Fall 12-2009

Teaching Science in Light of World View: The Effect of Contextualized Instruction on the Scientific Compatibility of Religious College Students' World Views

Paula Rae Gossard
University of Southern Mississippi

The University of Southern Mississippi

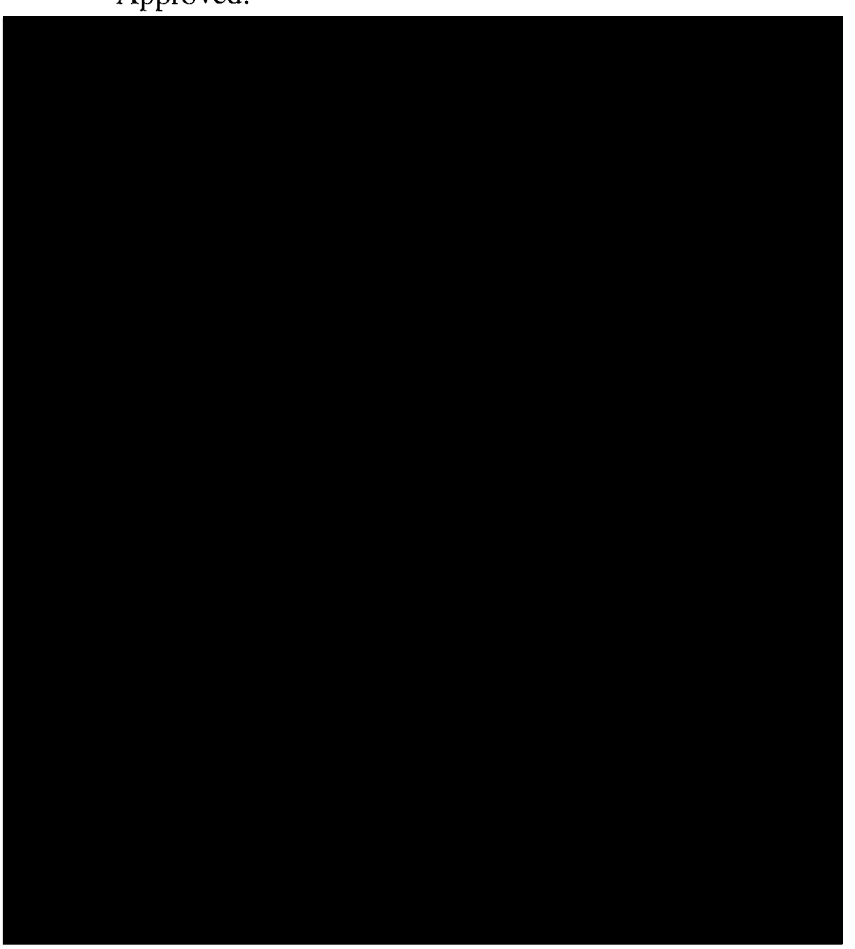
TEACHING SCIENCE IN LIGHT OF WORLD VIEW: THE EFFECT OF CONTEXTUALIZED INSTRUCTION ON THE SCIENTIFIC COMPATIBILITY OF RELIGIOUS COLLEGE STUDENTS' WORLD VIEWS

by

Paula Rae Gossard

A Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

Approved:



December 2009

The University of Southern Mississippi

TEACHING SCIENCE IN LIGHT OF WORLD VIEW: THE EFFECT OF CONTEXTUALIZED INSTRUCTION ON THE SCIENTIFIC COMPATIBILITY OF RELIGIOUS COLLEGE STUDENTS' WORLD VIEWS

by

Paula Rae Gossard

Abstract of a Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

December 2009

ABSTRACT

TEACHING SCIENCE IN LIGHT OF WORLD VIEW:

THE EFFECT OF CONTEXTUALIZED INSTRUCTION ON THE SCIENTIFIC COMPATIBILITY OF RELIGIOUS COLLEGE STUDENTS' WORLD VIEWS

by Paula Rae Gossard

December 2009

Authors of recent science reform documents promote the goal of scientific literacy for all Americans (American Association for the Advancement of Science, 1989, 1993). Some students, however, feel apprehensive about learning science due to perceptions that science is antagonistic to their world views (Alters, 2005; Esbenshade, 1993). This study investigated the effect of an introductory science course taught in the context of a Christian, theistic world view on the scientific compatibility of religious college students' world views. For the purposes of this study, students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation were used as indicators of the scientific compatibility of their world views. One hundred and seventy-one students enrolled in a core curriculum, introductory science course at a Christian university participated in this study by completing pre-instruction and post-instruction survey packets that included demographic information, the Student Understanding of Science and Scientific Inquiry questionnaire (Liang et al., 2006), the Affective Attitude toward Science Scale (Francis & Greer, 1999), and the Origins Survey (Tenneson & Badger, personal communication, June, 2008). Two-tailed paired samples *t* tests were used to test for significant mean differences in the indicator variables at a .05

level before and after instruction. Pearson correlation coefficients were calculated to determine if relationships were present among the indicator variables at a .05 level before and after instruction. Students' self-identified positions regarding creation were analyzed using a chi-square contingency table. Results indicated that there were statistically significant changes in all indicator variables after instruction of the contextualized course. The direction of these changes and shifts in students' self-identified positions regarding creation supported the conclusion that students developed a more scientifically compatible world view after contextualized instruction based on the indicators used in this study. Weak positive correlations were found between nature of science understanding and young earth creation before and after instruction; weak negative correlations were found between nature of science understanding and old earth creation and evolutionary creation before, but not after, instruction. Conclusions, implications for practice, and recommendations for future research are included.

ACKNOWLEDGMENTS

I would like to thank Dr. Sherry Herron, chair of the dissertation committee, and the other committee members Dr. J.T. Johnson, Dr. Gail Russell, Dr. Christopher Sirola, and Dr. Mary Nell McNeese for their advice, support, and encouragement, not only throughout this project, but during many hours in the classroom as well. Appreciation is expressed to Dr. Herron for her enthusiastic faith in my abilities and to Dr. Johnson for his consistent availability during this study. To the authors of the instruments used in this research I extend my gratitude for their gracious generosity and for quick responses to my many emails. Thanks also to Celia Young, whose ability to keep track of multiple graduate students, each with different demands and deadlines, is nothing short of amazing.

Special thanks go to Dr. Todd Williams and Dr. David Vanderpoel for seeing more in me than I saw in myself and for giving me time away from my professional duties over the course of five years to pursue this degree. My colleagues and friends in Virginia, Pennsylvania, and Mississippi deserve recognition for being eager sounding boards as I tried out many dissertation ideas before settling on this one, and for supporting me through the entire process. This study would not have been possible without the participation of students in my Introduction to the Natural Sciences course and I thank them for their help.

No acknowledgement would be complete without recognizing the important role my parents have played in instilling in me a lifelong love of learning and recognition of

the value of hard work. And finally, this degree would have been impossible without the loving support and encouragement of my husband, Carl, who took on four summers of seemingly endless extra work so that I could pursue this dream. *Soli Deo gloria.*

TABLE OF CONTENTS

LIST OF TABLES

Table

CHAPTER I

INTRODUCTION

The condition of science education in the United States has been a subject of discussion for several decades. Many different measures of science achievement demonstrate that despite calls for reform in science education, American students are lagging behind students in other developed countries (Cavanaugh, 2006; National Science Teachers Association (NSTA), 2008). Warning that the United States could be facing an economic, scientific, and technological crisis, the Committee on Science, Engineering and Public Policy called for nearly $10 billion in federal funding in an effort to remedy this situation; much of this money was aimed at improving K-12 science education (Viadero, 2005). Authors of science education reform documents such as *Science for All Americans* (American Association for the Advancement of Science (AAAS), 1989), *Benchmarks for Science Literacy* (AAAS, 1993), and *The National Science Education Standards* (National Research Council (NRC), 1996) emphasize the need to develop scientifically literate citizens. According to these documents, a scientifically literate person understands that science is a human enterprise with strengths and limitations, knows the basic concepts of science, and "uses scientific knowledge and scientific ways of thinking for individual and social purposes" (AAAS, 1989, p. xvii).

Educators and researchers have commented on the use of the word "literacy" in these reform documents. If developing scientific literacy means to promote "scientific ways of thinking," then the authors of these documents presuppose something about the nature of thinking and knowing in science (epistemology) and

the reality of what is being thought about (ontology) (Allen & Crawley, 1998). Whether these presuppositions are clearly understood by scientists, science educators, and ultimately by science students is a valid and important question (Cobern, 1991; Allen & Crawley). Cobern (1996) suggests that the word literacy was borrowed from language literacy, which encompasses not only reading and writing, but also recognizing the cultural context in which a language is understood. A teacher once comforted a frustrated English-speaker who was trying to learn Japanese by saying, "Language is not like math; logic doesn't always help. You must study carefully, using your intuition" (Suzuki & Miura, 2001); this emphasizes that words in one language have unique cultural connotations in another language (Cobern, 1994). To become literate in a second language often means viewing the world in ways that are different from our own.

The development of scientific literacy requires students to develop a second language based upon the presuppositional framework of scientific thinking. Without question, science changes how we view the world. From Copernicus to Einstein, science has changed our ideas about reality and about how we come to know and interpret that reality. According to Cobern (1996), the development of scientific literacy, while an important and worthwhile goal, will only happen when scientific ways of thinking fit "one's sense of self and environment, personal goals and understanding of how the world really is—in short, if one has a scientifically compatible world view" (p. 7). Science educators seek to have students understand, value, and incorporate scientific epistemology in their own lives. The question is how to help students integrate parts of this new way of viewing the world—a scientific

world view—into the world view they already hold, particularly if the two are based on contradictory presuppositions. This introduction looks at religious students' interactions with science education and with science in general, highlighting difficulties that arise for some students resulting from differences in the presuppositions of a scientific world view and a theistic world view. The idea of a scientifically compatible world view will be examined as well and possible indicators for evaluating the scientific compatibility of a world view will be presented. It will be argued that the conceptual change model, which advocates addressing students' scientific misconceptions in order to change them, is not a sufficient model for the development of a scientifically compatible world view and that instruction contextualized within students' pre-existing world views offers a more hopeful alternative for achieving scientific literacy.

