	21.4 % agree 78.6 % disagree	25.0 % agree 75.0 % disagree
<b>26. I believe it is important to know the source of my students' prior knowledge.</b>			
	91.7 % agree 8.3 % disagree	92.9 % agree 7.1 % disagree	91.7 % agree 8.3 % disagree
<b>27. I would avoid the issue of Earth origins because of community concerns.</b>			
	16.7 % agree 83.3 % disagree	7.1 % agree 91.9 % disagree	0 % agree 100 % disagree
<b>28. I am aware of controversy surrounding the scientific methodology dating the age of the Earth.</b>			
	41.7 % agree 58.3 % disagree	85.7 % agree 14.3 % disagree	83.3 % agree 16.7 % disagree
<b>29. I understand the religious based concerns about evolution and age of the Earth.</b>			
	66.7 % agree 33.3 % disagree	92.9 % agree 7.1 % disagree	91.7 % agree 8.3 % disagree
<b>30. My personal knowledge of scientific issues has significantly increased since completion of my undergraduate degree.</b>			
	66.7 % agree 33.3 % disagree	Question not present on post-survey	
<b>31. I feel knowledgeable enough to explain the principles of radiometric dating techniques.</b>			
	75.0 % agree 25.0 % disagree	71.4 % agree 28.6 % disagree	75.0 % agree 25.0 % disagree
<b>32. Creationist ideas have no place in public school science classes because they are based on religion rather than science.</b>			
	16.7 % agree 83.3 % disagree	57.1 % agree 42.9 % disagree	58.3 % agree 41.7 % disagree
<b>33. The Bible (specifically referring to the Old Testament, or Torah) is the inspired word of God and is completely factual.</b>			
	8.3 % agree 91.7 % disagree		
<b>34. I feel knowledgeable enough to explain non-radiometric techniques for measuring relative ages of Earth materials.</b>			
	16.7 % agree 83.3 % disagree	Question not present on post-survey	
<b>35. I oppose all efforts to require or promote the teaching of creationism in public schools.</b>			

Pre-lesson survey (whole) n=13	Pre-lesson survey (part correlated) n=12	Post-lesson survey (whole) n=14	Post-lesson survey (part correlated) n=12
	50.0 % agree 50.0 % disagree	57.1 % agree 42.9 % disagree	66.7 % agree 33.3 % disagree
<b>36. Science teachers should not advocate any religious view about creation, nor advocate the converse: that there is no possibility of supernatural influence in bringing about the universe as we know it.</b>			
	58.3 % agree 41.7 % disagree	64.3 % agree 35.7 % disagree	66.7 % agree 33.3 % disagree

Since only twelve individuals returned surveys that could be matched with each other, the following observations are based on the second and fourth columns of Table 5-1. It appears that the lesson presentation or the follow-up discussion may have influenced the respondents to:

- Begin to feel more comfortable teaching controversial issues (Question 6).
- Understand the young-Earth arguments better (Question 7).
- Feel less prepared to handle the topic of Earth age in a classroom of diverse beliefs (Question 10).
- Feel less like discussing multiple viewpoints about the origin of life in their classroom (Question 11).
- Feel less comfortable teaching multiple views on the age of the Earth (Question 13).
- Be more familiar with religious creation texts (Question 15).
- Maintain their belief that there is ample evidence to prove the Earth is old (Question 17).

- Feel less like discussing multiple viewpoints about the age of the Earth in their classroom (Question 18).
- Continue to be certain that they need to understand students' prior knowledge (Question 19).
- Be more certain that they would not avoid the age issue due to religious overtones (Question 20).
- Feel less knowledgeable about the theories of creationism (Question 21).
- Feel somewhat more certain that modern scientific theory is compatible with religion (Question 22).
- Feel slightly less certain that we can know for certain how old the Earth is (Question 24).
- Feel more like there is a place for discussing creationist ideas in a science classroom (Question 25).
- Still feel almost certain that it is important to know the source of a student's prior knowledge (Question 26).
- Feel more certain that they would not avoid the issue of Earth origins because of community concerns (Question 27).
- Be more aware of controversy surrounding the scientific determination of Earth age (Question 28).
- Understand religious based concerns about evolution and the age of the Earth better (Question 29).

- Feel just as knowledgeable about radiometric dating techniques (Question 31).
- Feel more certain that creationist ideas have no place in science classes because they are religious based (Question 32).
- Be slightly more opposed to all efforts to require or promote the teaching of creationism in schools (Question 35).
- Be more certain that science teachers should not advocate religious views about creation or the converse (Question 36).

#### 5.4 Responses to Qualitative Survey Questions

Both surveys had several qualitative questions following the Likert scale questions. Tables 5-2 through 5-6 show the responses to these questions. Respondents one through twelve are the preservice teachers who returned both surveys. Respondents thirteen and fourteen are the two who did not turn in the pre-survey. The fifteenth person in attendance at the class did not complete enough of the pre-survey to answer any of the qualitative questions. I have left the qualitative responses in these tables in the same wording and format as originally written.

Table 5-2 Religious Affiliations of Respondents

<b>Please identify any religious affiliation that you have. If none, write "NONE".</b>
Respondent 1. Catholic
Respondent 2. Christian
Respondent 3. None
Respondent 4. Catholic (kind of)
Respondent 5. None
Respondent 6. None
Respondent 7. None
Respondent 8. Lutheran
Respondent 9. Raised Catholic BUT – Now recognize commonality of all religions. It is these commonalities I believe in, i.e. Religion
Respondent 10. Catholic
Respondent 11. Episcopal
Respondent 12. Catholic

Table 5-3 Pre-lesson Survey Descriptions of Knowledge of Creationism

<b>Please briefly describe, in your own words, the theory(ies) of creationism as it relates to the age of the Earth and the origin of life. Use the back, if necessary.</b>
Respondent 1 - I am not familiar with Islamic or Eastern philosophies in terms of the age of the Earth, etc., but as far as Christian religion is concerned I know that people believe that God was the creator of the Earth and all life. Some western religions believe in Adam and Eve (origin) or other interpretations.
Respondent 2 - God creates - Earth, animals (all species), plants, etc. Change occurs over time – Microevolution
Respondent 3 - A supreme being created everything from a void and created all plants/animals for benefit of man who was created in this god's image. (Christian) Or all of life is a dream and we are dream makers (Toltec).
Respondent 4 - Well there is one where the Earth was created by god in 7 days, and then a Bishop calculated the age of Earth to be 6,000 years
Respondent 5 - Briefly, that if you count the ages of the various people mentioned in the bible, and add them up, you would come up with the age of the Earth (Bishop Ussher).
Respondent 6 - God made the Earth in seven days. He also made Adam and Eve and from

<b>Please briefly describe, in your own words, the theory(ies) of creationism as it relates to the age of the Earth and the origin of life. Use the back, if necessary.</b>
there time began.
Respondent 7 - I don't have a grasp of creationism as a science or scientific theory. It seems to me that creationism came about and exists only as a means of challenging the theory of evolution. The basis for the idea of creationism as it relates to age of the Earth and origin of life are founded in the Bible. However, any "science" done in the name of creationism seems to be an effort to debunk the theories of evolution rather than to support notions of when and how God created Earth and life on Earth with scientific data. The way I understand the creation theory is that the world and all living things were created in a one-time event by an intelligent creator (God) and such events are not occurring now and will never occur again. The Bible and Genesis is taken as the literal history of the Earth and of life on Earth, which were all created by the creator in 6 days.
Respondent 8 - The Earth is 4.5 billion years old. Formed from interstellar dust/debris. Life evolved from simple organisms over time, via the presence of water, oxygen, carbon compounds, sunlight/energy. I think its possible that a god-like force aided in the creation of the universe and life.
Respondent 9 - god created the Universe, Earth and Man in 7 days.
Respondent 10 - God created the Earth and the Universe, man and all life on Earth. Uncertain about the age of the Earth as it relates to creationism.
Respondent 11 - Based upon Biblical record the age of the Earth is only tens of thousands of years old.
Respondent 12 - 7 days of creation. Each day certain events happened to conclude with the creation of Earth and all its beings.

Table 5-4 Pre-lesson Survey Descriptions of Knowledge of Evolutionism

<b>Please briefly describe, in your own words, the theory(ies) of evolutionism as it relates to the age of the Earth and the origin of life. Use the back, if necessary.</b>
Respondent 1 - Geological – the Earth's crust reveals organisms that are different from those living today and that existed millions of years ago. Biological - Darwin's theory of natural selection discusses the process for living things (i.e. variations (favorable / unfavorable), survival and reproduction). Primordial soup theory - Miller/Urey experiment that explains the origin of life (organic elements)
Respondent 2 - Microevolution: species change over time/survival of the fittest. Time can be gauged by layers
Respondent 3 - Universe formed from a "singularity". All forces combined at 10-42



<b>Please briefly describe, in your own words, the theory(ies) of evolutionism as it relates to the age of the Earth and the origin of life. Use the back, if necessary.</b>
seconds after big bang. Stars form and die, solar systems form and die. Life started as simple cells, maybe just replicating chemicals. Over time complexity increased (this is against entropy, but sunlight adds energy to system). Natural selection and mutation etc. lead to "survival of fittest".
Respondent 4 – The theory of evolution proposes that creatures today evolved from past creatures. Mutations that randomly occur are passed on if they cause the species to live long enough to procreate. This is Darwin's natural selection. Darwin believes that these mutations occur slowly where Gould believes they occur in spurts, which accounts for lack of links in geologic record.
Respondent 5 – The Earth may be dated / organisms may show evolution through relative dating (microevolution) as well as evolutionary trends in microevolution as describe in "The Beak of the Finch". Otherwise, the theory states that all life descends from a single life form that has evolved and changed over time to form many life types. Strongest surviving/weakest [...] extinct, etc.
Respondent 6 - I'm not sure which theory whether its big bang or some other formed the Earth and universe. Because of all the elements and water life formed and evolved over millions of years.
Respondent 8 – Life on Earth evolved over the last 4.5 billion years via chemical reactions with water, oxygen, carbon compounds, sunlight/energy. Life evolved from simple organisms over time. I think a god-like force aided in this creation and evolution of life.
Respondent 9 – We use fossils, isotope and radioactive dating methods. Plate tectonics also give evidence of Earth "behavior" and therefore age.
Respondent 10 - Evolution implies that all life evolved from another or previous life form. Uncertain again how it relates to the age of the Earth.
Respondent 12 - There was a primordial soup that developed which allowed for C,N,O,S,P. The elements required for nucleic acids were present. Earth was created through several processes. Life on Earth evolved from aquatic origins to terrestrial. Life evolved from single-celled organisms to complex multiple celled organisms. Animals evolved from simple creatures to more intelligent creatures. Animals learned to use tools. Animals evolved usable body parts (adiposable thumb).

Table 5-5 Post-lesson Indications of New Learnings

<b>Was there any information presented that you feel you hadn't been aware of before?</b>
<b>Science Approach to Age of the Earth –</b>
Respondent 3 - non-radiometric techniques

<b>Was there any information presented that you feel you hadn't been aware of before?</b>
Respondent 8 - I knew about this. Do not know a lot about non-isotope methods (stratigraphy?).
<b>Young-Earth Creationist Responses –</b>
Respondent 1 - I had no idea that people even had this view, so the examples were very helpful.
Respondent 3 - fast fossil like "facts"
Respondent 4 - Yes, I had no idea how they backed up their beliefs and really didn't understand that it is a major issue
Respondent 6 - I was interested in learning more about these. They seem very in-depth and plausible without further analysis.
Respondent 8 - Did not know much about this. Beyond fundamentalist issues, did not know much about arguments debunking science, 4.5 billion year old Earth.
Respondent 9 - Yes - some of the details. The "scientific" research surprised me.
Respondent 11 - I was not aware of the array of examples/data currently being used to support this viewpoint.
Respondent 12 - Never knew fossilized hammer, rapid petrification, Helium in Earth's atmosphere.
Respondent 13 - I had not heard of young-Earth creationists and would like to see more evidence that backs up their claims.
Respondent 14 - Yes - I would like to know more about this position. I could not argue intelligently against it or for it.
<b>Response of the Scientific Community –</b>
Respondent 1 - It was great to see the variety of the responses (i.e. people, organizations).
Respondent 2 - I find it interesting that the issue often goes back to sci vs. religion rather than the original issue - people in dissidence would rather separate the two than find equilibrium - yet learning occurs by finding that balance
Respondent 8 - I know about the 4.5 billion science theory, did not know about scientists philosophical positions on all of it.
Respondent 11 - I was not aware of the internet sites rebuking young-Earth stance.
Respondent 12 - Not surprising
<b>Pedagogical Considerations –</b>
Respondent 1 – Cognitive dissonance
Respondent 2 - The breakdown of the spectrum of creationists
Respondent 3 - Know source of prior knowledge
Respondent 4 - Before this I would have avoided the topic altogether. I feel now that I at least understand where young Earth's are coming from even if I don't understand their evidence.
Respondent 6 - not aware of the extent of the "data" and "research" that had been accumulated

<b>Was there any information presented that you feel you hadn't been aware of before?</b>
Respondent 7 - I was clueless going in on how to present this material in a respectful, complete and scientific manner.
Respondent 8 - Had not thought about how to handle student situations, learned a lot from this session.
Respondent 9 - yes - It was also great to hear a model for response
Respondent 12 - This provided more clarification
Respondent 13 - The continuum was a great way to look at how students feel with new information
Respondent 14 - Yes - I will address student concerns according to the model presented

Table 5-6 Post-lesson Indications of Omitted Information

<b>Is there any information that you feel should have been presented that wasn't?</b>
<b>Science Approach to Age of the Earth -</b>
Respondent 4 - Depending on audience, more detail could have been addressed but I don't think this is the point of the presentation.
Respondent 8 - What are other non-isotopic dating measuring methods?
Respondent 9 - ways that the 2 ideas can coincide
Respondent 12 - error of tolerance for dating
<b>Young-Earth Creationist Responses -</b>
Respondent 4 - I would have liked to know what is behind their beliefs, i.e. what in Bible causes strife.
Respondent 7 - I would have liked to become more familiar with different institutes conducting research.
Respondent 8 - Maybe some of their main web pages - where does the Republican party fall in with this?
Respondent 12 - other religions than Christianity
Respondent 13 - More concrete evidence to support their theories.
Respondent 14 - No - Just raising the issue was enough for this period of time. In a longer class I'd like more info.
<b>Response of the Scientific Community -</b>
Respondent 8 - Who are the leading thinkers/scientists today? What is their position?
Respondent 12 - it would be interesting to hear politicians point of view
<b>Pedagogical Considerations -</b>
Respondent 8 - How to handle irate parents.