Competing World Views and Science Education

A world view is a collection of beliefs, values, and assumptions about the basic nature of reality that gives people an epistemological framework for making sense of the world, persuading them to think, act, and feel in predictable ways (Cobern, 1991; Liu & Lederman, 2007; Tsai, 2001). These beliefs, values, and assumptions about the nature of reality are commonly called world view presuppositions (Cobern; Sire, 1976). Students' world views determine how and what they learn, no matter what the instructor believes he or she is teaching: "In human mental architecture, world view is the foundation upon which one constructs cognitive and perceptual frameworks" (Cobern, p. 21). This makes the topic of world views an important one for educators.

Two world views create confusion in the science classroom: a scientific world view and a theistic world view. These world views are based on conflicting presuppositions. Strict adherence to an entirely scientific world view is called scientism (Francis & Greer, 2001; Fulljames, 1991; Koul, 2006), and is grounded in naturalism, empiricism, and mechanism. Scientists seek natural rather than supernatural explanations of events and observations and deal only with observable phenomena (AAAS, 1989; American Scientific Affiliation (ASA), 2003). In contrast, a theistic world view entertains the existence of a deity or deities in a realm that cannot be empirically verified and recognizes revelation apart from direct sensory input (Sire, 1976; Vlach, 2008). Additionally, Reiss (2008) points out that "many religions give weight to personal and/or institutional authority in a way that science generally strives not to" (p. 162). The role of empirical evidence in the generation of scientific knowledge is a notable distinction from theistic reliance on the authority of a text or religious leader.

A theistic world view encompasses many religious traditions and epistemologies. Christian theism acknowledges one God as described in the Bible, and revolves around four essential theological components: the creation of the universe and all living and nonliving things within it, the fall and resulting corruption of humans, the redemption of humans through the physical death and resurrection of Jesus Christ, and the eventual consummation of a new heaven and a new earth (Blocher, 2004). Students with a Christian theistic world view are the focus of this research; the term "religious" will be used to denote students with a Christian theistic world view, although in other circumstances the term could apply to Hindu or Muslim

students as well. There are also people with a theistic world view who would not necessarily consider themselves religious because of the "living out" of religion that is implied by this word. In this study, religious students are actively involved in regular prayer, Bible reading and study, church attendance, and ministry-related service within their communities

Some religious students feel tension and apprehension when studying science. Esbenshade (1993) observed that "...students [have] concerns about how scientific theories may be related to the religious teachings they believe and the spiritual insights they have. These concerns create an undercurrent of personal and intellectual concern..." (p. 334). One factor complicating religious students' experience with science is a world view based on a literal interpretation of the Bible. Based on a literal interpretation of the Bible, all of creation was completed by God in six, 24-hour days, a view called young earth creationism (Tenneson & Badger, 2008). While not all religious students accept this interpretation of the Bible, those who do so find the billions of years required for biological evolution and supported by geological evidence to be incompatible with their world view. Some students believe that accepting the naturalistic presuppositions of science undermines their beliefs and ultimately leads to non-theistic world views such as philosophical naturalism or atheism (Alters, 2005; Johnson, 1995).

> If they [religious students] learn evolution, this might lead to believing that God does not exist, that God is not responsible for their lives, or that their scriptures are less than accurate. And if these changes in their beliefs were to

> occur, they further believe they will have lost their faith or at least compromised the foundations of their faith. (Alters, 2005, p. 103)

For these students, the epistemology of science is irreconcilable with a theistic world view (Boehlke, Knapp, & Kolander, 2006; Lawson & Weser, 1990). Religious students, particularly those at the college level, try to integrate their learning with their world view to form a consistent and cohesive whole (Alters). For many students, the perceived conflict between their world view and science produces a classroom experience that is, "simply overwhelming academically, emotionally, and spiritually" (Alters, p. 105). Religious students are often reluctant to learn about science because they perceive the subject as antagonistic to their deeply held beliefs and values (Alters; Sinclair & Pendarvis, 1998; Sinclair, Pendarvis, & Baldwin, 1997). Some science educators say that this antagonistic view of science and religion comes from a lack of understanding of the nature of science and the process of scientific inquiry (Schroeder, 2006); others say that religious students hold non-scientific misconceptions and that teaching for conceptual change will help these students resolve their discomfort (Demastes, Good, & Peebles, 1995).

Conceptual Change and Scientific Compatibility

A brief review of science education literature reveals the application of the conceptual change model to correcting scientific misconceptions about varied topics, from mixtures and chemical compounds (Costu, Unal, & Ayas, 2007) to Lamarckian conceptions about natural selection (Geraedts & Boersma, 2006). Within the constructivist theoretical framework from which the conceptual change model emerged, learning is said to occur by a series of changes to a pre-existing cognitive

framework, brought about by rational evaluation of new experiences, information, or concepts (Cobern, 1996; Demastes et al., 1995; Posner, Strike, Hewson, & Gertzog, 1982). Students bring beliefs and ideas to the science classroom that differ from those of the scientific community. These preconceptions arise from prior school learning or students' interactions with the social or physical world (Posner et al.). To bring about conceptual change, instructors are encouraged to identify students' preconceptions, provide a mechanism that forces students to confront their preconceptions and evaluate their usefulness in light of a new situation or information, and finally, to help students reconstruct their cognitive framework, internalizing their new understanding (Committee on Undergraduate Science Education, 1997). Students who have gone through the process of conceptual change should arrive at a more scientifically superior conception, i.e., a conception that is more intelligible, plausible, and fruitful (Cobern).

A major critique of the conceptual change model is that beliefs are sometimes treated as scientific misconceptions (Hokayem & BouJaoude, 2008). Research on conceptual change related to biological evolution shows that this model is ineffective in changing students' cognitive frameworks when the perceived preconception has a strong belief component. Students learn evolutionary theory, for example, but they often do not change their beliefs about creation (Chinsamy & Plaganyi, 2007; Lawson & Weser, 1990; Sinclair et al., 1997). As evidenced by these studies, "comprehension does not necessitate apprehension" (Cobern, p. 592). Researchers are recognizing the influence of students' world views on learning and suggest that "rational arguments are not sufficient to cause conceptual change as would be the case with

preconceptions that do not have religious undertones" (Hoyakem & Boujaoude, 2008, p. 397). Cobern (1991, 1994, 1996) and others contend that the conceptual change model is an inappropriate approach to science education because it seeks to promote scientific understandings as superior to previously conceived, common sense world views that serve a different, but not necessarily inferior, purpose (Anderson, 2007; Eisen & Westmoreland, 2009). Cobern (1996) argues that:

> Conceptual change instruction is intended to foster a scientific view of the world. This goal is wrong-headed. Science needs to be joined with the other school disciplines in the common goal of developing student world views of which science is one articulated component. (p. 579)

In addition to scientific preconceptions, students are wrestling with conflicting world view presuppositions and, based on the research literature, asking them to adopt conceptual change that has no meaning within their world view is ultimately fruitless.

If the goal of science education is to foster a scientifically compatible world view and not a strictly scientific world view, then science education should "teach scientific understanding within the actual worlds in which people live their lives" (Cobern, p.589). This implies that science education may be most effective when contextualized within students' own world views. Thus, the purpose of this research is to investigate whether a contextualized instructional methodology that makes evident the presuppositions of both scientific and theistic world views will promote greater scientific compatibility of religious college students' world views. The indicators of scientific compatibility that will be used in this study are taken from the contention that, "science education should foster presuppositions that allow for the

possibility of science understanding and positive attitudes toward science, i.e., a scientifically compatible world view" (Cobern, 1991, p. 66). Accordingly, students' understanding of the nature of science and their affective attitudes toward science will be two indicators of a scientifically compatible world view used for this study. Because the literature reflects a lack of correlation between acquisition of scientific knowledge and changes in religious students' beliefs about creation, such belief changes would be noteworthy. Thus, changes in students' beliefs about creation will be examined as third indicator of the changing scientific compatibility of their world views. Because these indicators are not themselves world view presuppositions but rather are predicated upon such presuppositions, they are useful only as secondary, not primary, indicators of students' world views (Hermann, 2007).

Research Question

What is the effect of contextualized instruction on the scientific compatibility of religious college students' world views? For the purposes of this study, the scientific compatibility of students' world views will be inferred from students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation.

Research Sub-problems

1. Are there significant mean differences in students' understanding of the nature of science before and after instruction of the contextualized science course?
2. Are there significant mean differences in students' affective attitudes toward science before and after instruction of the contextualized science course?

3. Are there significant mean differences in students' beliefs regarding creation before and after instruction of the contextualized science course?

4. Are students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation related before instruction of the contextualized science course?

5. Are students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation related after instruction of the contextualized course?

Research Hypotheses

1. There are statistically significant mean differences in students' understanding of the nature of science before and after instruction of the contextualized science course.

2. There are statistically significant mean differences in students' affective attitudes toward science before and after instruction of the contextualized science course.

3. There are statistically significant mean differences in students' beliefs regarding creation before and after instruction of the contextualized science course.

4. There are statistically significant relationships among students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation before instruction of the contextualized course.