<b>Is there any information that you feel should have been presented that wasn't?</b>
---------------------------------------------------------------------------------------

Respondent 12 - argument of Bible not being factual
-----------------------------------------------------

### 5.5 Implications from Correlations

So far I have only listed the responses to the survey without trying to draw any conclusions from the data. I chose to compile one last set of data observations before defining any conclusions. As stated before, I ran Pearson and Spearman correlations between each of the questions. Appendix D shows the results of these correlations for all thirty-two Likert scale questions. The following subsections show the results of the significant correlations. They are described in order beginning with the most statistically significant correlations. As stated in Appendix D, all correlations discussed here are significant to at least the 0.05 level. The axes are labeled with the values of the responses on the Likert scale, with 1 representing “definitely disagree” and 4 representing “definitely agree.”

### 5.5.1 Questions 10 and 7

The most statistically significant positive correlation was the relationship between questions 10 and 7 (Fig. 5-1). According to this scatterplot, as the preservice teachers gained a more complete understanding of the arguments for a young-Earth, their feelings of adequacy to deal with the issue of Earth age and origin among diverse beliefs increased.

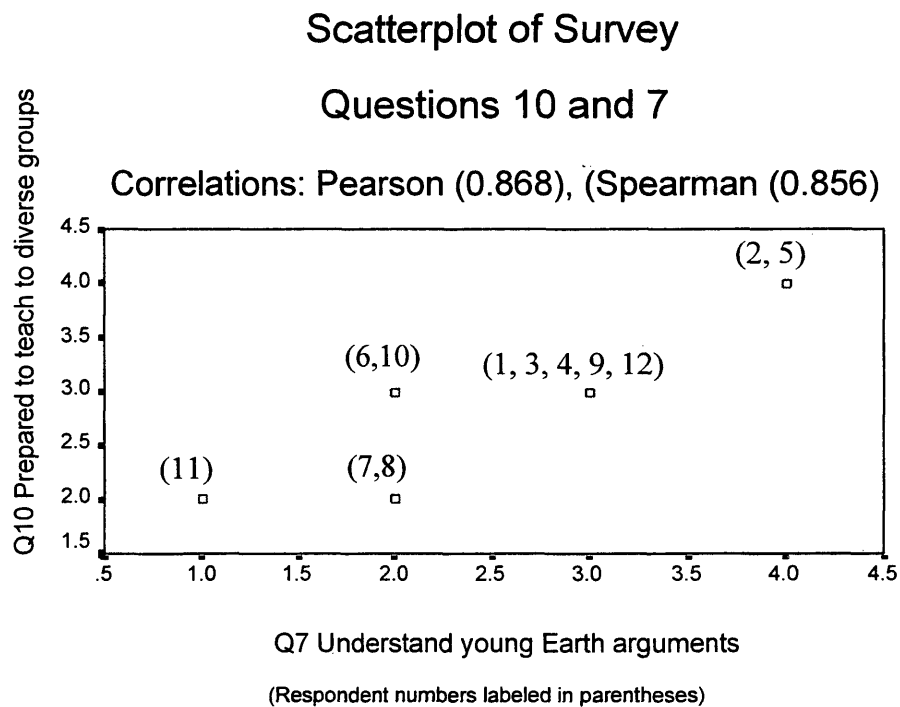


Figure 5-1 Correlation of Questions 10 and 7

As respondent number four stated, “Before this I would have avoided the topic altogether. I feel now that I at least understand where young Earth’s are coming from even

if I don't understand their evidence.” I think this relationship would be worth exploring in future study.

### 5.5.2 Questions 21 and 29

The second most significant positive correlation is depicted in Fig. 5-2. As the preservice teachers gained more knowledge of creationist theories, their understanding of the religious-based concerns about evolution and Earth age increased. I'm not sure that

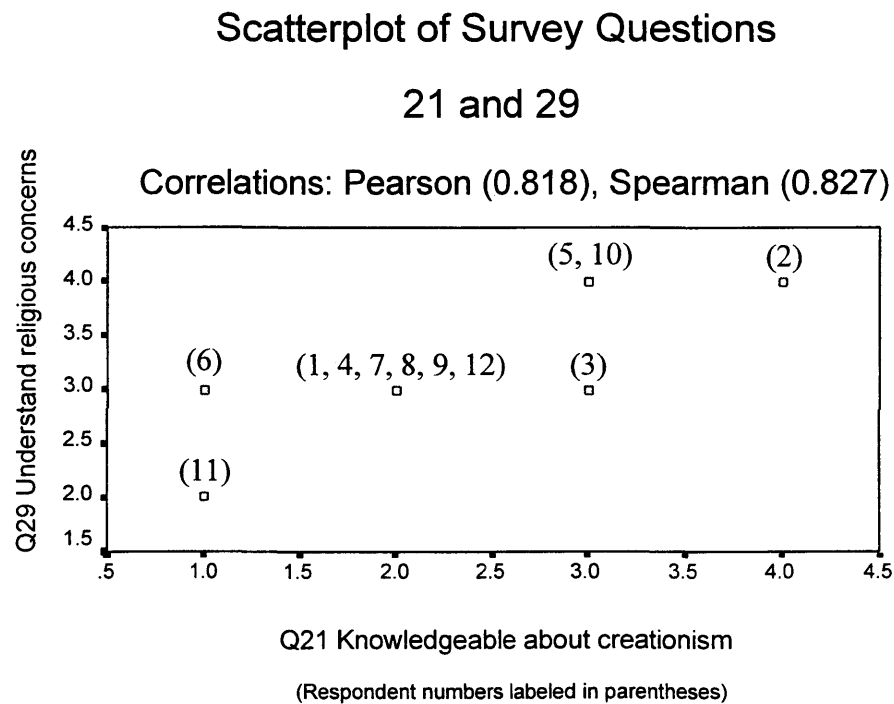


Figure 5-2 Correlation of Questions 29 and 21

either of these variables is dependent on the other. This particular relationship may be directly influenced by some of the other variables included in the study. For example, the

knowledge of creationist theories is likely accompanied by knowledge of how the young-Earth creationists seek to disprove an old age of the Earth. Any arguments that are directly tied to a particular interpretation of the biblical text is likely to lead to further understanding of the religious-based concerns attached to those arguments.

#### 5.5.3 Questions 20 and 27

Pre-service teachers have a tendency not to avoid the issue of Earth origins due to either religious overtones or community concerns. This is a rather obvious correlation. The Pearson correlation was 0.756 and the Spearman correlation was 0.798. I chose not to display the scatterplot for this correlation, but it shows that all of the respondents said that they would not avoid the issue of Earth age for either one of these reasons.

#### 5.5.4 Questions 8 and 33

The more the preservice teachers consider themselves religious, the less factual and divinely inspired they deem the Bible. This seemed to be a strange correlation to me and may be indicative of the relative strength of the correlations. However, the question about the Bible was written with the intent to indicate the level of conservativeness in the respondents who identified themselves with the Christian faith. The question said, “The Bible (specifically referring to the Old Testament, or Torah) is the inspired word of God and is completely factual.” I think that my use of the word “completely” in conjunction with the word “factual” may have prompted some individuals to disagree with this

statement even if they have a basic belief in the Bible. This is an assumption that is based on the fact that seven of the twelve respondents identified themselves with a Christian-based religion. One of the respondents (Respondent 1), who was identified with the Catholic faith, added the words “man’s interpretation” in the margin next to this question.

#### 5.5.5 Questions 29 and 15

Figure 5-3 indicates that as familiarity with religious creation texts increases, the understanding of religious-based concerns about evolution and Earth age increases. This seems to be an obvious correlation, but it also seems to show that if the preservice teachers are not

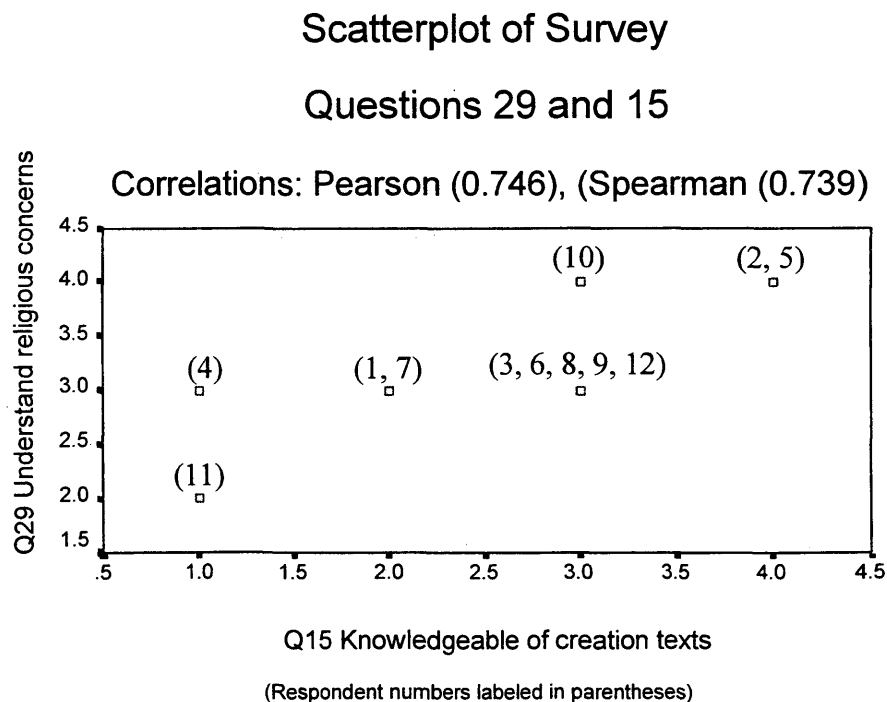


Figure 5-3 Correlation of Questions 29 and 15



potential students who may come into their classroom who have different views of the reliability of science than the teachers anticipated. Respondent four said, “I had no idea how they backed up their beliefs and really didn't understand that it is a major issue”.

#### 5.5.6 Questions 29 and 10

The topics of the questions in this correlation are very similar to those in section 5.4.2. As the understanding of religious-based concerns about evolution and Earth age increases, feelings of preparedness in preservice teachers to deal with diverse views and backgrounds increases (see Fig. 5-4).

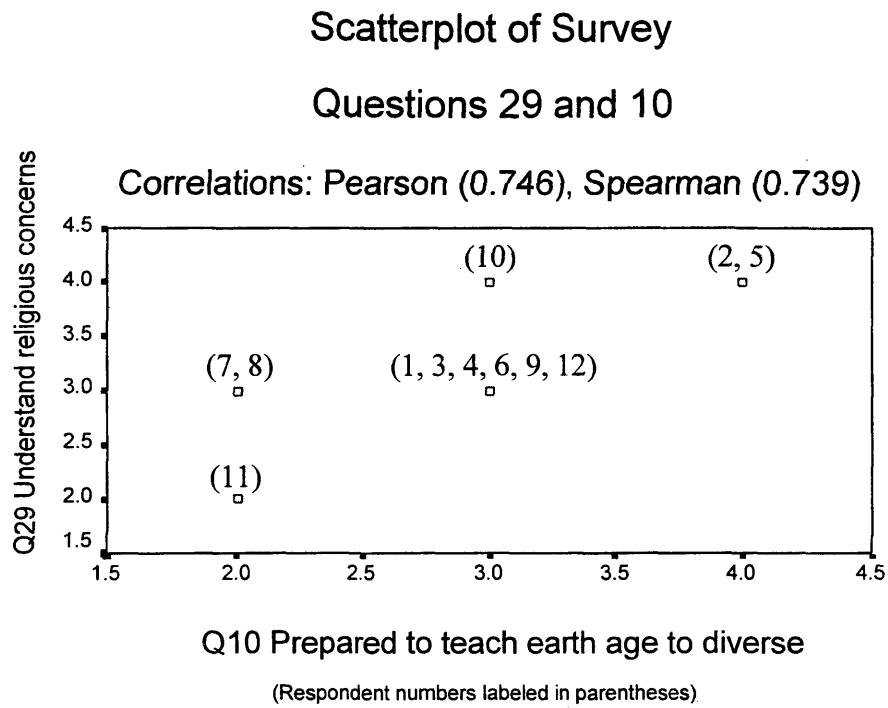


Figure 5-4 Correlation of Questions 29 and 10

5.5.7 Questions 7 and 21

Figure 5-5 represents another correlation that seems rather obvious. It indicates that as knowledge of creationism increases, understanding of young-Earth arguments increases. I think it is important to note that I attempted to word both questions in such a way that knowledge and understanding would not necessarily be equated with agreement.

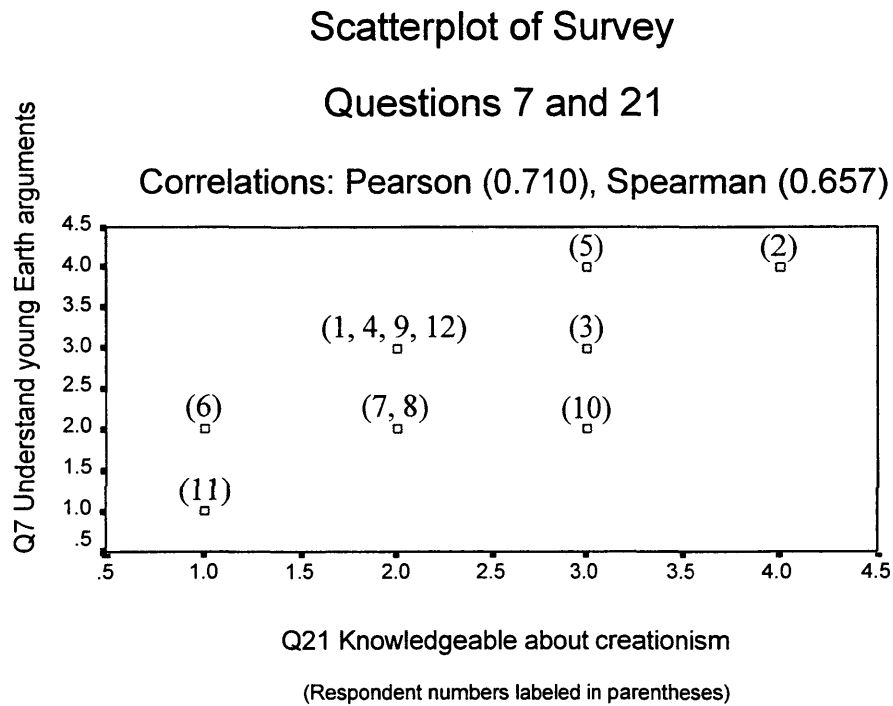


Figure 5-5 Correlation of Questions 7 and 21

### 5.5.8 Questions 17 and 35

As belief in the sufficiency of evidence for an old Earth increases, opposition to the teaching of creationism in public schools increases. Figure 5-6 illustrates that the Pearson and Spearman correlations, though still significant, are beginning to be less so. However, the statement of this correlation seems to match common experience. The scientific community is in very strong agreement on the weight of evidence for an old age of the Earth, and the scientific community is quite opposed to the teaching of creationism.

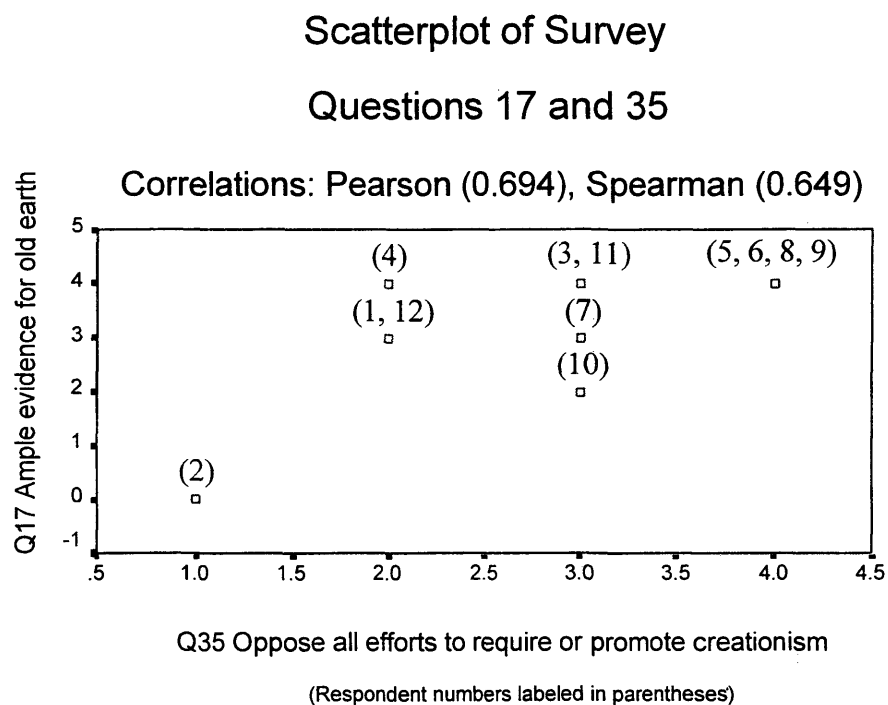


Figure 5-6 Correlation of Questions 17 and 35

### 5.5.9 Questions 10 and 15

Figure 5-7 illustrates a correlation that is very similar to the one presented in section 5.4.1. As familiarity with religious creation texts increases, feelings of adequacy to deal with Earth age and origin among people of diverse backgrounds increases.

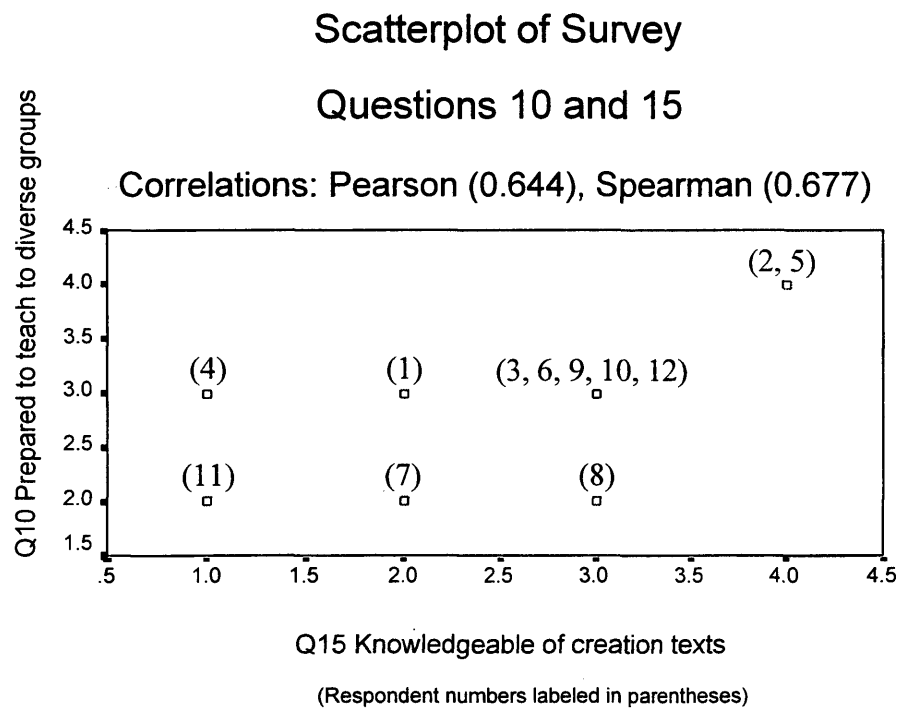


Figure 5-7 Correlation of Questions 10 and 15

### 5.5.10 Questions 21 and 10

As knowledge of various theories of creationism increases, feelings of adequacy to deal with Earth age and origin among people of diverse backgrounds increases (see figure 5-8). Figures 5-1, 5-7 and 5-8 seem to confirm a basic premise of the National Science Teachers Association position on dealing with controversial issues such as this in science education. I'll elaborate on this in a later section. This completes the presentation of the most significant positive correlations.

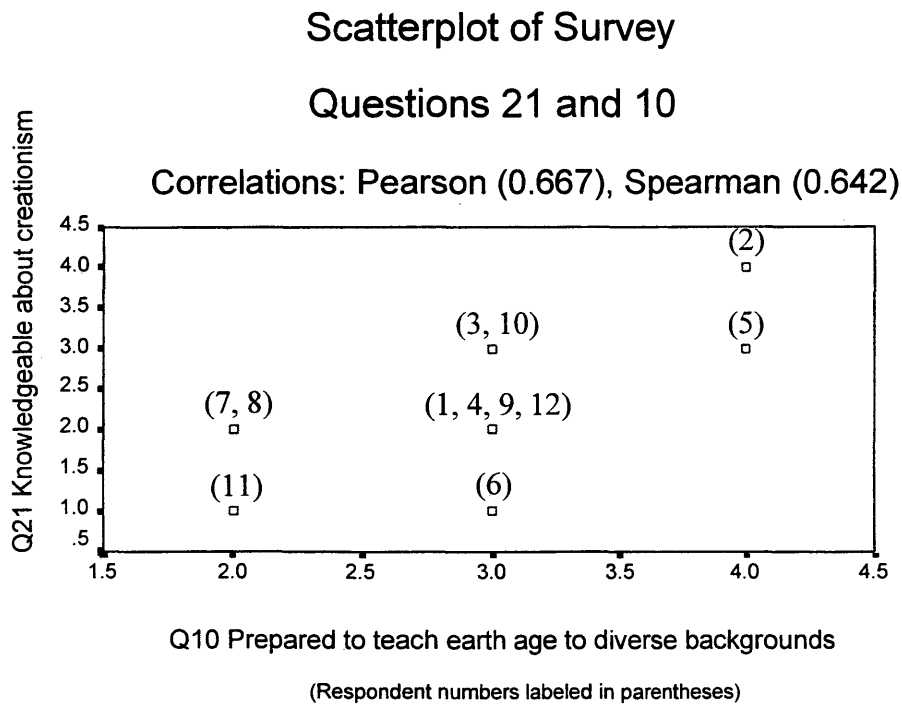


Figure 5-8 Correlation of Questions 21 and 10

### 5.5.11 Questions 17 and 33

The next few sections, including this one, present the negative correlations, again discussed in order of decreasing statistical significance. Figure 5-9 implies that as feelings that the Bible or Torah is the factual, inspired Word of God increase, feelings that there is ample evidence for a 4.5 billion year age for the Earth decrease. Question 33 only appeared on the pre-lesson survey, and there was nothing in the presentation designed to influence any change of opinion in this area, so I don't think much should be inferred from this correlation.

### Scatterplot of Survey Questions 17 and 33

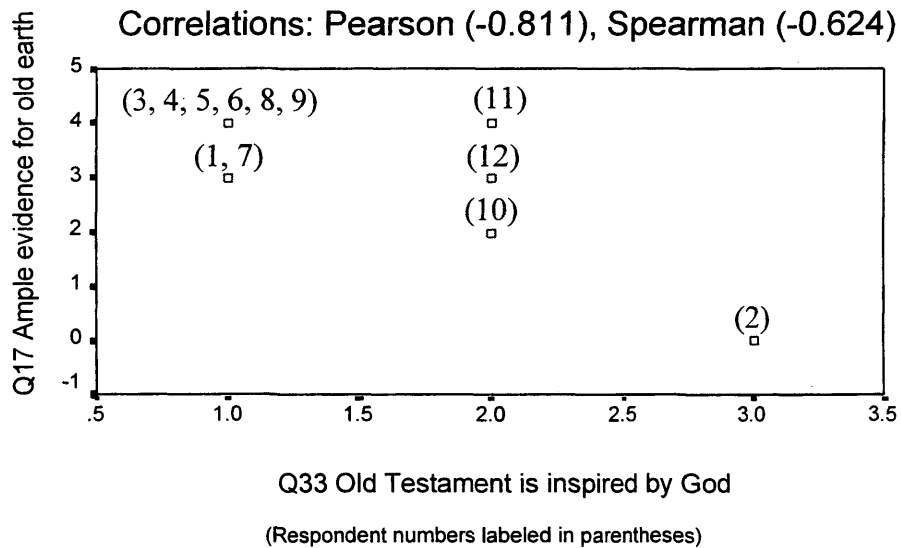


Figure 5-9 Correlation of Questions 17 and 33

### 5.5.12 Questions 6 and 20

Section 5.4.3 discussed the indications that preservice teachers tend not to allow community concerns or religious overtones to dissuade them from dealing with the topic of Earth age. However, Figure 5-10 indicates that as comfort level increases for dealing with controversial issues, whatever hesitancy there might have been to avoid dealing with Earth origins because of religious overtones diminishes.