5. There are statistically significant relationships among students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation after instruction of the contextualized course.

Delimitations

1. This research is limited in scope to college students who profess to have a Christian theistic world view as evidenced by their agreement with the university's statement of faith, which is a condition of acceptance to the university.
2. Because the effect of a particular contextualized science course is being examined in this study, the research is limited to those students enrolled in the course.
3. This study does not examine the extent or degree of changes in students' world views, but seeks only to identify if changes are present based on the chosen indicators of a scientifically compatible world view.
4. There may be other indicators of the scientific compatibility of religious students' world views, but this study is limited to the three presented in this introduction.

Definition of Terms

Atheism: belief that God does not exist (Kemering, 2006)

Affective attitude: the feelings that a person has about an object, based on his or her knowledge and belief about that object (Kind, Jones, & Barmby, 2007)

Creation: the biblical teaching about God creating all that exists out of nothing (Latin: *creatia ex nihilo)* as found in the book of Genesis (Haarsma & Haarsma, 2007).

Constructivism: a theory of learning that says: 1) knowledge is not passively received but actively built up by the cognizing subject and 2) the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality (von Glasersfeld, 1989)

Empiricism: reliance on sense experience or data as the source of ideas and knowledge (Kemering, 2006)

Epistemology: the study of the possibility, origins, nature, and extent of human knowledge (Kemering)

Evolution/Biological evolution: a process that results in heritable changes in a population spread over many generations or any change in the frequency of alleles within a gene pool from one generation to the next (Scott, 2004)

Mechanism: belief that science can explain all natural phenomena in terms of the causal interactions among material particles, without any reference to intelligent agency or purpose (Kemering)

Naturalism: belief that all objects, events, and values can be wholly explained in terms of factual and/or causal claims about the world, without reference to supernatural powers or authority (Kemering)

Nature of science: a way of knowing, or the values and beliefs that are inherent to the development of scientific knowledge (Lee, 2007)

Ontology: a branch of metaphysics concerned with identifying, in the most general terms, the kinds of things that actually exist; explicit assertions and implicit presuppositions about the reality of entities, substances, or beings (Kemering)

Presuppositions: first-order assumptions which are by their nature neither true nor false, verifiable nor unverifiable (Kearney, 1984)

Scientism: the view that scientific methods and scientific theories can attain to absolute truth (Fulljames, 1991)

World view: A world view is a collection of beliefs, values, and assumptions about the basic nature of reality (Cobern, 1991)

Young earth creation: God suddenly made the physical realm and life out of nothing in six consecutive 24-hour periods between 8,000 and 10,000 years ago (Tenneson & Badger, 2008)

Assumptions

1. Participants responded honestly and thoughtfully to all survey questions.
2. Participants honestly agreed to the university's statement of Christian faith and can thus be assumed to hold to a biblically-based Christian theistic world view.
3. The participants in this study are representative of the population of college students currently enrolled in universities in the United States who hold a Christian theistic world view.
4. The participants in this study are generally reflective of the population of college students currently enrolled in universities in the United States apart from world view differences.

The Importance of the Study

Nearly half of all Americans express the belief that humans have not undergone any evolutionary development; almost as many reject evolutionary theory in favor of a biblical account of creation. One hundred million American, almost one-third of the U.S. population, identify themselves as fundamentalist Christians. Ninety percent of Americans are associated with religious congregations and 70% say they pray at least once a week (Eisen & Westmoreland, 2009). The multiyear National Study of Youth and Religion suggests that a substantial majority of 12th graders

mirror the U.S. adult population, having a belief in God and a connection to an established religious community (Anderson, 2007). Based on these statistics, students with theistic world views are arguably found in every college science classroom in the United States. Science education research shows that while these students comprehend much of what they are taught about science as a valuable way of thinking and knowing, they are not apprehending this knowledge (Cobern, 1996). Science education reform documents emphasize the need to develop scientifically literate citizens (AAAS, 1989, 1993; NRC, 1996). With this goal in mind, and as the U.S. searches for ways to remain competitive in the modern world of rapidly advancing science and technology, the question of how to reach this group of religious students becomes ever more important.

Of greater consequence to some educators than students' eventual instrumental value as scientists or technicians is the development of college students as individuals. According to Donnelly (2006), the purpose of liberal arts education is the intellectual development of students. The contribution of science education to this development should be based on the distinct epistemology of science: "To have a knowledge of science and its particular mode of understanding the world as a significant and distinctive form of human intellectual activity is part of what it is to be educated" (Donnelly, p. 625). To understand the distinctive nature of scientific thinking, it is necessary for students examine the world view presuppositions not only of science, but also of their own world views and of other world views to which they are exposed. The goal is for students, "especially in the 21st century global landscape,

[to] be able to identify and critically evaluate conflicting world views" (Eisen & Westmoreland, 2009, p. 23).

This study is important for several reasons. First, it collects baseline data about understanding of the nature of science, affective attitudes toward science, and beliefs about creation of a particular group of religious college students. This establishes a basis of comparison for other groups of similar college students in future research. The effect of world view contextualized instruction on students' understandings, attitudes, and beliefs has not been reported in the current literature. If such instruction is found to be effective in promoting a more scientifically compatible world view among religious college students, it will provide further rationale for approaching science education from a world view perspective in an effort to achieve scientific literacy. Finally, this study is important because it assists a unique group of students who have struggled to incorporate their religious beliefs with their science learning, and provides for them a potential mechanism by which to develop a coherent and cohesive world view.

CHAPTER II

LITERATURE REVIEW

This study investigated the effect of contextualized instruction on the scientific compatibility of religious college students' world views. This review begins with an examination of the literature on world views and the interaction between science and religion, with particular attention paid to the relationship between world views and science education and the differences between Christian theistic and scientific world views. A brief discussion of the scientific compatibility a world view is also included. For the purposes of this study, students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation were chosen as indicators of the scientific compatibility of their world views. Thus, this review also reports on the existing understandings and currently accepted theoretical frameworks regarding the nature of science, attitudes in general, attitudes toward science in particular, and Christian beliefs regarding creation. Finally, existing research on contextualizing instruction in light of students' world views will be reviewed.

World Views, Science, and Religion

Defining World View

World view, taken from the German word *Weltanschauung*, is described as a set of beliefs, values, or assumptions about the nature of reality that forms the frame of reference by which a group of people makes sense of the world (Liu & Lederman, 2007; Tsai, 2001). Cobern (1991) defines a world view as "a culturally dependent, implicit, fundamental organization of the mind" (p. 19). A person's world view influences his or her cognitive processes, learning style, decision making, interpretation of natural

phenomena, and construction of perceptual frameworks (Cobern, 1991; Liu & Lederman, 2007; Tsai, 2001). Founded upon presuppositions that may or may not be explicitly acknowledged or articulated, a world view provides an epistemological standard upon which thinking is based (Tsai).

Formation of a World View

All people interact with the world around them and thus, all people develop a world view (Proper, Wideen, & Ivany, 1988). The formative, childhood years are most instrumental in world view formation. As children interact with their social and physical environment, they gradually, and mostly unconsciously, develop world view presuppositions (Cobern). World view presuppositions are not necessarily accurate, yet they provide a rational, coherent, consistent way of understanding the world (Kearney, 1984) and incline a person to think and act in predictable ways (Cobern, Proper et al.). Formal education contributes explicitly to the process of world view development and, since science teaching deals directly with the physical environment, it plays a particularly important role in shaping a student's world view (Proper et al.). In adulthood, a person's world view becomes less flexible to allow for cognitive stability, but still serves an adaptive function in the face of new environments and experiences. While world view presuppositions are strongly held, they are "not immutable" (Cobern, p. 21) and are subject to evolution and change. Anderson (2007), however, says that such changes are small and occur over long periods of time. Although presuppositions are rarely explicitly stated or examined, they provide the fundamental structure and content of a world view.

World View Structures

Several frameworks for describing world views have been proposed, beginning with what Pepper (1961) called world hypotheses, that is, hypotheses that people have and use about the world itself. Pepper proposed six world hypotheses, each based on its own root-metaphor, a commonsense metaphor that explains phenomena encountered in daily life (Kilbourn, 1984). According to Pepper, the six primary ways people interpret and structure their experience are animism, mysticism, formism, mechanism, contextualism, and organicism. The two world hypotheses most closely related to this study are animism, including theism and Christian fundamentalism, which is based on the root-metaphor of spirit, and mechanism, which is based on the root-metaphor of a machine. While Pepper's world hypotheses form the historical foundation for world view studies, subsequent frameworks are more applicable to this current research.

Additional approaches to classifying world views as proposed by Roberts and Aoki were reported in Proper et al. (1988). Roberts presented three modes of explanation within which world views can be categorized: the magical, the religious, and the scientific. Aoki categorized world views by their related epistemologies to arrive at three orientations for knowing: empirical-analytical, situational-interpretive, and critical. Sire (1976) catalogued seven world views based on the conception held by each of the nature of external reality and prime reality, the nature of humanity (human life, death, and purpose), the nature of knowledge and what it means to know, and the nature of morality. Sire's catalog of world views includes Christian theism, deism, naturalism, nihilism, existentialism, Eastern pantheistic monism, and new consciousness.