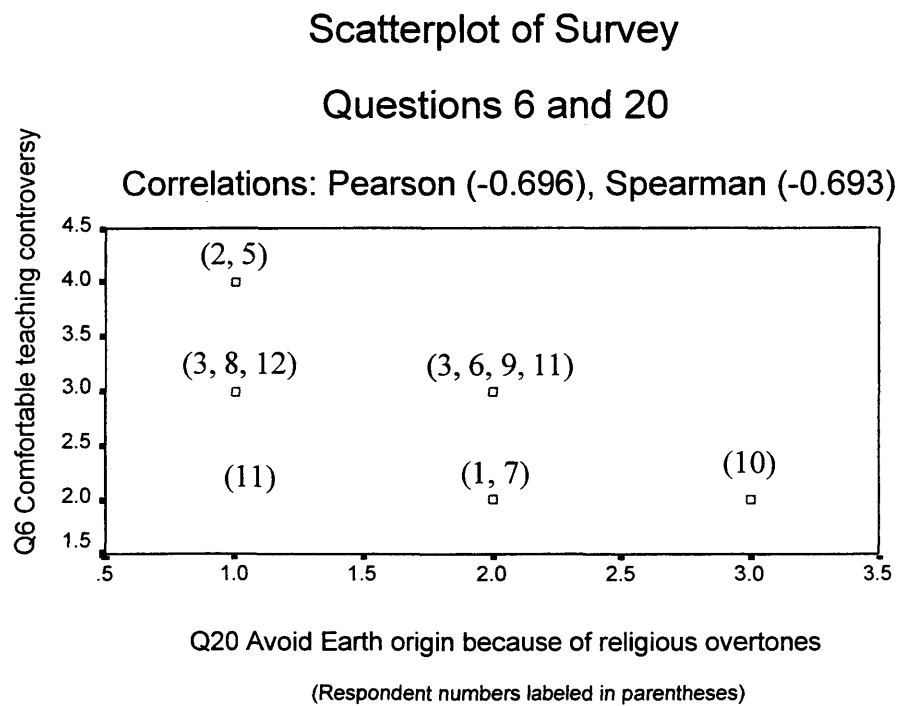


Figure 5-10 Correlation of Questions 6 and 20



### 5.5.13 Questions 18 and 35

Though still statistically significant, this correlation (Figure 5-11) is less strong than the last few I've examined. It is another fairly obvious correlation that shows as feelings that multiple viewpoints about Earth age should be discussed in classrooms increase, opposition to all efforts to require or promote the teaching of creationism decreases. I think the interesting thing about this correlation lies in the lower Pearson and Spearman significance figures. I would have expected the correlation to be stronger.

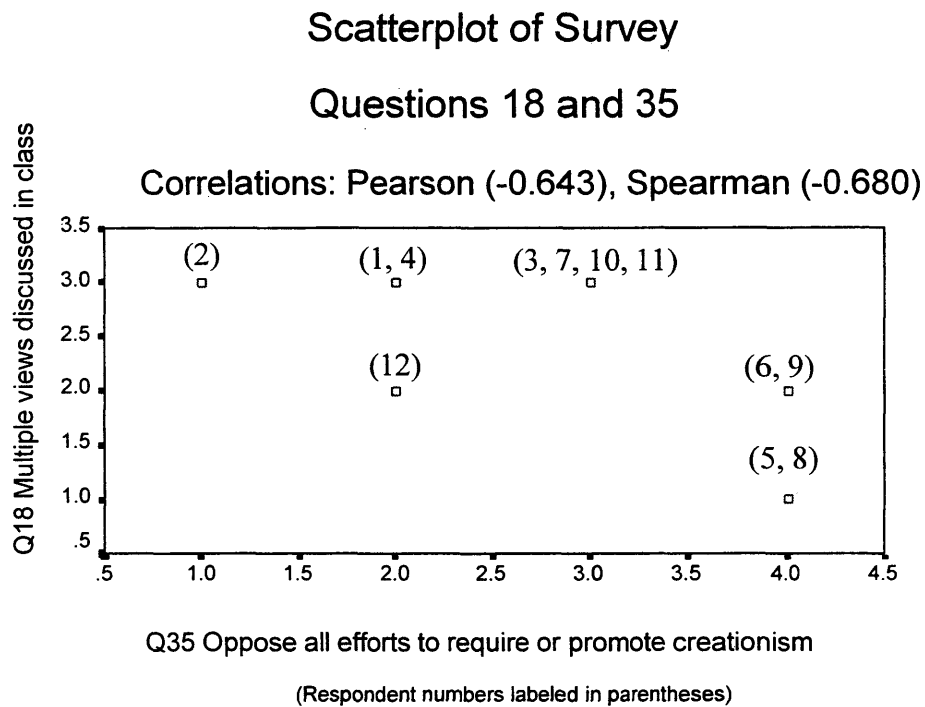


Figure 5-11 Correlation of Questions 18 and 35

#### 5.5.14 Questions 14 and 18

Figure 5-12 shows a correlation that is also only moderately statistically significant, but I find it interesting anyway. It indicates that as knowledge of evolution increases, feelings that multiple viewpoints about Earth age should be discussed in classrooms decreases. Again, this project did not focus on any aspects of the theory of evolution, but the correlation indicates a similar pattern to the one discussed in section 5.4.11. Evolutionary theory is strongly supported in the scientific community, and it appears that as that support strengthens, there is more resistance to discussing opposing viewpoints.

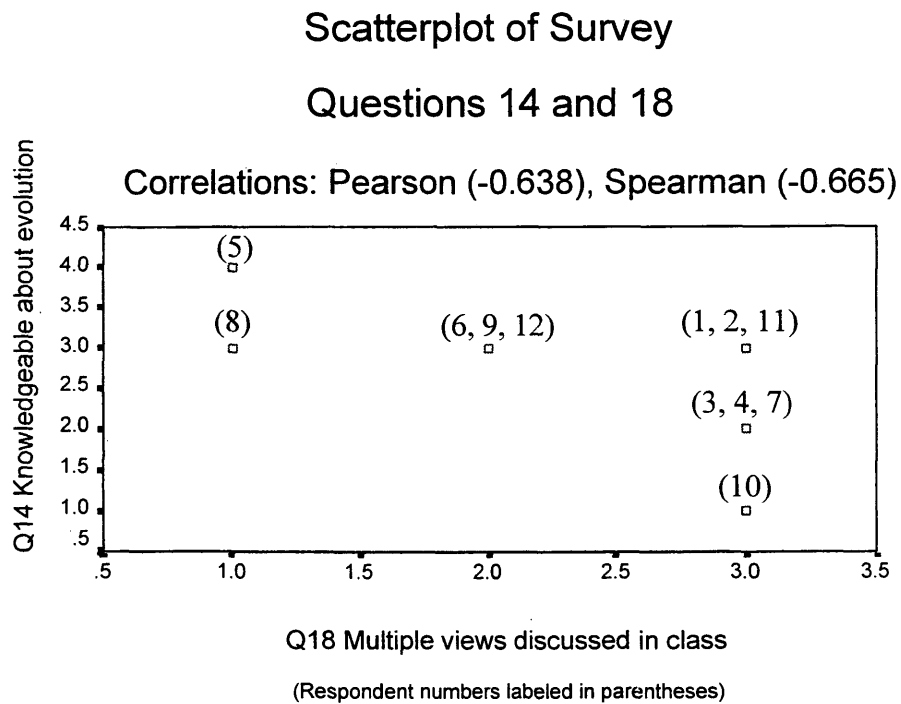


Figure 5-12 Correlation of Questions 14 and 18

### 5.5.15 Questions 6 and 27

Section 5.4.16 presented a similar finding to this one. As comfort level increases for dealing with controversial issues, the tendency to avoid dealing with Earth origins because of community concerns decreases (see Figure 5-13). This seems to imply that it is familiarity with a topic, and not concern with how the public may respond, that is a determining factor in how willing a preservice teacher is to deal with a controversial topic.

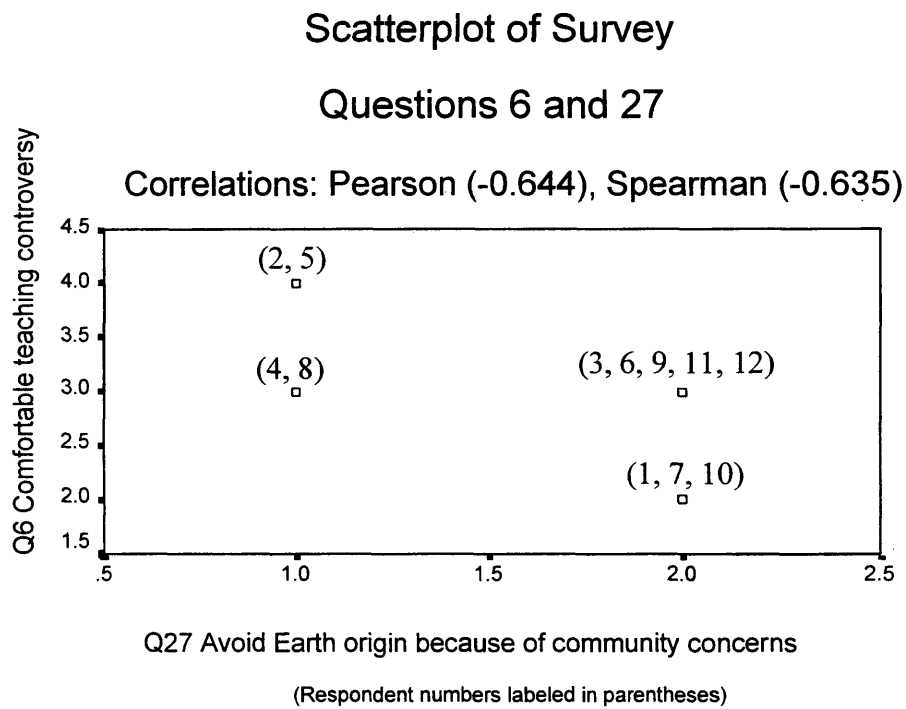


Figure 5-13 Correlations of Questions 6 and 27

### 5.5.16 Questions 7 and 25

The final correlation that I chose to present says that as understanding of young-Earth arguments increases, feelings that there is no place for a discussion of those ideas in the classroom decrease (see figure 5-14). Even though this correlation is the least statistically significant of the ones I chose to present, I think it draws this section to a close

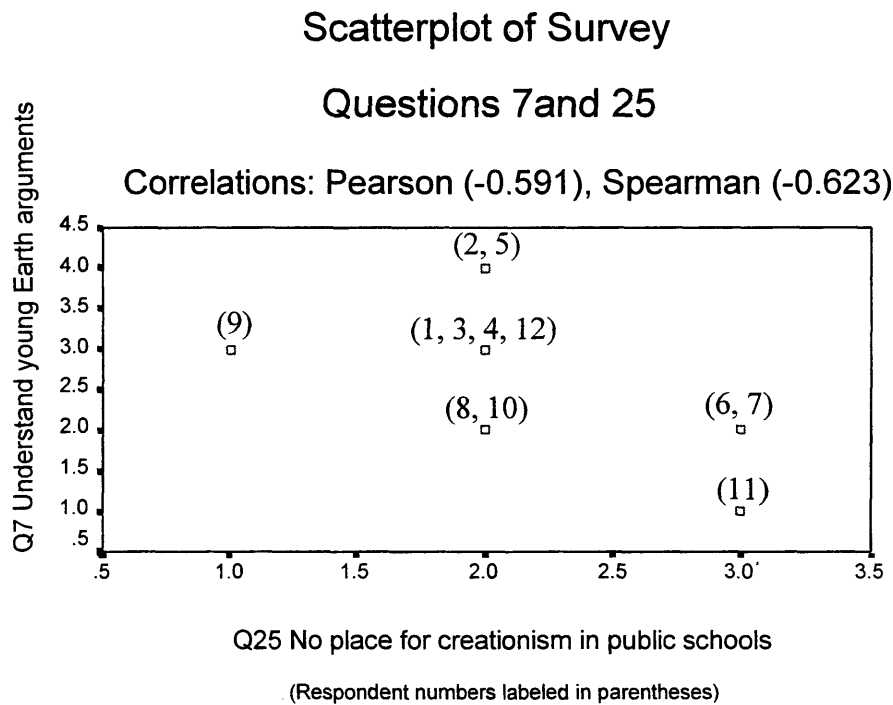


Figure 5-14 Correlation of Questions 7 and 25

on an interesting topic. It is my perception that the preservice teachers, when presented with information about the motivations behind the young-Earth viewpoint, and the types of arguments being presented, have begun to feel that a discussion of these ideas is relevant to the success of science education. This is because of the need to be open about the processes of science investigation and the effect the preconceptions have on the way that people learn science. This is a significant aspect of Chinn's and Brewer's educational model, and my point in doing this project.

#### 5.6 Conclusions from the Data

The correlations that I have presented here represent the most significant correlations in the data. Table 5-7 shows which of my variables (Section 4.2) are represented by these correlations.

Table 5-7 Variables Associated with Correlations

Variables	Number of Correlations	Questions Involved
Pedagogy – Pedagogy	1	5 – 12*
Fear – Fear	3	27 – 20, 6 – 27, 6 – 20
Awareness – Awareness	2	14 – 28*, 7 – 21
Awareness – Religion	1	29 – 21
Awareness – Education	1	30 – 14*
Awareness – Knowledge	2	7 – 10, 10 – 21
Awareness – Policies	2	18 – 14, 25 – 7
Religion – Religion	2	33 – 8, 29 – 15
Religion – Education	1	30 – 22*
Religion – Knowledge	3	10 – 29, 15 – 10, 17 – 33
Education – Education	1	23 – 9*
Knowledge – Policies	1	17 – 35
Policies – Policies	1	35 – 18

(Correlations marked with a \* were not discussed in this thesis)

It is interesting to note that the most correlations among individual variables occur within the “fear” variables and between the Religion and Knowledge variables. I think it is reasonable to expect questions representing the same variable to correlate. I decided to do a final set of correlations by adding the scores from all the questions within each particular variable and then seeing if any relationships show up between these sums. The only one that was statistically significant was between the Religion variable and the Awareness variable. The scatterplot for this correlation is shown in Figure 5-15.