Kearney (1984) presented a systematic logico-structural model of world views based on fixed world view universals which are populated by varying world view presuppositions. Kearney presents a medical analogy which is useful in understanding this model. A physician has a list of several parameters or universals such as blood pressure, temperature, pulse, and respiration which form a common framework for all patients. Each patient's particular vital signs are examined and understood within this framework. Similarly, every world view has a common structure or framework composed of seven world view universals. Kearney's seven world view universals are Self, Non-self or Other, Classification, Relationship, Causality, Space, and Time. Presuppositions are the content of these seven, universal categories much as a patient's vital signs are the content of the physician's medical framework. According to Kearney's model, the specifics of the presuppositions within and between these universals differ from person to person. The composite of these categories forms a person's world view (Cobern, 1991; Kearney, 1984). To illustrate how an identical universal can be populated with differing presuppositions, the world view universal Self exhibits significant differences in presuppositions between the world views relevant to this research:

> The biblical man's sense of self-identity was tied to his belief in an omnipotent and more or less benevolent deity who...elevated [man] to a special place among God's creatures. The scientific response...amounted to a shift from an image of Self as subject under God to an image of Self as having mastery over nature through understanding of her laws. (Kearney, p. 133)

Based solely on examining this single universal, it becomes evident that there is divergence between a scientific world view and a Christian theistic world view. These two world views will be contrasted more completely in the next section.

Christian Theistic and Scientific World Views

Every person has a world view that is comprised, in part, of their understanding of the nature of reality and the nature of knowledge (Anderson, 2007). Although most people never clearly articulate their world views, their lives operate within a framework that is deep-seated, relatively stable, and foundational. According to many of the researchers cited earlier in this review, there are just a few basic world views. For the purposes of this study, it is important to recognize the characteristics of a Christian theistic world view and of a scientific world view. A Christian theistic world view tries to "provide a comprehensive explanation of reality that is rooted in the word of God [the Bible]" (Thiessen, 2007) and is generally recognized as encompassing the following tenets (Blocher, 2004; Christian Apologetics Research Ministry (CARM), 2009; Sire, 1976):

1. God exists and is infinite, sovereign, and personally knowable.
2. God created an orderly, intelligible, and changing universe. God exists apart from this universe.
3. The unseen, supernatural world is as real as the physical world.
4. Humans were created in the image of God with personality, creativity, and morality.
5. There is continuation of some part of human life after death.
6. Ethics originate in the nature and character of God.

7. History is the progressive fulfillment of God's purpose for people.

8. Truth about God, mankind, and the creation are found in The Bible.

In contrast, the characteristics of a naturalistic scientific world view include (Cobern,1991; Liu & Lederman,2007; Sire, 1976):

1. Matter and energy are all that exist.

2. The universe is a closed system, operating by fixed laws according to natural processes.

3. Personality is a complex relationship of physical and chemical properties.

4. Death is the end of personality and individuality.

5. The events of history are related by cause and effect, but have no overarching purpose.

6. Ethics are a human construction based on needs and interests.

7. Knowledge about nature is obtained through testable hypotheses based on empirical data.

It is not possible for one person to simultaneously subscribe to both of these world views in their entirety. As frameworks for understanding the nature of reality and the nature of knowledge, they contain mutually exclusive statements. The interaction between these two world views is considered in the next section with an examination of the literature addressing science and religion.

The Interaction between Science and Religion

Science and religion are different. Although most people understand this fact, many people have trouble explaining the nature of the difference (Skehan, 2000) probably because each is difficult to define in its own right. For the purposes of this

review, science simply refers to the empirical study of the order of nature (Barbour, 1990). Defining religion concisely has confounded many scholars, but can be considered "any specific system of belief about deity, often involving rituals, a code of ethics, a philosophy of life, and a world view" (Robinson, 2007). Without question, scientific ideas have had a transformative effect on religious world views over the past several hundred years (Harrison, 2006). Many books have been written about this interaction, which is complex and often controversial. These works usually cite the conflict between Galileo and the Catholic Church as one of the earliest examples of conflict between science and religion (Barbour; Hutchinson, 1993; Skehan, 2000). As the nature of the epistemology of science changes from positivism (a philosophy that holds that the only authentic knowledge is based on sense experience) to an understanding of scientific knowledge as tentative and theory-laden (influenced by the theories held by working scientists), the nature of the interaction between science and religion also changes. Conflict is no longer the only option, but is one end of a continuum along which scientists, theologians, and philosophers place different views of this interaction (Barbour; Harrison). Three basic positions along the science-religion continuum will be described. Research shows that religious students are found occupying each of these positions and probably inhabit intermediate positions not explicitly described here (Roth & Alexander, 1997; Tsai, 2001).

Antagonism (Conflict). The antagonism (or conflict) view says that science and religion exist in a state of competition and outright conflict (Barbour; Harrison). At one end of the spectrum is scientific naturalism (or scientism), which makes two fundamental claims: (a) scientific inquiry is the only reliable source of knowledge; and (b) matter and

energy are the only fundamental realities in the universe. The assumption is that scientific inquiry produces genuine knowledge because scientists study real objects to produce claims that are publicly verifiable and reproducible. These claims are tested against experimental observations; explanations that are comprehensive with predictive power are accorded status as real knowledge. According to this view, religion is comprised of superstitious beliefs about non-material, supernatural objects as opposed to real knowledge about real objects. Science is seen as "objective, open-minded, universal, cumulative, and progressive....religious traditions are said to be subjective, closed-minded, parochial, uncritical, and resistant to change" (Barbour, 1990, p. 5).

A reductionist point of view characterizes many scientific materialists including Carl Sagan, now deceased, and E.O. Wilson who believes that all phenomena in the natural world (including human behaviors that seem to deny evolutionary explanations such as religious beliefs and altruism) will eventually be explained solely in terms of "the actions of material components, which are the only effective causes in the world" (Barbour, p. 4). This view is in direct conflict with a theistic world view that says there is an unseen deity acting outside the realm of empirical evidence and that human life itself is not reducible to chemical reactions or material components, but is invested with an unobservable soul or spirit.

At the other end of the spectrum, yet sharing common characteristics with scientific materialism, is biblical literalism. Much as scientific materialism defines matter and energy as the ultimate reality, biblical literalists define absolute reality as infallible truth that is found in the Bible. When the claims of science conflict with the claims of scripture, biblical literalists reject the claims of science based on their view that absolute

truth about reality lies in the Bible. This poses significant problems for science students, who feel there is an "either/or" choice between some theories (such as evolution) and their religious beliefs (Sinclair & Pendarvis, 1998). Such a position interferes with learning science (Roth & Alexander, 1997).

Independence. The independence view of the relationship between religion and science suggests that there is no conflict between the two because they belong to different domains with different subject matter. The National Academy of Sciences (NAS, 2008) espouses this view saying, "Science and religion are based on different aspects of human experience....Attempts to pit science and religion against each other create controversy where none needs to exist" (p. 12). Science investigates value-neutral facts about the observable world, deals in objective reality, and is interested in prediction and control. Religion, on the other hand, makes evaluations regarding the world to arrive at values and meanings, to make recommendations about a way of life, and to encourage allegiance to certain moral principles (Ayala, 2000; Barbour, 1990; Harrison, 2006). "Some would say that science deals with the "how" questions and religion deals with the "why" questions" (Anderson, 2007, p. 666). The late Stephen Jay Gould (1997), Harvard University paleontologist, noted public proponent of evolution, and self-proclaimed agnostic advocated this point of view and referred to science and religion as non-overlapping magisteria (NOMA):

> 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. (n.p.)

The independence view concludes that science and religion both make claims about the real world, but from different perspectives, serving different, but equally valid functions. Once criticism of this viewpoint is that it does not provide the integrated, overarching explanation of the diversity of human experience that some people seek (Barbour, 1990; Harrison, 2006).

Complementarity (Dialogue). In the complementarity view, science and religion are components of an integrated world view, within which each contributes to the other. "The hope of those adopting this particular approach is that the claims of modern science and those of traditional religion can be rendered mutually coherent" (Harrison, p. 360). Roth and Alexander (1997) showed that when dialogue is properly encouraged in the classroom, "there are ways in which science and religion can be accommodated by one and the same person without leading to problematic and incoherent constructions of Self" (p. 143). Changing conceptions of the nature of science have called into question the historically sharp contrast between objective science and subjective religion. The theory-laden nature of scientific findings, along with the creative nature of theory development, means that scientific epistemology is no longer viewed as objective and positivistic, but as subjective, tentative, and subject to change. That there are multiple accepted interpretations for the behavior of subatomic particles in quantum mechanics illustrates the tentative nature of interpreting seemingly objective empirical data. Many current scientific models are conceptual representations of material objects such as atoms or quarks that have never been directly observed. In these respects science is not significantly different from religion. According to Barbour, metaphors and models are prominent in religious language and also describe things that are not seen. The scientific

criteria for judging the worth of theories (how well they explain what is observed, how well they tie new knowledge to previous knowledge, and the degree of their predictive power) have parallels in theological explanations and understandings of human experience. Barbour (1990) quotes the philosopher Holmes Rolston who said, "Religious beliefs interpret and correlate experience much as scientific theories interpret and correlate experimental data" (p. 23). In these respects, science and religion can be seen as having a complementary relationship.

A Scientifically Compatible World View

In science education reform documents, an oft-stated goal for American students is the development of a scientific world view (AAAS, 1989, 1993; NRC 1996). Cobern (1991), however, says it is a misnomer to speak of a scientific world view unless these documents are advocating the development of strict naturalism or scientism as an appropriate goal of science education. This goal would be almost impossible for religious students to achieve. Hermann (2007) found that a strong religious world view was highly correlated with a weak scientific world view. In attempting to find middle ground, where scientific literacy can exist within two different world views, perhaps it is better to speak in terms of the development of a scientifically compatible world view (Cobern). What might a scientifically compatible world view look like?

Smith and Scharmann (1999) speak about claims, questions, and fields of study as being more scientific versus less scientific rather than strictly delineating between scientific and non-scientific. Likewise, it seems that a world view can be said to be more or less scientifically compatible without necessitating a strict delineation into completely opposing camps. A person with a more scientifically compatible world view would

understand and value the characteristics that make any question or field of inquiry *more* scientific, namely: the importance of empirical evidence supporting testable hypotheses, the self-correcting (tentative) nature of scientific inquiry, and the explanatory and predictive power of theories that demonstrate coherence with other knowledge (Smith & Scharmann, 1999). People behave more scientifically if they seek answers to questions that have scientific characteristics, remain open-minded about and skeptical of their conclusions, and are impartial and objective in analyzing their data (Smith, 1994). Additionally, a person with a more scientifically compatible world view would recognize those characteristics that make a question or field of inquiry *less* scientific including: resorting to supernatural causes or explanations for physical phenomena, valuing authority (e.g., the Bible) over evidence, and valuing faith over reason (Smith & Scharmann). It is important to note that these latter are not negative values or explanations; they are simply not *scientific* values or explanations.

To the extent that people recognize what does and does not properly fall within the realm of scientific inquiry, these people can be said to demonstrate a more or less scientifically compatible world view. For example, according to this description, a biblical literalist holding an antagonistic view of science and religion displays a less scientifically compatible world view. A biblical literalist does not acknowledge the validity of scientific evidence if the resulting scientific claims conflict with a literal interpretation of scripture; instead the authority of text is valued over the authority of evidence. Persons with an independent or complementary view of science and religion may demonstrate a more scientifically compatible world view based on their apparent understanding of the nature of science, the respect accorded to valid scientific theories

and evidence, and their acceptance of the possible integration between scientific findings and their religious faith.

World Views and Science Education

The direct interaction of world view and science education was not studied until relatively recently, although because of the pervasive influence of a person's world view, its effects on learning have been studied peripherally for decades (Proper et al., 1988). A group of early studies focused on world view implicit in science curriculum, also called the "hidden curriculum" (Kilbourn, 1984). Ausubel (1966) critiqued two BSCS (Biological Science Curriculum Study) biology texts and found that they contained a mechanistic bias her described as bordering on polemic. Kilbourn analyzed a Canadian biology text using Pepper's world hypotheses with similar results (Proper et al.). The consistent conclusion of studies of this type was that scientism, "the assumption that science designates the true and ultimate way to solve the problems of nature and man" (Proper et al., p. 548), was being actively promoted, and yet was rarely expressed explicitly to the students. Researchers strongly criticized this hidden curriculum, claiming that promoting, but not acknowledging, the narrowness of this world view severely and perhaps unethically (Kilbourn) limited students' abilities to understand and interpret their life experiences (Proper et al.).

Other investigations of world views and science education focused on the world views of teachers and students and the effect of these world views on various aspects of the classroom learning environment. Proper et al. analyzed the types of world views presented by science teachers and the ways in which these world views were presented. Their findings indicated that teachers communicated scientism explicitly through the

content of their courses and implicitly through the manner and attitude with which they taught. Tsai (2001) studied Taiwanese students' ideas about the origins of earthquakes soon after a severe earthquake shook their hometown and found that these ideas were strongly related to the students' world views. Even after explicit instruction about the natural causes of earthquakes, students retained world view beliefs about the causality of earthquakes that were related to supernatural myths and forces. This study added support to the abundance of evolution-related research concluding that students retain world view beliefs even in the face of explicit instruction and scientific evidence about natural phenomena contrary to their beliefs (Lawson & Weser, 1990; Lawson & Worsnop, 1992; Tsai).

Another body of research investigated the effects of world view differences on science education in unique cultural settings (Allen & Crawley, 1998; Waldrip, Timothy, & Wilikai, 2007). In two ethnographic studies, Native American Kickapoo students and school-aged Melanesian villagers were described as experiencing difficulty with border crossing, which is the attempted integration of scientific knowledge with a cultural world view in which scientific understanding has little relevance, importance, or coherence (Aikenhead in Allen & Crawley). In both studies, students held culturally-dependent world views that prevented them from being successful in the science classroom (Allen & Crawley; Waldrip et al.). The researchers concluded that to facilitate learning of relevant science skills and understanding, students' world views must be explicitly acknowledged along with those of the instructor and the scientific world view he or she is attempting to present (Allen & Crawley). Further recommendations included that teachers understand and explicitly teach the nature of science and that textbooks, since they so often are

considered authoritative by students, be examined for world view biases which should be made explicit to the students. Conclusions drawn from this cross-cultural research have relevance for students with a theistic world view. The considerable difference between scientific and theistic world views requires religious students to experience border crossing between two world views in a manner similar to that of cross cultural students.

Recommendations for Teaching Science to Religious Students

Sinclair and Pendarvis (1998) recommended several practical, research-based strategies for helping religious students resolve the tension they experience between their beliefs and science in the classroom. First, science teachers should not ignore students' beliefs, but should encourage open discussion of those beliefs and whether they do or do not cohere with a scientific epistemology (Scharmann, 1993). Second, instructors should present a more "human" side by being willing to discuss their own personal resolution of these issues (Esbenshade, 1993). Next, student preconceptions, whether of religious origin or not, should be addressed explicitly and precisely, preferably with instructional approaches that promote honest, intellectual questioning. Finally, the idea of "teaching less, better" (AAAS, 1989) should be applied to the sequencing and integrating of instruction when potentially contentious issues are being discussed, particularly when teaching evolutionary theory.

Within the context of excellent instruction, Nelson (2000) also suggested integrating science and religious beliefs by explicitly addressing the acceptance of scientific findings, particularly those regarding evolution, by various theologians and religious organizations in order to lessen students' perceptions that either science or their religion is accurate. For example, he suggests that students be assigned

theological readings illustrating the legitimacy and importance of intermediate positions along a faith-science world view continuum. Students can also be exposed to young earth creation, old earth creation, and evolutionary creation so they realize that "creationism" is not one, monolithic belief (Tenneson & Badger, 2009). As Liu and Lederman (2007) postulated, "People with different world views probably have concurrently different views about science; such differences need to be acknowledged and incorporated into the science curriculum" (p. 1301).

Cobern (1991) urged that the goal of science education should be to "foster presuppositions that allow for the possibility of science understanding and positive attitudes toward science, that is, a scientifically compatible world view" (p. 66). Based on this urging, the researcher chose to investigate three possible indicators of the scientific compatibility of students' world views: 1) students' understanding of the nature of science (Cobern; Tsai, 2001); 2) students' affective attitudes toward science (Cobern); and 3) students' beliefs regarding creation (Hermann, 2007). The latter was selected because it indicates the degree to which a person values the textual authority of the Bible over the authority of scientific evidence. To continue the review of the literature, these three indicators will be considered in more depth.

The Nature of Science

The Nature of Science Defined

John Dewey observed that understanding the scientific method is more important than the acquisition of scientific knowledge (McComas, Clough, & Almazroa, 2002). By "scientific method," Dewey meant the way in which science is done, known today as the "nature of science." Authors and researchers agree that the nature of science is the realm

where the philosophy, sociology, history, and psychology of science intersect to describe how scientists work and how science interacts with and is directed by society (Lee, 2007; Liu & Lederman, 2007). In some senses, it is the "social studies of science" (McComas et al., 2002, p. 5). Despite disagreement between philosophers of science (Elfin, Glennan, & Reisch, 1999) and scientists (Ryder, Leach, & Driver, 1999; Schwarz & Lederman, 2008), there is consensus among science educators about the tenets that define the nature of science as evidenced by international science reform documents (McComas & Olson, 2002): scientific knowledge is tentative but durable, empirically based, subjective, partly the product of human creativity and imagination, and socially and culturally embedded (Abd-El-Khalick et al., 1998; Lee; Liang et al., 2006; Liu & Lederman; McComas et al.; Osbourne, Collins, Ratcliffe, Millar, & Duschl, 2003; Schwartz & Lederman). These tenets are discussed in greater detail below based on the work of the researchers cited here.

Tentative but durable. Scientific knowledge is both tentative and durable. As new observations are made, theories may be revised or discarded completely based on new evidence. The process of scientific inquiry gives us confidence in theories, while allowing for the application of scientists' changing understandings. As Liang et al. (2006) observed, "The history of science reveals both evolutionary and revolutionary changes" (p.7). Change occurs slowly, however, and in small increments, accounting for the durable nature of scientific understandings.

Because science is frequently perceived as a body of immutable truths, changes in scientific theory can cause people to question the validity of the entire scientific enterprise. People who understand the tentative nature of science will be less cynical

about science and less inclined to dismiss entire bodies of knowledge because of the changing nature of particular theories (Anderson, 2007). "Perceiving science as a process of improving our understanding of the natural world [instead of an uncertain enterprise] turns the notion of tentativeness into a strength rather than a weakness" (McComas et al., 2002, p. 27).

Empirically based. Scientific knowledge is based on scientists' observations of the natural world and the phenomena seen in that world. Although science relies heavily upon observation and experimentation, there is no one correct scientific method. Scientists may use the traditional question-hypothesis-experiment-conclusion method of investigation, but they are equally likely to make inferences from historical or strictly observational data. No matter what method is used, scientists value accurate record keeping, verifiable data that is publicly reported, and peer review of their conclusions.

Subjective. All scientists, while trying to remain objective and precise, bring a theoretical perspective to their work. Hence, all scientific questions, observations, experiments, and explanations are framed by scientists' previous understandings. This is what is meant by science being "theory-laden."

Creative and imaginative. Scientists raise questions, develop methods to investigate those questions, and formulate inferences based on their observations of the natural world. These processes, while objective and based on prior knowledge, are inherently creative and rely on the scientist's imagination.

Socially and culturally embedded. Science influences culture and is, in turn, influenced by the values and expectations of the culture in which it is practiced. People of

all cultures are scientists and their social and cultural traditions impact the nature of their work.