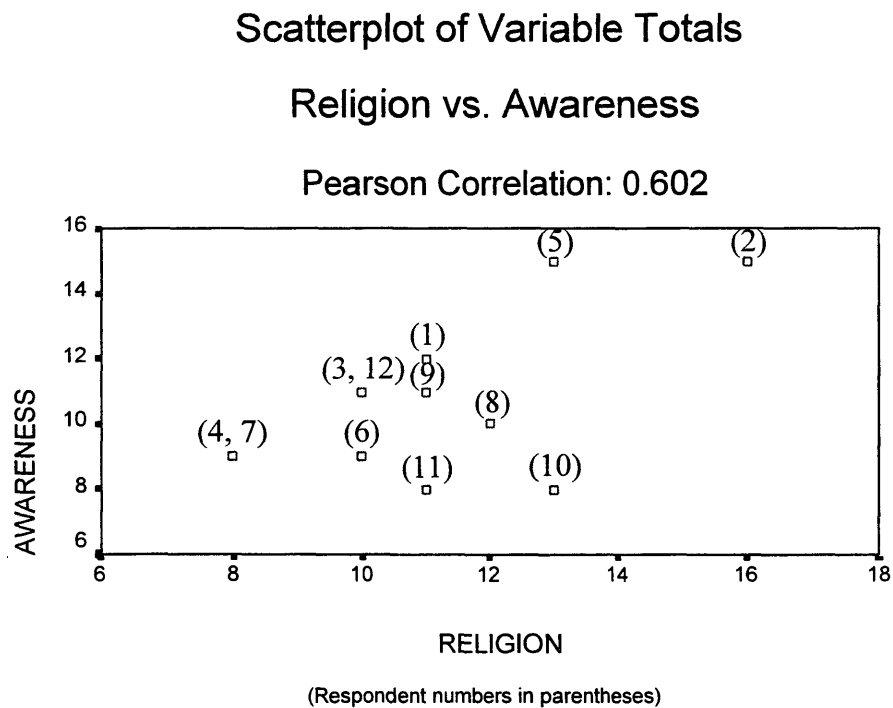


Figure 5-15 Correlation of the Sum of the Awareness Questions and the Sum of the Religion Questions.

This correlation is not very strong, but indicates that a person's awareness of creationist ideas and the controversies surrounding them seems to be tied to the religious tendencies of the person. I think, though, that in order for the arguments of young-Earth creationists to be successfully examined in science education, these two variables should become separate.

Referring back to section 5.4, of the sixteen most significant relationships found in the pre- and post-lesson surveys, ten (62.5%) of them deal with similar topics (see table 5-3).

Table 5-8 Topics Associated with the Correlated Questions

Correlated Questions	Topics
7-10	Understanding of young Earth arguments vs. comfort level of teaching
21-29	Creationism knowledge vs. understanding of religious concerns
15-29	Familiarity with creation texts vs. understanding of religious concerns.
29-10	Understanding of religious concerns vs. preparedness to teach
7-21	Knowledge of creationism vs. understanding young-Earth arguments
10-15	Familiarity with creation texts vs. feelings of adequacy to teach
21-10	Knowledge of creationism vs. comfort with diversity
6-20	Comfort with controversy vs. willingness to address origins in face of community concerns.
6-27	Comfort with controversy vs. willingness to address origins in face of religious overtones.
7-25	Understanding young-Earth arguments vs. feelings of increased appropriateness as a point of discussion in education.

I believe that these ten correlations can essentially be summed up in the following statement: As future educators gain more familiarity with religious texts and creationist



arguments, they will be more inclined to feel comfortable and prepared to address the topic of the age of the Earth with scientific accuracy and integrity while engaging, with compassion and understanding, the preconceptions of a diverse group of learners.

I believe this conclusion is consistent with the National Science Teachers Association publication The Creation Controversy and the Science Classroom, which has a multipart position statement that includes the following:

Policy makers and administrators should not mandate policies requiring the teaching of creation science or related concepts. . . . Science teachers should not advocate any religious view about creation, nor advocate the converse. . . . Publishers should not be required or volunteer to include disclaimers in textbooks concerning the nature and study of evolution (Skehan and Nelson, 2000).

This statement is different from that of GSA or AGU in that it encourages teachers not to advocate or teach creationism, but does not discourage them from discussing the concept in class. In the same publication, Skehan says, “The education of science teachers who will likely face these topics should include something about the premises and procedures of modern biblical interpretation and the distinct roles of scientific knowledge and religious faith.”

### 5.7 Thesis Conclusion: A Model for Geoscience Education

This paper has dealt with several aspects of education in the geosciences. I have discussed the variety of viewpoints that exist in modern society concerning creationism and specifically the age of the Earth. Chapter two examined ways that geoscientists in history have addressed developments in their scientific endeavors as they related to contemporary religious views. Next, I looked at research into how people learn and examined ways that

the topic of Earth age and origins might be presented. Then I did a pilot study examining the influence that an open discussion of the various parameters of this topic had on the pedagogical beliefs of preservice teachers. Based on this work, I propose the following synthesis of an educational model for presenting controversial topics that I feel is applicable at all levels and situations of education, including the public school classroom, church education programs, the university setting, and policy and educational program implementation in the professional geoscience community.

1. **When a topic is to be presented, the educator** (refer back to the definition of this term in section 1.3.1) **must first of all attempt to discover the preconceptions that the recipients of the information are likely to have about the material.** The purpose of this is to establish if the material is even controversial in the context of the particular educational environment, and to develop an understanding of the source of any preconceptions. The purpose should not be to ridicule the preconceptions. By developing this personal understanding, the educator can better select anomalous data that will challenge the learner to critically examine the relevant theories.
2. **When new material is being presented to the learner, it is appropriate and helpful to discuss historical examples of scientific discourses surrounding the topic.** This discussion should be framed or accompanied by a discussion of Chinn and Brewer's hierarchy of responses to anomalous data. In this way, the recipients of the information will understand both the historical way that people

have responded, and also, hopefully, see their own tendencies in responding to the data.

3. **When anomalous data have been selected and presented, the educator should encourage the learner to critically examine the data in the context of both the theory the educator is presenting, and the preconceptions of the learner.** It is important at this point for the educator to acknowledge areas where science may be limited in its understanding of the topic. This will help the learner to see that the educator is willing to look critically at the validity of his own theories as well.
4. **If the educator wants the learners to accept a new theory that is significantly different to the one they currently hold, he should seek to provide an anchor point in the old theory around which the learners can construct the new theory.** This anchor point can be a relatively minor point, but since the learners will be seeking to regain cognitive consistency, they need something to hold on to so they don't have to abandon everything. The educator can direct the learner to further resources that are prepared by individuals or groups who have successfully identified an anchor point for the new theory that is compatible with both the preconceptions of the learner and with the science of the theory being presented.
5. **Finally, the educator should remember that the goal might not always be to effect theory change, but rather to increase the critical thinking abilities of**

**the learner.** One philosophy that I have held in my teaching experiences is that I am not nearly as concerned with what my students end up believing about science as I am that they can substantiate the reasoning and evidence behind their beliefs. Of course, my students and I are bound to the standards of science education that have been implemented by the State of Colorado. However, if my students can't identify the evidences and reasoning that lie behind scientific knowledge, then the knowledge will not be retained for very long.

#### 5.8 Ideas for Further Research and Application

This thesis is truly a pilot or proof of concept study. The group of preservice teachers was very small, so the conclusions that are based on their responses to the surveys are only indicators of what may be found in a larger test group. The relation between sample size and population is such that, aiming for a desired confidence level of 95%, with my sample size of 12: if 50% of my sample gave the same answer to a question, then according to standard statistical metrics I would conclude that for a population of 100 preservice teachers the confidence interval would be only about 27. In other words, my sample size would only enable me validly to conclude that if a question had been asked to a population of 100 preservice teachers, then between 23% (50-27) and 77% (50+27) would have been likely to answer the same way. This clearly means that to carry this proof of concept study forward I need to do research with a larger sample size that should also be related to a more clearly defined population. Indeed, in recognition of this fact I have

attempted to provide enough information in this thesis to allow myself or other interested researchers to expand my efforts with a more statistically significant group. My sampling came from the population of preservice teachers in secondary education at UCD and is indicative of the viewpoints of individuals in that particular setting. However, to be more useful, a study like this should be expanded to include other members of the preservice teacher population. For example, the study should be broadened to include the elementary education students at that institution. It would be even better to obtain a sampling from other area institutions. These particular preservice teachers are all studying at the graduate level, but it would be interesting to expand the study to include preservice teachers at the undergraduate level, and also to sample experienced classroom teachers. I also think it would be interesting and necessary to do a similar study among the other people included in my initial definition of the term “educator.” For example, how would this educational model be received by a group of people being trained for a technical science field? How would this model fit in the practice and philosophy of the educators teaching in the technical fields (such as at Colorado School of Mines)? I feel that this information would be useful to any person who will be placed in the role of educator in the sciences. Even outside of standard educational environments, the “educator” in any given situation will benefit from an understanding of learning theory and how people tend to respond to science instruction.

Policy statements issued by professional organizations should take these learning theories into account. Further research should be done to see how policy development has

been influenced by learning theory in the past, and how it might be altered in the future to more effectively influence the dissemination of geoscience information. In the educational field, school districts and individual schools need to put into place programs that will train their existing staff to more effectively deal with controversial issues. Teachers have very little extra time to research the controversies and locate resources and anomalies that they can use, so they will need some help collecting this material and learning how to present it in an informed but sensitive manner. However, if the goal in science education is to produce not only scientifically literate individuals, but also people who can think critically and evaluate the merits of differing viewpoints, the time and energy necessary to research and teach about controversial issues will be well spent.

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## APPENDIX A

# Research Memo

**Date:** 2/7/02

**To:** Science Teacher Candidates

**From:** Steve Owens, Science Teacher at Northglenn High School

**RE:** Survey for Research Project

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Dear Teacher Candidates:

I am conducting a research study with the teacher candidates from UCD on approaches to controversial issues in the classroom. Specifically for this study, the impact of creation/evolution issues on science education will be studied. This research is being done in conjunction with UCD Professor Mike Marlow. I would appreciate it if you would complete the survey as a prelude to a discussion about the issues surrounding this topic. The results of the survey will be analyzed in preparation for completion of a Master's Thesis for the Geology Department at Colorado School of Mines. The information will also be shared at the National Science Teachers Association Conference in San Diego at the end of March.

Your participation will be kept anonymous and will not in any way affect your grades at UCD or your work in the partner schools. I have asked for a 4-digit identifier at the top of the first page solely for the purpose of cross-referencing answers. You will be given the opportunity to volunteer your name at the end of the survey for a possible future clarification interview. This is entirely optional.

**For cross-referencing purposes only, please write a unique 4-digit number in this space \_\_\_\_\_. This number may be asked for again in a follow-up survey, but will not be used to identify you individually.**

1. **What gender are you?** M F
2. **What is your age?** 20-30 31-40 41-50 51-60 61+
3. **How many years of education have you completed?**

\_\_\_\_\_ years home-schooled

\_\_\_\_\_ years in elementary public schools

\_\_\_\_\_ years in secondary public schools

\_\_\_\_\_ years in elementary private schools

\_\_\_\_\_ years in secondary private schools

\_\_\_\_\_ years in post-secondary education

Degree earned \_\_\_\_\_

Subject \_\_\_\_\_

Degree earned \_\_\_\_\_

Subject \_\_\_\_\_

4. **How many years teaching experience have you had?**

\_\_\_\_\_ years home-school

\_\_\_\_\_ years in elementary public schools

\_\_\_\_\_ years in secondary public schools

\_\_\_\_\_ years in elementary private schools

\_\_\_\_\_ years in secondary private schools

\_\_\_\_\_ years in post-secondary education



For questions 5 – 36, please fill in the circle of the number that best describes your response.

<b>KEY for #5-36</b> <b>4 – Definitely Agree</b> <b>3 – Somewhat Agree</b> <b>2 – Somewhat Disagree</b> <b>1 – Definitely Disagree</b>
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5. I have encountered individuals who have preconceived notions that affect how they learn about science.  
 4       3       2       1
6. I am comfortable teaching controversial issues.  
 4       3       2       1
7. I understand the arguments proposed for a young (less than 50,000 years old) Earth.  
 4       3       2       1
8. I consider myself a religious person.  
 4       3       2       1
9. My pre-university education was primarily through the American Public School System.  
 4       3       2       1
10. I currently feel prepared to handle the topic of Earth age and origin in a classroom of diverse backgrounds and beliefs?  
 4       3       2       1
11. I feel that multiple viewpoints about the origin of life should be discussed in the public school classrooms.  
 4       3       2       1
12. I have encountered individuals who disagree with mainstream scientific theory based on their prior knowledge.  
 4       3       2       1
13. I am comfortable teaching multiple views on the age of the Earth.  
 4       3       2       1
14. I feel that I am knowledgeable about the various theories of the evolution of life.  
 4       3       2       1
15. I consider myself familiar with some religious creation texts, such as those of the Christian, Judaic or Islamic religions.  
 4       3       2       1
16. My pre-university education included some parochial or religious training.  
 4       3       2       1
17. I believe that there is ample evidence to indicate the Earth is approximately 4.5 billion years old.  
 4       3       2       1