Scientific theories and laws. Instruction about the nature of science should also clarify the difference between scientific theories and laws. Despite the current tendency to use the word theory synonymously with "guess," scientific theories are not guesses, but are well-substantiated explanations of some part of the natural world. Scientific laws, on the other hand, are generalized descriptions of phenomena in the natural world. Theories explain; laws describe. Theories do not ever become laws, no matter how much new evidence is gathered to support the theory; both, however, are subject to change based on new observations.

Misconceptions about the Nature of Science

Misconceptions about the nature of science have been reported for many populations including primary school students, college graduates, scientists, science teachers, pre-service science teachers, and science majors (Abd-El-Khalick et al., 1998; McComas, 2002; Ryan & Aikenhead, 1992; Ryder et al., 1999). Based on the responses of over 2000 Canadian high school junior and seniors, Ryan and Aikenhead concluded that students could not distinguish between science and technology; were not aware of the effect of values on science; expressed a hierarchical relationship between hypotheses, theories, and laws; did not understand the social and creative nature of science; and thought there was just one correct scientific method. McComas listed fourteen widely held myths regarding the nature of science, including: scientific laws are absolute and unchanging; data that is carefully gathered will result in sure knowledge; science and its methods produce absolute proof; and science and its methods can answer all questions.

Cobern (1991) and Tsai (2001) suggest that students' understanding of the nature of science may be closely related to the scientific compatibility of their world views but that the exact nature of this relationship is not known.

The Importance of the Nature of Science

While researchers have not investigated misconceptions about the nature of science of religious college students, it is assumed that they will share the misconceptions of the general population. If students believe the myths about science described by McComas (2002), the conflict view of the interaction between science and religion is reinforced. A view that science produces absolute truth and can answer all questions cannot be accommodated within a Christian theistic world view and students in this position may reject the validity of the scientific enterprise altogether (Anderson, 2007). If these misconceptions can be corrected, however, Christian students may find it possible to integrate the work of science with their world view. Matthews (2002) described the nature of science as providing tools which students use to think about science, but warned against a "scientific catechism" approach, where students are simply indoctrinated to parrot their teacher's view of the complexity of scientific thought. The goal of nature of science instruction at the science-religion interface is to give students tools for insightful evaluation of scientific claims so they can determine for themselves how or if these claims can be accommodated within their Christian world view.

There is consensus among all interested parties—educators, researchers, scientists, politicians, and policy-makers—that promoting an understanding of the nature of science is an important goal for science educators (AAAS, 1989; Lee, 2007; McComas & Olson, 2002; NRC, 1996). The reasoning, in most cases, centers on the quest for

scientific literacy for all Americans as voting members of a democratic society. Driver, Leach, Millar and Scott (1996) highlighted this, and four additional reasons, why such nature of science knowledge is valuable:

1. *Democratic.* As citizens participating in a democracy, there is a social responsibility to make informed decisions regarding scientific issues. "Citizens have a voice in science funding decisions, evaluating policy matters and weighing scientific evidence provided in legal proceedings. At the foundation of many illogical decisions and unreasonable positions are misunderstandings of the character of science" (McComas et al., 2002, p. 3).

2. *Utilitarian.* An understanding of the nature of science helps make sense of science and of technological objects and advances; hence, the nature of science has practical applications.

3. *Cultural.* An appreciation of the scientific enterprise as a major component of modern culture is enhanced by understanding the processes of science.

4. *Moral.* The nature of science deals with the values and norms within the scientific community.

5. *Educational.* Knowing about the nature of science supports successful learning of scientific content. Research shows that students are interested in discussions of the nature of science (McComas et al.).

There are also sociological and philosophical reasons for emphasizing the nature of science in the science classroom. Aspects of the nature of science are related to understanding and interpreting many current and/or controversial issues in science including multicultural and feminist concerns (Matthews, 2002), the creation-evolution

debate, and the interaction of religion and science. The latter two are of particular importance in this study.

Teaching the Nature of Science

Authors of science reform documents call strongly for the inclusion of nature of science concepts in science education (AAAS, 1989; 1993; NRC, 1996) and the rationale for this inclusion is supported by the research literature (Abd-El-Khalick et al., 1998; Eflin et al., 1999; Lee, 2007). Teachers often fail to include these concepts in their lesson plans, however, because they don't feel that they adequately understand the nature of science (McComas, et al., 2002). In a 1991 survey, only 13% of undergraduate and 19% of graduate programs had nature of science courses in their teacher education curriculum. Yet some view of the nature of science is implicitly taught in every science classroom, whether teachers realize it or not (Ryder et al., 1999). Because it is important to "teach the teachers", much of the research literature presents pre-service teachers' understandings of the nature of science. The most effective method of instruction for reaching this group of future teachers is debated: should the nature of science in be embedded in science teaching methods classes or in content classes or should formal history and philosophy of science courses be taught? All have been discussed and advantages and disadvantages of each have been identified (McComas & Olson, 2002).

Additional findings about the most effective way to teach the nature of science are included in the research literature. Many studies support the importance of teaching the generalized tenets of the nature of science, such as those presented earlier, as opposed to complex philosophical arguments (Abd-El-Khalick et al.; Eflin et al.; Matthews; McComas et al., 2002; Schwartz & Lederman, 2008). The nature of science should also

be taught in light of the cultural world view of the students (Liu & Lederman, 2007). Whether the nature of science is integrated with content subject matter or is taught as a separate component of a particular class does not affect students' understanding as long as the concepts are made explicit to students (Khishfe & Lederman, 2007). The assumption that students will absorb an understanding of the nature of science by hearing about scientific discoveries or learning scientific content has been unsupported by several studies (Khishfe & Lederman; McComas et al.; Pigliucci, 2007). In a recent doctoral dissertation on changing students' understandings of the nature of science, Vanderlinden (2007) concluded that the requirements for effective nature of science instruction include an explicit approach, student reflection about specific nature of science concepts, and both contextualized and de-contextualized settings for instruction of nature of science concepts.

Attitudes

Definition of Attitude

Because psychologists have spent nearly 100 years investigating peoples' attitudes (Koballa, 1988), there are many different definitions of "attitude" found in the research literature. Within the past twenty years, most attitude researchers have agreed that an attitude is an evaluative judgment directed toward an object (the attitude object) based on beliefs about that object (Azjen, 2001; Barmby, 2008; Blalock et al., 2008; Brossard, Lewenstein, & Bonney, 2005; Crano & Prislin, 2006; Kind et al., 2007; Koballa). The attitude object can be of any nature or type (Barmby), for example, various aspects of experiencing science. These evaluative judgments are expressed along a continuum from positive to negative (Blalock et al., 2008) such as good-bad, harmful-

beneficial, pleasant-unpleasant, and likable-dislikable (Azjen, 2001). A recent comprehensive definition of attitude was offered by Crano and Prislin (2006): "An attitude represents an evaluative integration of cognitions and affects experienced in relation to an object" (p. 347).

Attitude Formation

Various models of attitude formation have been proposed. Some psychologists believe that attitude formation includes aspects of cognition, affect, and behavior (Azjen; Barmby, 2008; Crano & Prislin; Kind et al., 2007). Others disagree and subscribe to the Affective Primacy Hypothesis in which affect takes precedence over cognition in producing evaluative judgments (Azjen). The commonly accepted Expectancy-Value Model associates attitudes with beliefs (Azjen; Fazio & Petty, 2008; Fishbein 1963 in Fazio & Petty; Kruglanski & Stroebe, 2005). In this model, attitudes arise "spontaneously and inevitably" (Azjen) as beliefs are formed about objects. The formation of a belief is a cognitive act. Each belief associates the object with a certain attribute. "So, just as an attitude can be thought of as an object—evaluation association, a belief can be viewed as an object—attribute association" (Fazio & Petty, p. 134). According to the Expectancy-Value Model, attitude is determined by the subjective value placed on the attitude object's attributes, along with the strength of the association between the object and the attribute.

For example, according to the Expectancy-Value Model, students' attitudes toward science come from their beliefs about science. If a student believes that science (the object) is boring (an attribute) but that scientific advances (the object) are beneficial (an attribute), the student's attitude toward science is based on the value the student

places on "boring" versus "beneficial" as well as the relative strength of these associations in the student's mind. As seen in this example, people can form many different beliefs about an attitude object. Only those beliefs that are readily accessible in a person's memory influence their attitude at any given moment (Azjen, 2001). The accessibility of a belief increases with the importance of the belief and with more frequent and recent activation of the belief (Azjen). Strong attitudes are associated with more accessible beliefs and are relatively stable over time, resistant to persuasion, and good predictors of behavior (Azjen). Additionally, the "highly personal relevance of information on which an attitude is based has been found to increase [the attitude's] strength" (Azjen, p. 37).

Because this study involves religious college students, it is important to understand how such a student's attitude toward science may be formed. According to Ellison and Musick (1995), members of Conservative Protestant (Christian) denominations generally express more negative views of the scientific community than do other Americans. This finding is consistent with the Expectancy-Value Model of attitude formation. These attitudes toward science may be shaped by strongly held beliefs that science (the object) is purely naturalistic (an attribute), which is an attribute Christians value negatively since it seems to lead to an atheistic world view (Johnson, 1995). Because this belief is tied to their Christian world view, the belief is important and relevant to them and is activated frequently, leading to a strong attitude that is stable over time and highly resistant to change (Azjen).

Attitude Change

Several models have been proposed for attitude change (Brossard et al., 2005; Crano & Prislin, 2006; Krough & Thomsen, 2005). The Elaboration Likelihood Model says that attitude change occurs in three steps. First a message is presented to a person. If the receiver is able and is properly motivated, he or she will elaborate, or systematically analyze the message (Brossard et al.; Crano & Prislin). If the message is well-reasoned, data-based, logical, and persuasive, it often succeeds and the receiver's attitude is shifted toward a new position. If the message is illogical and poorly conceived, then it does little to bring about attitude change. If the receiver is not motivated or able to analyze the message, he or she often shortcuts the elaboration stage and uses a heuristic (e.g., "Dad's usually right") or peripheral cues (e.g., an attractive message source) to form a changed attitude. Changed attitudes resulting from these types of shortcuts are less stable, less resistant to pressure, and less likely to cause behavioral changes than those that are formed systematically and analytically (Crano & Prislin).

Because people can hold many beliefs about the same object, a new attitude may not completely replace an old attitude, but may simply override it (Azjen, 2001). The changeable nature of an attitude is tied to its specificity; the more specific an attitude, the more likely it is to be changed. For example, a science teacher's attitude toward plate tectonics as a theory is less likely to be changed than her attitude toward using a specific textbook (Koballa, 1988). This study examines changes in affective attitude toward science of religious college students. In the context of the Elaboration Likelihood Model, in order for attitude change to occur, students must be motivated and able to attend to a new message about the nature of science and its integration with their Christian theistic

world views. It is the responsibility of the instructor to make sure that the message is logical, data-based, well-reasoned, and persuasive.

Attitudes toward Science

Definition of Attitude toward Science

For the purpose of this study, attitude toward science will be defined as "a learned disposition to evaluate in certain ways objects, people, actions, situations, or propositions involved in learning science" (Laforgia, 1988, p. 410). The phrase "attitude toward science" is inconsistently applied by researchers, educators, and the public (Barmby, 2008; Blalock et al., 2008; Kind et al., 2007; Laforgia). Two particular issues regarding this confusion will be addressed. First is the distinction between attitude toward science and scientific attitudes. The second is that attitude toward science, while often treated as one construct, has many dimensions.

Scientific attitudes. Scientific attitudes are generally described as mindsets for thinking or working in a scientific way (Barmby). Laforgia listed eight components of a scientific attitude including: curiosity, willingness to suspend judgment, rationality, open-mindedness, critical-mindedness, objectivity, intellectual honesty, humility, and reverence for life. When polled, scientists themselves agreed that the terms honest, truthful, innovative, inventive, curious, creative, and skeptical were good descriptors of a scientific attitude (Laforgia). Generally, scientific attitudes describe attitudes toward ideas and information, attitudes regarding the evaluation of those ideas and information, and a commitment to particular scientific beliefs (Laforgia).

Attitude toward science. Attitude toward science is often treated as a monolithic entity, but in reality has many constructs. Generally, attitude toward science can be seen

as "a way of mapping students' cognitive and emotional opinions about various aspect of science" (Kind et al., 2007, p. 873). In a comprehensive survey of science attitude instruments developed between 1935 and 2005, Blalock et al. (2008) identified four different categories of measurement: attitude toward science; scientific attitudes; understanding the nature of science; and scientific interest. The first of these, attitude toward science, usually includes the emotional reactions of students toward science, including interest, satisfaction, and enjoyment (Blalock et al.). Barmby (2008) observed that the dimensions of attitude toward science differ with context: students can have an attitude toward "school" science or an attitude toward "real" science and these often differ. This aspect of attitude toward science, which is being measured by this study, is sometimes called the affective attitude toward science since it involves emotions and feelings (Francis & Greer, 1999). The second category, scientific attitudes, has been described previously. The third category, understanding the nature of science, is a more cognitive dimension of this construct and involves "the aims of science, its epistemology, its tactics, its values, its institutional functions, its interactions with society, and its human needs" (Aikenhead in Blalock et al.). Finally, scientific interest is a category usually associated with having an interest in scientific careers, rather than interest in science generally.

Measurement of Attitude toward Science

Given the plethora of definitions and constructs that are labeled "attitude toward science," creating a meaningful measurement of attitude toward science has been difficult. Too often, researchers have taken a pragmatic approach, using simple-response, Likert-type, easily-scored scales to investigate the complexity and ambiguity of a

complicated psychological construct (Brossard et al., 2005; Kind et al., 2007). Many instruments fail to clearly articulate which construct of attitude toward science is being measured (Barmby, 2008; Blalock et al., 2008; Kind et al.; Krough & Thomsen, 2005). Critics point to the need for instruments to be explicit about what aspect of attitude toward science is being measured (Barmby; Kind et al.), for consensus to be reached on common terminology and clear concepts among science educators (Blalock et al.), and for theoretical frameworks regarding attitude toward science to be established before instruments are developed (Blalock et al.; Osbourne et al., 2003).

Additional criticism was leveled at the psychometric properties of instruments in this area. Of 66 instruments evaluated by Blalock et al., 29 were referenced multiple times, whereas 37 were referenced only once, implying "a lack of published replication or follow-up studies" (p. 966). Almost half of the instruments lacked at least one important component of psychometric evidence (internal reliability, test-retest reliability, content validity, or construct validity) yet were recommended as acceptable instruments by their authors. Critics are vocal about instruments' shortcomings in the areas of validation and replication (Blalock et al.), lack of open-response items that allow for description of complex attitudes (Brossard et al., 2005), and demonstrated uni-dimensionality that is confirmed by reliability and factor analysis data (Kind et al.). The instrument selected for this study was chosen because of its demonstrated uni-dimensionality with respect to the affective attitude construct. As a result of poorly developed instruments and a tendency to ignore the influence of confounding variables such as student personality or socioeconomic status, attitudes toward science research has produced few conclusive results (Krough & Thomsen, 2005).

General Research Findings on Attitudes toward Science

Because of a lack of standardized definitions and adequate instruments, findings in attitude toward science research are difficult to compare and the context within which each study has been conducted must be considered. Barmby (2008) compares this situation to the fable of the blind men and the elephant: "researchers touch different parts of the phenomenon and nobody holds a view of the whole" (p. 1077). The literature does, however, contain a few substantive conclusions confirmed by multiple studies.

Attitudes toward science in school continue to decline. Students say they do not enjoy science in school because they perceive it as impractical, poorly explained, or irrelevant (Barmby). It is clear that the science teacher is a more important influence on attitude toward science than are curricular variables (Oliver-Hoyo & Allen, 2005; Osbourne et al., 2003), the effect of particular science curricula or programs on students' attitude toward science is inconclusive (Schibeci, 1984). Boys tend to have more positive attitudes toward science than girls at all age levels, but attitude toward science in school declines as students move to higher grades for both boys and girls (Barmby; Schibechi). There is a noticeable difference in attitude among girls for certain types of science classes, with biology being preferred over the physical sciences (Schibeci). Although Schibeci reported that home and peer group had an uncertain, indirect influence on students' attitude toward science, Papanastasiou and Zembylas (2004) found the opposite: students who perceive that their environment (friends, family, and school) consider science important have more positive attitudes toward science. Blalock et al. (2008) reported that although students' interest in school science is declining, their attitude toward science in general is not. Of importance for this study, Fulljames (1991)

found that high school students who believe that Christianity necessarily involves creation have a lower interest in science than those students who do not believe that Christianity necessarily involves creation.

The positive correlation between attitude and learning has been clearly documented in the research (Kind et al., 2007; Oliver-Hoyo & Allen, 2005; Schibeci, 1984; Turkmen, 2007). "Learning clearly has an affective component and developing positive attitudes is important for students' achievement" (Kind et al., p. 872). The importance of attitude toward science has risen due to the widely accepted assumptions that achievement and attitude are directly related and that affective variables are as important as cognitive variables in molding student learning (Oliver-Hoyo & Allen).

Attitude toward Science in Higher Education

There are few generalized findings regarding attitude toward science among college students, and even fewer about the attitudes toward science of religious college students. In one study focusing on the interaction between the religiosity of college students and science, Brazelton, Frandsen, McKown, and Brown (1999) found that university students who scored high on a scale of religious commitment had unfavorable attitudes toward science as a career choice. Most of the research involving university students, however, focuses on two areas: (a) the effect of specific instructional strategies on students' attitudes toward science in classes designed for science majors; and (b) the attitude toward science of elementary education majors. Oliver-Hoyo and Allen found that active learning environments that included cooperative learning, hands-on activities, real-world applications, and engaging technology improved college students' attitudes toward science in an introductory chemistry class. Including nature of science instruction

in general science classes improved students' attitudes toward science and their science achievement as well (Turkmen, 2007).

Research shows that many pre-service elementary teachers have limited science knowledge as well as poor attitudes toward science, resulting in a lack of confidence in teaching science. For teachers in the classroom, this translated into less time spent teaching science and resulted in teacher-centered rather than student-centered instruction (Palmer, 2004). This finding causes concern because the attitudes of elementary education majors toward science are particularly important in terms of achieving science literacy goals as recommended by reform documents (AAAS, 1989, 1993; NRC, 1996). A clear lack of research about religious college students' attitudes toward science makes this current study of interest.

Beliefs regarding Creation

One of the tenets of a theistic world view is that God created the matter and energy of which the universe is made (Sire, 1976). The Christian story of creation is found in Genesis, the first book of the Bible. While scholars debate who wrote Genesis and the date of its authorship, it is certain that the author was not a witness to the events described in the creation story. Thus, there is disagreement among biblical scholars about how to interpret the Genesis account of creation (Skehan, 2000). Some scholars see it as a myth or allegory, much like creation stories of other ancient cultures, i.e., the Babylonian Enuma Elish. Others believe that Genesis is a God-inspired narrative of the origin of the universe that describes the events of creation in literal detail. Viewpoints exist between these boundaries as well (Haarsma & Haarsma, 2007). In general, anyone who believes

that a supernatural entity created the known universe is broadly considered to be a creationist ((NAS, 2008).