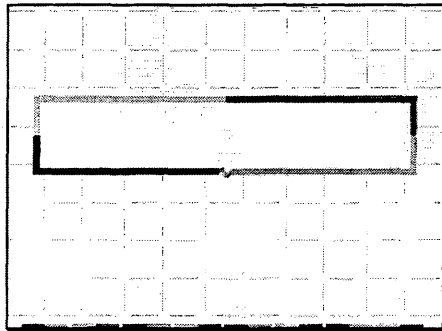
18. I feel that multiple viewpoints about the age of the Earth should be discussed in the public school classrooms.  
 4       3       2       1
19. I believe it is important to understand my students' prior knowledge before teaching a concept.  
 4       3       2       1
20. I would avoid the issue of Earth origin because of the religious overtones.  
 4       3       2       1
21. I feel that I am knowledgeable about the various theories of creationism.  
 4       3       2       1
22. I believe that modern scientific theory is compatible with the religion.  
 4       3       2       1
23. My pre-university education included either home-schooling or private school.  
 4       3       2       1
24. I feel that there is no way to know for certain how old the Earth is.  
 4       3       2       1
25. I feel that there is no place for a discussion of the ideas of creationism in a public school science classroom.  
 4       3       2       1
26. I believe it is important to know the source of my students' prior knowledge.  
 4       3       2       1
27. I would avoid the issue of Earth origins because of community concerns.  
 4       3       2       1
28. I am aware of controversy surrounding the scientific methodology dating the age of the Earth.  
 4       3       2       1
29. I understand the religious based concerns about evolution and age of the Earth.  
 4       3       2       1
30. My personal knowledge of scientific issues has significantly increased since completion of my undergraduate degree.  
 4       3       2       1
31. I feel knowledgeable enough to explain the principles of radiometric dating techniques.  
 4       3       2       1
32. Creationist ideas have no place in public school science classes because they are based on religion rather than science.  4       3       2  
 1

33. **The Bible (specifically referring to the Old Testament, or Torah) is the inspired word of God and is completely factual.**  
O 4            O 3            O 2            O 1
34. **I feel knowledgeable enough to explain non-radiometric techniques for measuring relative ages of Earth materials.**  
O 4            O 3            O 2            O 1
35. **I oppose all efforts to require or promote the teaching of creationism in public schools.**  
O 4            O 3            O 2            O 1
36. **Science teachers should not advocate any religious view about creation, nor advocate the converse: that there is no possibility of supernatural influence in bringing about the universe as we know it.**  
O 4            O 3            O 2            O 1
37. **Please identify any religious affiliation that you have. If none, write "NONE".**
38. **Please briefly describe, in your own words, the theory(ies) of creationism as it relates to the age of the Earth and the origin of life. Use the back, if necessary.**
39. **Please briefly describe, in your own words, the theory(ies) of evolutionism as it relates to the age of the Earth and the origin of life. Use the back, if necessary.**

If you would be willing to be contacted (if necessary) for further clarification of your responses, please print your name here \_\_\_\_\_

**APPENDIX B**

Slide 1



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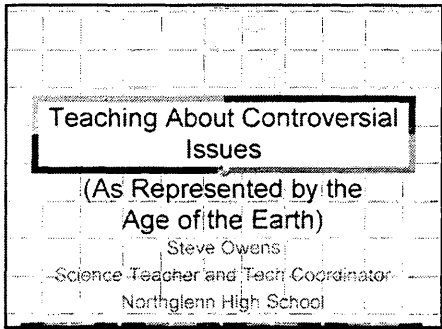
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Slide 2



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Slide 3

**Purpose**

My Purpose.

- \* **IS NOT** to teach dating techniques (rock dating, or course)
- \* **IS NOT** to teach about creationism
  
- \* **IS** to look at thinking behind various approaches.

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Slide 4

**Personal Involvement**

- \* Teaching Experience
- \* My beliefs
- \* Church leadership
- \* Past encounters with young-earth students
- \* Colorado School of Mines
  - Geology graduate/USGS employee – Young-earthier
  - Geology student's confusion

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Slide 5

**Why is this topic important?**

- \* Representative of multiple topics that are deemed controversial in science.
  - Evolution
  - Origin of Life
  - Origin of the Universe
  - Geologic Processes and Sedimentation
  - Uniformitarianism
  - Plate Tectonics
- \* Any science educator needs to be prepared to deal with topics such as these with classes of diverse opinions.

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## Slide 9

**Textbook Presentation<sup>1</sup>**

- \* Age of Earth is **commonly regarded** as about 4.5 to 4.6 billion years.
- \* Oldest dated rocks are found in northwestern Canada  $\approx$  4.03 billion years old
- \* Isotopic dating – radioactive elements sealed inside newly crystallized minerals decay at a measurable rate.
- \* Comparing parent to daughter element ratios determines the actual age of the crystal.

No mention of non-radiometric ways of applying minimum date ranges to rocks.

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## Slide 10

**Radioactive Decay<sup>1</sup>**

- \* Radioactive decay is the spontaneous nuclear disintegration of isotopes with unstable nuclei
- \* When protons are lost, the element (parent) changes to another element (daughter)
- \* Parent atoms decay at a proportionally constant rate, apparently unaffected by chemistry or pressure/temperature changes.
- \* Time for one-half of the parent to decay is the element's half-life.

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## Slide 11

**Calculating a Rock's Age<sup>1</sup>**

- \*  $N$  = number of parent atoms left
- \*  $N_0$  = number of parent atoms initially
- \*  $e$  = mathematical constant (2.718)
- \*  $\lambda$  = decay constant (atoms decayed/time)
- \*  $t$  = time since formation
- \*  $t_M$  = half-life of the mineral

$$N = N_0 e^{-\lambda t} \quad \lambda = \frac{\ln 2}{t_M} = \frac{0.693}{t_M}$$

$$t = \frac{t_M}{0.693} \ln \frac{N_0}{N}$$


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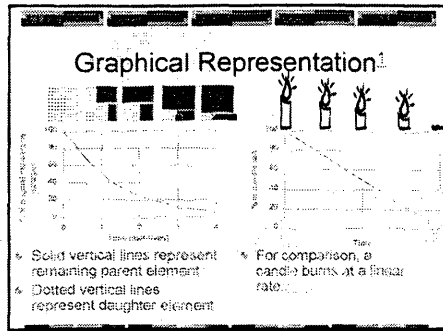
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Slide 12




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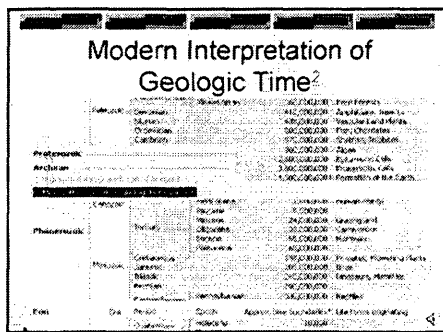
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Slide 13




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Slide 14

### Reasons for Christian Opposition

- Belief in Biblical Inerrancy
- Wording of Genesis Creation Account
- Fundamentalism

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Slide 15

**Relevant Biblical Texts – Inerrancy<sup>4</sup>**

- ✦ All Scripture is God-breathed and is useful for teaching, rebuking, correcting and training in righteousness. <sup>2</sup> Timothy 3:16
- ✦ Above all, you must understand that **no prophecy of Scripture came about by the prophet's own interpretation.** For prophecy never had its origin in the will of man, but **men spoke from God as they were carried along by the Holy Spirit.** <sup>2</sup> Peter 1:20-21
- ✦ **The law of the Lord is perfect,** Psalm 19:7
- ✦ I warn everyone who hears the words of the prophecy of this book: **if anyone adds anything to them, God will add to him the plagues described in this book.** <sup>19</sup>And if anyone **takes words away from this book of prophecy, God will take away from him his share in the tree of life and in the holy city, which are described in this book.** Revelation 22:18

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Slide 16

**Relevant Biblical Texts – Creation<sup>4</sup>**

- ✦ <sup>1</sup> In the beginning **God created the heavens and the earth.**
- ✦ <sup>2</sup> And God said, "Let there be light," and there was light. . . . And there was evening, and there was morning the **first day.**
- ✦ <sup>4</sup> And God said, "Let there be an expanse between the waters to separate water from water." . . . And there was evening, and there was morning the **second day. . . third day . . . fourth day . . . fifth day . . . sixth day.** (Genesis 1)
- ✦ <sup>1</sup> Thus the heavens and the earth were completed in all their vast array. <sup>2</sup> **By the seventh day God had finished the work he had been doing, so on the seventh day he rested from all his work.** (Genesis 2)
- ✦ <sup>1</sup> For in six days the Lord made the heavens and the earth, the sea, and all that is in them, but he rested on the seventh day. (Exodus 20)

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Slide 17

**Fundamentalism**

- ✦ 5 Basic Doctrines (stated in 1909) regarding<sup>3</sup>
  - Trinity
  - Jesus Christ's Deity
  - Second Coming
  - Salvation
  - Scripture
- ✦ **Scopes Trial** – W.J. Bryan, noted fundamentalist, admitted possible "long" days of creation <sup>2</sup>
- ✦ This led many fundamentalists to **add a doctrinal statement incorporating "recent" creation of the earth.**<sup>3</sup>

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Slide 18

**Biblical Inerrancy<sup>3</sup>**

- ✦ "Our insistence upon the doctrine of six-day creation is a **direct, and necessary**, extension of our doctrine of Scripture."
- ✦ "To defend six-day creation is to defend the proposition that the Bible means what it says, and that its meaning is clear. If our Bibles mean whatever we want them to mean in Genesis 1, then why not at every other juncture where God's Word offends the sensibilities of man's reason?"
- ✦ Is six-day creation a stumbling block to would-be believers? If so, let them also stumble at the offense of the cross. Let them scoff at swimming axe heads, manna from heaven and, most unbelievable of all, the resurrection of the dead.

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Slide 19

**Young-Earth Arguments**

- ✦ Point out errors in old-earth interpretation
- ✦ Provide evidence for young earth

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Slide 20

**Radiocarbon Dating<sup>3</sup>**



<p>Blum found an <i>Acerosanthus</i> radio carbon dated at 19,000 years old!</p>	<p>The new lava dome (dated) from Mount St. Helens was formed in 1980. In 1987 five specimens were taken from this dome at five different locations and subjected to conventional Potassium-Argon dating. The results indicated ages of less than one half to almost three million years old, all from eleven year old rock.</p>	<p>Carbonized stick embedded in "110 million year old limestone" radio carbon dated at 12,900 years old!</p>
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Slide 21

**Fossilized Hammer**

\* The wood handle is partially coalified with quartz and calcite crystalline inclusions. Tests performed at Barstow Laboratory document the hammer's unusual metallurgy, 90% iron, 2.6% chlorine and 74% sulfur (no carbon). Density test indicate casting of exceptional quality. A unique coating of FeO, which does not readily form under present atmospheric conditions, appears to inhibit rusting. The enclosing rock contains Lower Cretaceous fossils. It is a concretionary sandstone nodule from the nearby cliff which is made up of concretionary sandstone nodules.




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Slide 22

**Rapid Petrification**

\* The rubber-soled boot with petrified cowboy (human) leg, bones and all was found in a dry creek bed near the West Texas town of Iranan, about 1989 by Mr. Jerry Stone, an employee of Converse oil company. Only the contents of the boot are fossilized, not the boot itself, demonstrating that some materials fossilize more readily than others. The bones of the partial leg and foot within the boot were revealed by an elaborate set of C.T. Scans performed at Harris Methodist Hospital in Bedford, Texas on July 24, 1997.




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Slide 23

**Malachite Man**

\* Skeletons of ten perfectly modern humans have been excavated from fifty eight feet down in the Dakota Sandstone, over an area spanning about 50 by 100 feet. This formation is a member of the Lower Cretaceous, supposedly 140 million years old. It is known for its dinosaurs and is the same formation found at Dinosaur National Monument. The bones are partially replaced with malachite (a green mineral) and turquoise, thus appropriately named "Malachite Man".




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Slide 24

**Evidence for Human coexistence with Dinosaurs<sup>6</sup>**

The Burdick Track is in Cretaceous limestone, found near Glen Rose, Texas. (famous for it's dinosaur tracks)

Evolutionary theory claims that humans were separated from these dinosaurs by over 100 million years, so [evolutionists] just say, "It is carved." This assumption has been disproved by cross-sectioning. Carving would randomly cut across the internal rock structures. However, if those structures follow the contours of the impression, the carving theory would be falsified. Internal structures dramatically conform to the shape of both the heel impression and the great toe impression.




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Slide 25

**Earth's Magnetic Field**

- \* The magnetic field is decreasing at a rate of 5% per 100 years<sup>1</sup>.
- \* Measured field strengths of typical stars, (which would exceed the maximum for Earth), indicate that Earth's field could have been at a maximum no more than 10,000 years ago<sup>2</sup>.

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Slide 26

**Comets**

- \* Comets lose material as they approach the sun in their orbit.
- \* There are short period comets whose orbits **require** that they should have lost their material by now.
- \* Their **calculated maximum age** is less than 10,000 years old.<sup>3</sup>

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Slide 27

### Helium in Earth's Atmosphere?

- Helium is built up in the atmosphere from radioactive isotopes, volcanic eruptions and nitrogen interactions with cosmic ray neutrons.
- The average rate of thermal escape of  $^4\text{He}$  is about  $6 \times 10^8$  atoms/cm<sup>2</sup>-sec. The present abundance of  $^4\text{He}$  in the atmosphere would accumulate in about two million years. The rate of thermal escape of  $^4\text{He}$  has been estimated to be about 4 atoms/cm<sup>2</sup>-sec, also much less than its estimated influx.
- Using these estimated fluxes of helium, the present abundance of  $^4\text{He}$  would accumulate in 1.8 million years. Only 370 thousand years would be required to supply the atmosphere with its present content of He.
- The helium must be escaping from the atmosphere in some way for the evolutionary model to be true. Otherwise, there would be a great deal more helium today.

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Slide 28

### Granite Crystal Halos?

- Dr. Robert V. Gentry has radiometric evidence that the basement rock of the earth was formed in a cool state, not in a molten condition. A cool initial state of the earth gives support to a young age for the earth. His research involves the study of pleochroic halos (colored spheres) produced by the radioactive decay of Polonium 218. He analyzed over one hundred thousand of these halos in granitic rocks which had been taken from considerable depths below land surface and in all parts of the world.
- 1) The Polonium 218 was primordial that is to say, this radioactive element was in the original granite. 2) Because the halos can only be formed in the crystals of the granite, and the Polonium 218 half-life is only 3 minutes, the granite had to be cool and crystallized originally. The Polonium 218 would have been gone before molten granite could have cooled. It would take a very long time for a molten earth to cool.

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Slide 29

Ozark Christian College



### Colleges Creation & Science Course Guide

- Creation and Science is required for each of the following degrees: B. Th., BBL, and BCE. Usually SI 181 is taken during a student's first year at OCC.

*The Christian of today lives in a world where science dominates much of life. In such a world it is essential for the Christian to know how his faith is to be related to science. This is especially true in light of the fact that much of what is considered to be scientific is permeated with evolutionary thinking. The Christian must be able to distinguish true science from false. He must also be aware of the real challenge the theory of evolution presents to evangelizing today.*

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Slide 33

**Carl Sagan<sup>2</sup>**

✦ "In many cultures it is customary to answer that God created the universe out of nothing. But this is mere temporizing. If we wish courageously to pursue the question, we must, of course ask next where God comes from? And if we decide this to be unanswerable, why not save a step and conclude that the universe has always existed?"

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Slide 34

**Claude Allegre<sup>3</sup>**

✦ "Science and religion are two separate aspects of human activity. They should stay separate. Nothing is to be gained by mixing the issues."

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Slide 35

**Stephen Jay Gould<sup>1</sup>**

✦ No . . . conflict should exist because each subject has a **legitimate magisterium**, or domain of teaching authority--and **these magisteria do not overlap** (the principle that I would like to designate as NOMA, or "nonoverlapping magisteria"): The net of science covers the empirical universe: what is it made of (fact) and why does it work this way (theory). The net of religion extends over questions of moral meaning and value. These two magisteria do not overlap, nor do they encompass all inquiry.

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Slide 39

**Geological Society of America<sup>2</sup>**

- ✦ The immensity of geologic time and the evolutionary origin of species are concepts that pervade modern geology and biology. These concepts must therefore be central themes of science courses in public schools; **creationist ideas have no place in these courses because they are based on religion rather than science.** Without knowledge of deep time and the evolution of life, students will not understand where they and their world have come from, and they will lack valuable insight for making decisions about the future of their species and its environment.

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Slide 40

**National Science Teachers Association<sup>5</sup>**

- ✦ Policy makers and administrators should not mandate policies requiring the teaching of creation science or related concepts.
- ✦ Science teachers should not **advocate any religious view** about creation, nor advocate the converse.

Publishers should not be **required or volunteer** to include disclaimers in textbooks concerning the nature and study of evolution.

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Slide 41

**NSTA Guidelines<sup>6</sup>**

- ✦ Discuss strength of support of issues
- ✦ Don't only present conclusions – teach thinking and development as well
- ✦ The education of science teachers who will likely face these topics should include something about the premises and **procedures of modern biblical interpretation** and the distinct roles of scientific knowledge and religious faith.

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Slide 42

**American Scientific Affiliation  
Guidelines<sup>2</sup>**

- Present well-established data and conclusions forcefully.
- Distinguish clearly between evidence and inference.
- Discuss unsolved problems and open questions candidly.

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Slide 43

**Learning Research**

- How People Learn - 1999
- Cognitive Dissonance - 1957
- Typical Student Responses - 1993, 1999
- Models of approaching controversial topics

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Slide 44

**How People Learn - 1999<sup>1</sup>**

- Students come to the classroom with preconceptions about how the world works. **If their initial understanding is not engaged**, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom.

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Slide 45

**Cognitive Dissonance -1957<sup>2</sup>**

- \* Cognitive consistency is the tendency for a person to exhibit beliefs and actions that are logically consistent with one another.
- \* When he/she experiences cognitive dissonance, the person unconsciously seeks to restore consistency by changing his or her behavior, beliefs, or perceptions.

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Slide 46

**Typical Student Responses  
1993 - 1997<sup>2,3</sup>**

- \* Ignoring data
- \* Rejecting data
- \* Questioning the validity of data
- \* Excluding data
- \* Holding data in abeyance
- \* Reinterpreting data
- \* Accepting data and making peripheral changes
- \* Accepting data and making theory changes

New Learning

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Slide 47

**Models<sup>2</sup>**

<ul style="list-style-type: none"> <li>* Influence prior learning                     <ul style="list-style-type: none"> <li>• Gain an understanding of the student's conceptions.</li> <li>• Check for prior learning, and its source.</li> </ul> </li> <li>* Introduce an alternative theory</li> <li>* Introduce anomalous data for examination in the context of multiple theories</li> <li>* Encourage deep processing of information                     <ul style="list-style-type: none"> <li>• Have students defend their position</li> <li>• Help students see relevance</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>* Avoid ridicule of prior learning</li> <li>* As the educator, learn enough about various sides to argue their validity, whether you believe it or not.</li> <li>* Acknowledge limitations of science</li> </ul> <p><b>GOAL:</b></p> <ul style="list-style-type: none"> <li>• Not necessarily to alter theory</li> <li>• To get students to think critically about</li> </ul> <p>Deal with material as your class warrants it – Don't force a topic</p>
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Slide 48

**Ideas Specific to this Topic**

- Discuss learning responses (previous slide)
- Continuum of viewpoints
- History of scientists showing a fit between science and scripture
- Basics of Biblical interpretation
- Outside resources

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Slide 49

**Continuum of Viewpoints<sup>4</sup>**

- Flat Earth Creationist
- Geocentric Creationist
- Young-Earth Creationist
- Old-Earth Creationist
  - Gap Creationist
  - Day-Age Creationist
  - Progressive Creationist
  - Intelligent Design Creationist
- Theistic Evolutionist
- Materialistic Evolutionist

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Slide 50

**Timeline (A.D.)**

We are not to suppose that any truth concerning the Natural World can be an Enemy to Religion; for Truth cannot be an Enemy to Truth, God is not divided against himself

1600 Galileo Galilei (1632)

1644 René Descartes (1644)

1687 Robert Boyle (1693) Nicholas Nicolson (1690)

1687 Thomas Burnet (1694) Isaac Newton (1687) 1703

I, that had much rather have men not philosophers than not Christians, should be better content to see you ignore the mysteries of nature, than deny the author of it.

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Slide 51

**'I do believe that we cannot do a man a greater and a more irreparable injury than to unsettle in any way his religious faith. I believe, therefore, it is the duty of every scientific man, who is also a lover of his fellow-men, to attempt to restore again the faith which he himself, perhaps, has helped to destroy.'**

**Timeline (A.D.)**

- 1800
- William Buckland (1829)
- William Conybeare (1822)
- Benjamin Silliman (1837)
- Hugh Miller (1852)
- John Poo Smith (1852)
- Edward Hitchcock (1855)
- Joseph Le Conte (1859)
- Arnold Guyot (1864)
- J. William Dawson (1894)
- 1990

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Slide 52

**Biblical Interpretation**

- \* At least 3 major ways to interpret Genesis and still allow it to maintain inerrancy.
  - Literal 24-hour days
  - Long periods of time
  - Figurative, poetic language

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Slide 53

**Outside Resources**

- \* Online text (McGraw-Hill) references online resources
- \* American Scientific Affiliation
- \* Association of Christian Geologists
- \* Reasons to Believe

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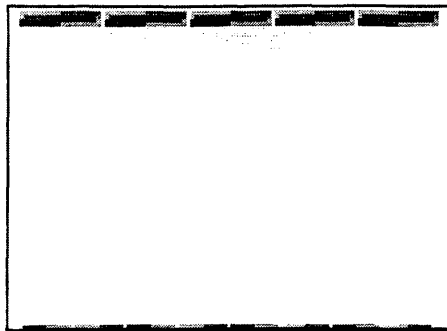
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Slide 54



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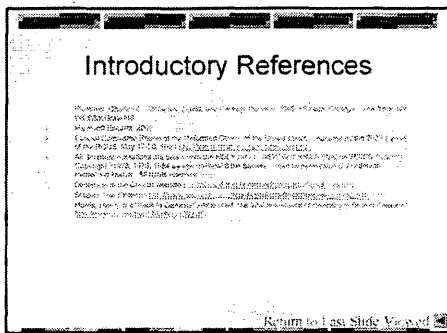
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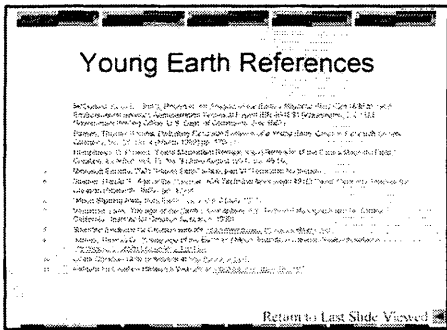
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Slide 56



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Slide 57

### Science Response References

- 1. Clark, Jonathan. "Assessing the Impact of Science Response Programs." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 2. Clark, Jonathan. "Assessing the Impact of Science Response Programs." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 3. Clark, Jonathan. "Assessing the Impact of Science Response Programs." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 4. Clark, Jonathan. "Assessing the Impact of Science Response Programs." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 5. Clark, Jonathan. "Assessing the Impact of Science Response Programs." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 6. Clark, Jonathan. "Assessing the Impact of Science Response Programs." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 7. Clark, Jonathan. "Assessing the Impact of Science Response Programs." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 8. Clark, Jonathan. "Assessing the Impact of Science Response Programs." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 9. Clark, Jonathan. "Assessing the Impact of Science Response Programs." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 10. Clark, Jonathan. "Assessing the Impact of Science Response Programs." *Journal of Environmental Education* 35(1): 1-10 (2004).

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### Learning Research References

- 1. Brown, M. "Learning Research." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 2. Brown, M. "Learning Research." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 3. Brown, M. "Learning Research." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 4. Brown, M. "Learning Research." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 5. Brown, M. "Learning Research." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 6. Brown, M. "Learning Research." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 7. Brown, M. "Learning Research." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 8. Brown, M. "Learning Research." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 9. Brown, M. "Learning Research." *Journal of Environmental Education* 35(1): 1-10 (2004).
- 10. Brown, M. "Learning Research." *Journal of Environmental Education* 35(1): 1-10 (2004).

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## APPENDIX C

For cross-referencing purposes only, please write the same unique 4-digit number in this space that you wrote on the pre-survey \_\_\_\_\_.  
This number will not be used to identify you individually.

<p><b>KEY for #1-22</b>  <b>4 – Definitely Agree</b>  <b>3 – Somewhat Agree</b>  <b>2 – Somewhat Disagree</b>  <b>1 – Definitely Disagree</b></p>
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For questions 1 – 22, please fill in the circle of the number that best describes your response.

1. I am comfortable teaching controversial issues.  
 4       3       2       1
2. I understand the arguments proposed for a young (less than 50,000 years old) Earth.  
 4       3       2       1
3. I currently feel prepared to handle the topic of Earth age and origin in a classroom of diverse backgrounds and beliefs?  
 4       3       2       1
4. I feel that multiple viewpoints about the origin of life should be discussed in the public school classrooms.  
 4       3       2       1
5. I am comfortable teaching multiple views on the age of the Earth.  
 4       3       2       1
6. I consider myself familiar with some religious creation texts, such as those of the Christian, Judaic or Islamic religions.  
 4       3       2       1
7. I believe that there is ample evidence to indicate the Earth is approximately 4.5 billion years old.  
 4       3       2       1
8. I feel that multiple viewpoints about the age of the Earth should be discussed in the public school classrooms.  
 4       3       2       1



9. I believe it is important to understand my students' prior knowledge before teaching a concept.  
 4       3       2       1
10. I would avoid the issue of Earth origin because of the religious overtones.  
 4       3       2       1
11. I feel that I am knowledgeable about the various theories of creationism.  
 4       3       2       1
12. I believe that modern scientific theory is compatible with the religion.  
 4       3       2       1
13. I feel that there is no way to know for certain how old the Earth is.  
 4       3       2       1
14. I feel that there is no place for a discussion of the ideas of creationism in a public school science classroom.  
 4       3       2       1
15. I believe it is important to know the source of my students' prior knowledge.  
 4       3       2       1
16. I would avoid the issue of Earth origins because of community concerns.  
 4       3       2       1
17. I am aware of controversy surrounding the scientific methodology dating the age of the Earth  
 4       3       2       1
18. I understand the religious based concerns about evolution and age of the Earth.  
 4       3       2       1
19. I feel knowledgeable enough to explain the principles of radiometric dating techniques.  
 4       3       2       1
20. Creationist ideas have no place in public school science classes because they are based on religion rather than science.  
 4       3       2       1
21. I oppose all efforts to require or promote the teaching of creationism in public schools.  
 4       3       2       1
22. Science teachers should not advocate any religious view about creation, nor advocate the converse: that there is no possibility of supernatural influence in bringing about the universe as we know it.  
 4       3       2       1

**This presentation was broken into four parts. Please respond to each reflection question in terms of the four parts of the presentation. Feel free to continue on the back or another sheet of paper.**

**1. Was there any information presented that you feel you hadn't been aware of before?**

**Science Approach to Age of the Earth –**

**Young-Earth Creationist Responses –**

**Response of the Scientific Community –**

**Pedagogical Considerations –**

**2. Is there any information that you feel should have been presented that wasn't?**

**Science Approach to Age of the Earth –**

**Young-Earth Creationist Responses –**

**Response of the Scientific Community –**

**Pedagogical Considerations –**

If you would be willing to be contacted (if necessary) for further clarification of your responses, please print your name here \_\_\_\_\_

## APPENDIX D

## Question Correlations

		Pearson Correlations							
	Ques	5	6	7	8	9	10	11	12
S	5	1.000	0.032	0.291	0.191	-0.194	0.161	0.225	0.741
p	6	0.066	1.000	0.562	-0.064	-0.051	0.593	-0.322	0.424
e	7	0.336	0.564	1.000	-0.193	-0.154	0.868	0.255	0.204
a	8	0.105	-0.063	-0.159	1.000	-0.110	-0.064	0.101	0.393
r	9	-0.063	-0.073	-0.205	-0.047	1.000	-0.051	0.102	0.051
m	10	0.155	0.556	0.856	-0.063	-0.073	1.000	0.288	0.220
a	11	0.081	-0.375	0.233	0.163	-0.003	0.239	1.000	-0.085
n	12	0.709	0.427	0.244	0.388	0.073	0.204	-0.107	1.000
	13	0.322	-0.037	0.448	0.264	-0.041	0.543	0.629	0.219
C	14	0.167	0.612	0.342	-0.020	-0.218	0.302	-0.425	0.457
o	15	0.076	0.593	0.557	-0.070	-0.139	0.677	-0.209	0.364
r	16	-0.389	-0.178	-0.413	0.192	-0.458	-0.067	0.018	-0.213
r	17	-0.383	0.302	-0.158	-0.509	0.030	-0.231	-0.547	-0.222
e	18	0.320	-0.433	-0.125	0.296	0.364	-0.100	0.614	0.000
l	19	0.196	-0.049	-0.139	0.090	0.604	-0.049	-0.292	0.049
a	20	-0.037	-0.693	-0.540	0.016	0.141	-0.298	0.305	-0.160
t	21	0.353	0.281	0.657	0.090	0.139	0.642	0.256	0.400
l	22	0.239	0.606	0.211	0.099	0.374	0.274	-0.238	0.672
o	23	0.063	0.073	0.205	0.047	-1.000	0.073	0.003	-0.073
n	24	0.393	-0.451	-0.238	0.273	-0.117	-0.308	0.318	-0.027
s	25	0.059	-0.204	-0.623	-0.128	0.475	-0.464	-0.229	-0.031
	26	-0.063	-0.427	-0.464	0.351	0.302	-0.427	-0.003	-0.321
	27	0.172	-0.635	-0.461	-0.053	-0.315	-0.346	0.114	-0.202
	28	0.570	0.404	0.536	-0.047	0.073	0.427	-0.083	0.598
	29	0.049	0.265	0.536	0.063	0.155	0.739	0.285	0.251
	30	0.215	0.633	0.282	0.260	-0.250	0.300	-0.181	0.650
	31	-0.095	0.512	0.018	-0.269	0.414	-0.019	-0.162	0.210
	32	-0.192	0.166	-0.337	-0.127	0.527	-0.386	-0.218	-0.138
	33	0.332	0.173	-0.009	0.796	-0.152	0.173	0.108	0.502
	34	0.363	0.402	-0.034	0.034	0.199	0.037	-0.360	0.657
	35	-0.436	0.089	-0.319	-0.467	0.008	-0.220	-0.478	-0.080
	36	0.248	0.150	-0.110	0.245	0.250	-0.017	-0.181	0.333

(Shaded values represent correlations significant at the 0.05 level, or better)

Pearson Correlations							
13	14	15	16	17	18	19	20
0.407	0.111	0.087	-0.388	-0.337	0.299	0.075	0.000
0.071	0.640	0.506	-0.204	-0.084	-0.443	-0.039	-0.696
0.474	0.351	0.589	-0.385	-0.337	-0.172	-0.118	-0.524
0.270	-0.126	-0.099	0.138	-0.558	0.270	0.106	0.075
0.086	-0.185	-0.139	-0.269	0.000	0.215	0.237	0.262
0.586	0.291	0.644	-0.051	-0.420	-0.100	-0.039	-0.278
0.672	-0.408	-0.184	0.102	-0.475	0.672	-0.275	0.348
0.272	0.105	0.322	-0.255	-0.364	-0.071	0.039	-0.139
1.000	-0.196	0.310	0.086	-0.684	0.566	-0.232	0.293
-0.206	1.000	0.316	-0.175	0.192	-0.638	-0.135	-0.598
0.278	0.406	1.000	0.069	-0.380	-0.504	-0.107	-0.189
0.086	-0.035	0.025	1.000	0.084	-0.043	-0.473	0.577
-0.514	0.257	-0.186	0.031	1.000	-0.401	-0.194	0.000
0.526	-0.665	-0.508	-0.156	-0.443	1.000	0.165	0.469
-0.285	-0.147	-0.094	-0.443	-0.246	0.246	1.000	-0.161
0.369	-0.481	-0.292	0.524	-0.114	0.439	-0.194	1.000
0.573	-0.153	0.648	-0.378	-0.454	0.138	0.094	-0.174
0.176	0.621	0.332	-0.183	0.257	-0.125	-0.046	-0.123
0.041	0.218	0.139	0.458	-0.030	-0.364	-0.604	-0.141
-0.018	-0.558	-0.513	-0.039	-0.497	0.612	0.362	0.115
-0.426	-0.090	-0.388	0.017	0.024	0.237	0.577	0.224
-0.041	-0.532	-0.439	-0.103	-0.363	0.561	0.604	0.141
0.223	-0.288	-0.330	-0.577	-0.115	0.289	-0.213	0.798
0.240	0.736	0.449	-0.413	-0.164	-0.200	0.049	-0.298
0.410	0.014	0.749	-0.111	-0.196	-0.107	0.105	-0.161
0.081	0.865	0.381	0.150	0.133	-0.417	-0.369	-0.296
-0.329	0.199	-0.162	-0.276	0.640	-0.053	0.000	-0.279
-0.267	-0.248	-0.263	-0.331	0.248	0.276	0.357	-0.136
0.327	-0.024	0.190	0.265	-0.624	0.308	0.210	-0.040
-0.282	0.510	0.000	-0.037	0.364	-0.183	0.135	-0.108
-0.420	0.275	0.228	0.332	0.649	-0.680	-0.365	0.201
-0.081	0.565	0.000	-0.083	-0.200	0.000	0.369	-0.115

Pearson Correlations							
21	22	23	24	25	26	27	28
0.423	0.138	0.151	0.397	-0.075	-0.173	0.175	0.483
0.353	0.556	0.057	-0.448	-0.196	-0.492	-0.644	0.424
0.710	0.146	0.171	-0.270	-0.591	-0.494	-0.485	0.511
0.148	0.065	0.067	0.242	-0.106	0.383	-0.050	-0.046
0.115	0.583	-0.960	-0.360	0.296	0.000	-0.277	0.051
0.667	0.266	0.057	-0.329	-0.432	-0.492	-0.368	0.424
0.275	-0.169	-0.011	0.329	-0.196	0.055	0.184	-0.085
0.432	0.604	-0.057	-0.030	-0.039	-0.383	-0.184	0.593
0.629	0.224	-0.010	-0.025	-0.364	0.046	0.155	0.272
-0.135	0.540	0.195	-0.513	-0.067	-0.564	-0.316	0.757
0.640	0.230	0.154	-0.487	-0.373	-0.446	-0.250	0.460
-0.355	-0.182	0.377	-0.090	-0.059	0.000	0.555	-0.409
-0.669	-0.040	0.056	-0.246	0.065	-0.271	0.152	-0.252
0.099	-0.143	-0.240	0.579	0.232	0.599	0.388	-0.243
0.091	-0.056	-0.501	0.346	0.636	0.380	-0.213	0.039
-0.161	-0.099	-0.187	0.123	0.161	0.225	0.756	-0.348
1.000	0.168	-0.132	-0.069	-0.455	-0.211	-0.426	0.275
0.127	1.000	-0.503	0.639	0.056	-0.390	-0.328	0.604
-0.139	-0.374	1.000	0.220	-0.448	-0.110	0.309	-0.057
-0.049	-0.594	0.117	1.000	0.346	0.482	0.324	-0.388
-0.507	0.053	-0.475	0.324	1.000	0.380	0.213	-0.039
-0.200	-0.362	-0.302	0.534	0.475	1.000	0.297	-0.383
-0.387	-0.323	0.315	0.318	0.246	0.197	1.000	-0.184
0.244	0.656	-0.073	-0.388	-0.057	-0.321	-0.202	1.000
0.827	0.088	-0.155	-0.194	-0.371	-0.307	-0.431	0.230
-0.064	0.747	0.250	-0.474	-0.160	-0.545	-0.217	0.633
-0.128	0.532	-0.414	-0.242	0.224	-0.339	-0.497	0.002
-0.211	0.180	-0.527	0.051	0.559	0.527	-0.239	-0.166
0.249	0.080	0.152	0.446	0.063	0.310	0.031	0.007
-0.105	0.614	-0.199	-0.101	0.272	-0.448	-0.158	0.292
-0.266	0.223	-0.008	-0.648	0.035	-0.539	0.054	-0.076
-0.335	0.498	-0.250	-0.092	0.551	0.250	0.000	0.633

Pearson Correlations							
29	30	31	32	33	34	35	36
0.075	0.202	-0.167	-0.293	0.354	0.332	-0.411	0.101
0.275	0.638	0.441	0.154	0.288	0.408	-0.011	0.159
0.650	0.240	-0.038	-0.331	0.102	-0.088	-0.343	-0.120
0.021	0.258	-0.292	-0.131	0.758	0.031	-0.484	0.258
0.118	-0.120	0.645	0.464	-0.204	0.175	0.171	0.120
0.746	0.319	-0.013	-0.374	0.288	0.058	-0.284	0.000
0.275	-0.159	-0.088	-0.242	0.186	-0.291	-0.489	-0.159
0.196	0.638	0.164	-0.154	0.525	0.640	-0.125	0.319
0.430	0.134	-0.202	-0.204	0.500	-0.245	-0.527	0.000
-0.067	0.822	0.216	-0.151	-0.058	0.500	0.195	0.548
0.746	0.325	-0.239	-0.299	0.230	-0.079	0.154	0.000
-0.059	0.120	-0.265	-0.331	0.102	-0.088	0.377	-0.120
-0.583	-0.088	0.353	0.036	-0.811	0.288	0.694	-0.263
-0.165	-0.403	-0.074	0.241	0.329	-0.245	-0.643	0.000
0.091	-0.369	-0.029	0.357	0.196	0.135	-0.342	0.369
-0.081	-0.327	-0.207	-0.181	-0.070	-0.120	0.234	-0.164
0.818	0.000	-0.087	-0.153	0.432	-0.135	-0.395	-0.246
0.056	0.682	0.628	0.220	0.121	0.581	0.178	0.455
-0.132	0.214	-0.566	-0.517	0.125	-0.195	-0.053	-0.214
-0.208	-0.468	-0.333	0.039	0.329	-0.103	-0.541	-0.094
-0.364	-0.185	0.204	0.561	0.039	0.270	0.026	0.554
-0.380	-0.514	-0.365	0.497	0.273	-0.564	-0.477	0.171
-0.426	-0.217	-0.479	-0.239	-0.092	-0.158	0.124	0.000
0.196	0.638	0.013	-0.154	0.119	0.291	-0.125	0.638
1.000	0.000	-0.146	-0.357	0.275	-0.135	-0.132	-0.185
0.036	1.000	0.237	-0.207	0.319	0.548	0.107	0.500
-0.159	0.271	1.000	0.507	-0.239	0.562	0.296	0.000
-0.353	-0.207	0.475	1.000	0.022	-0.076	-0.074	0.207
0.230	0.267	-0.249	-0.059	1.000	0.058	-0.626	0.319
-0.078	0.548	0.629	-0.076	0.117	1.000	0.274	0.274
-0.072	0.185	0.280	-0.051	-0.531	0.271	1.000	-0.214
-0.160	0.500	0.000	0.207	0.267	0.274	-0.170	1.000

## Most Significant Correlations Sorted from Highest to Lowest

Correlation	Questions
0.868	7-10
0.865	30-14
0.856	10-7
0.827	29-21
0.822	14-30
0.818	21-29
0.798	27-20
0.796	33-8
0.758	8-33
0.757	14-28
0.756	20-27
0.749	29-15
0.747	30-22
0.746	10-29
0.746	15-29
0.741	5-12
0.739	29-10
0.736	28-14
0.710	7-21
0.709	12-5
0.694	17-35
0.682	22-30
0.677	15-10
0.672	22-12
0.672	11-13
0.672	11-18
0.667	10-21
0.657	21-7

Correlatio	Questions
0.657	34-12
0.656	28-22
0.650	30-12
0.650	7-29
0.649	35-17
0.648	21-15
0.645	9-31
0.644	10-15
-0.591	7-25
-0.594	24-22
-0.598	14-20
-0.604	23-19
-0.623	25-7
-0.624	33-17
-0.626	33-35
-0.635	27-6
-0.638	14-18
-0.643	18-35
-0.644	6-27
-0.648	35-24
-0.665	18-14
-0.669	17-21
-0.680	35-18
-0.684	13-17
-0.693	20-6
-0.696	6-20
-0.811	17-33
-0.960	9-23
-1.000	23-9