The Spectrum of Creationist Beliefs

The public press casts creation and evolution as polar opposites locked in mortal combat; this view is promulgated by antievolution and evolution proponents alike (NAS; Scott, 2004; Skehan, 2000). In the science education literature, it is rare to see an article that mentions creationism without subsequent—usually immediate—mention of evolution. This controversy has set up a false dichotomy that frames the issue as "religious creationism" versus "atheistic scientism" (Skehan). Many people are unaware of the spectrum of beliefs between these two endpoints. An understanding of these intermediate positions may help foster more reasonable discussions of creation and evolution, particularly in the science classroom (Nelson, 2000; Skehan). The most well-recognized creationist views will be described here.

Young Earth Creation. Young earth creation (YEC) is the belief that the Genesis account of creation is scientifically accurate and should be read literally. Sometimes called scientific creationism by its proponents, this view is the least scientifically compatible position on the spectrum of beliefs regarding creation (Scott; Skehan). According to this view, God created all living things in a period of six, 24-hour days. Limited natural selection is accepted to explain adaptations within species, but evolution between species is rejected as is the big bang theory. Young earth creation accepts an age of the earth between 6,000 and 15,000 years old; a catastrophic worldwide flood subsequently fashioned Earth's present form and is responsible for the distribution of

fossils seen in the geologic column (Scott, 2004; Skehan, 2000; Tenneson & Badger, 2008).

Old Earth Creation. Old earth creation (OEC) is the belief that the earth is billions of years old, as supported by scientific evidence. In this view, God created everything, including life, by creative acts separated by long periods of time (gap creationism) or during days that were much longer than 24 hours (day-age creationism). These two positions allow for a literal interpretation of Genesis while accommodating the age of the earth, but do not allow for evolution between species or the big bang (Scott; Skehan; Tenneson & Badger). The most widely held modern view of creation is progressive creationism in which the age of the earth, the big bang, and increasing complexity of organisms over time as reflected in the distribution of fossils in the geologic column are accepted theories. OEC accepts the change of organisms within species over time, but does not accept evolution between species (Scott; Skehan).

Evolutionary Creation. Evolutionary creation (EC) accepts the age of the earth, the big bang, and biological evolution, but stresses that the evolution of organisms was purposefully guided by God. The creation account in Genesis is not considered literal or scientifically accurate, but God is acknowledged as the prime cause or creator (Scott; Tenneson & Badger).

Intelligent Design Creation. Intelligent design creation (IDC) is the newest form of creationism and echoes William Paley's "Argument from Design" (1803) which says that God's existence can be inferred from observing design in nature (Scott). For example, IDC points to molecular structures such as DNA that are too complicated to have evolved by chance or to bacterial flagella which display irreducible complexity,

meaning they couldn't have developed in step-wise fashion as predicted by evolutionary theory because all of the present parts are needed for successful functioning. Natural selection and the importance of genetic mutations are accepted, but IDC proponents claim these are not adequate to explain the evolution of one "kind" to another (Scott, 2004).

Theistic Evolution. Theistic evolution accepts all the findings of the modern sciences, including those of anthropology regarding human evolution. Theistic evolution embraces evolutionary theory in its entirety. Theistic evolutionists differ among themselves in their view of God's role in nature. Some say that God created matter, energy, and the natural laws by which matter and energy interact, then left the earth to operate entirely by those laws. Other theistic evolutionists would add that at important points in time (the creation of human beings, for example) God intervened in the natural world. The latter is the official view of the Catholic Church along with many mainline Protestant denominations (Scott).

Creation and the Classroom

Creationist viewpoints pose difficulties for students in the science classroom. The most obvious problem for religious students is that biological evolution, if described as random and purposeless, conflicts with their world view presuppositions that there is a God and that God created purposefully. Downie and Barron (2000) surveyed university biology students for ten years and found that of those who rejected the theory of evolution, 71% did so because they accepted a literal religious creation account, not because they questioned the strength or validity of the scientific evidence. Fifty percent of these students said there was no evidence that would convince them of the validity of

evolutionary theory. Strongly held beliefs interfere with students' abilities to objectively view scientific information (Sinclair et al., 1997). The more deeply ingrained the belief, the more difficult it is for students to impartially analyze the validity of scientific theories based on the empirical evidence that supports them (Sinclair & Pendarvis, 1998). Rather than becoming informed analysts of scientific findings, religious students sometimes become closed-minded skeptics of the entire scientific enterprise (Anderson, 2007; Downie & Barron, 2000; Johnson, 1995).

Teaching Science in a World View Context

Although there is an abundance of research literature on the interaction of religious beliefs and evolutionary theory, and some research on religious beliefs and other aspects of science attitudes and achievement, there is almost no research about teaching science more broadly in an explicit world view context. Shipman, Brickhouse, Dagher, and Letts (2002) investigated the effects of incorporating discussions about religion and science in a college level astronomy course and two recent doctoral dissertations (Hermann, 2007; Schroeder, 2006) addressed this topic as well. These studies will be reviewed here in some detail because of their relevance for this research.

Religion and Science in a College Astronomy Course

Shipman and fellow researchers observed the effect of modest inclusion of the relationship between religion and science in a college-level astronomy course at a secular university. Their research was framed in the context of world view theory (Cobern, 1991; 1994; 1996) and students' conceptual ecologies (Demastes et al., 1995). Motivated by the natural connection between certain course topics such as the big bang and related religious or cosmological questions, the researchers designed a curricular component

consisting of two written assignments, half of a 75-minute large-group lecture, and one reading of an article written by the course instructor. Their goal was to investigate whether students would engage in a dialogue between religion and science within their own conceptual ecologies or world views, whether such dialogue could be done with sensitivity to religious and non-religious students alike, and what students' responses would be to the curricular intervention. Nineteen students were interviewed three times during the course to obtain a more in-depth understanding of students' thinking; class assignments, examinations, and course evaluations were used as artifacts to help elucidate the perspectives of the class as a whole.

Utilizing categories suggested by Barbour (1990), the nineteen case study students and 84 students from the class as a whole were described by the terms distinct, transitional, convergent, or confrontational, indicating their view of the relationship between religion and science. Of surprise to the researchers was that no students were in the confrontational category. Shipman et al. (2002) acknowledged that this was unusual given the general feeling that religion and science are at odds with one another, and predicted that the findings might be different at a religiously-affiliated university. The researchers concluded that students did not object to inclusion of the dialogue between religion and science and that students incorporated these discussions into their conceptual ecologies and adjusted their world views to the extent that they were prepared and motivated to do so. Student support for inclusion of this topic was overwhelmingly positive, with only one student registering an objection in over 1300 course evaluations. The instructor's demeanor played an important role in the course; students noted that his acceptance of a variety of views and beliefs along with an impartial presentation of

scientific evidence in a dispassionate way was an important factor in the success of this intervention.

Shipman et al. (2002) is similar in many ways to the current study. Samples for both studies were selected from the population of university students in closely located geographic regions. The effect of an instructional and curricular intervention, including explicit discussion of world view-related issues, was investigated by both. In both cases, the goal of the intervention was to foster a constructive dialogue between science and religion for students, i.e., to promote a more scientifically compatible world view. These studies, however, differ in two important ways. The current study examines a sample of students with pre-existing Christian theistic world views. As Shipman et al. noted, religious students may display a more confrontational view of the relationship between science and religion than did their sample. The current study also looks at an entire course structured around emphasizing the dialogue between two different world views rather than the modest amount of curricular intervention in Shipman's research.

Christian University Science Faculty and Strategies for Instruction

Schroeder (2006) investigated the conceptual change strategies used by science faculty members at a private, Christian university to assist students in overcoming the observed tension between science and their beliefs. This qualitative study operated entirely within the conceptual change model and did not explicitly address world views or world view theory, although faith and beliefs were often cited. Based on extensive interviews with ten faculty members at the primary university and four faculty members used for triangulation from two similar universities, strategies used by faculty members were clearly grouped into three categories: time, talk, and trust. Conceptual change

required time, both face-to-face time with students to develop conceptual change and time for students to accommodate new understandings. Faculty members talking to students in class and outside of class, and talk between students were cited as critical in the process of conceptual change. Finally, the development of trust between students in the classroom and between students and faculty members was noted as key to conceptual change regarding belief-related issues. While this study was not explicitly based in a world view framework, it provided verification of the tension religious students face in the science classroom in a setting very similar to the one used in this study. Actual changes in students' scientific literacy was not the focus of Schroeder's research, so no results are available to establish the efficacy of the faculty members' strategies; the strategies of time, talk, and trust were helpful, however, for developing the instructional intervention for this present research.

World View Perspectives and Acceptance of Evolution

Hermann (2007) employed world view theory to identify factors affecting acceptance of evolution in high school biology students and biology teachers. Hermann modified the logico-structural world view model posed by Kearney (1984) and expanded by Cobern (1991) by grouping world view presuppositions into an original construct called world view perspectives. This quantitative study of scientific and religious world view perspectives also investigated factors influencing the development of each. Strong religious world view perspectives and exposure to religious factors were associated with a lower understanding of evolution, thus suggesting that religious world view presuppositions may hinder the learning of evolution. The strongest interaction in Hermann's study was that between the strength of a scientific world view perspective and

the strength of a religious world view perspective: his conclusion was that a stronger scientific perspective caused a weaker religious perspective or that a stronger religious perspective causes a weaker scientific perspective.

While the object of Hermann's (2007) study was acceptance of evolution by high school biology students and teachers, the underlying purpose of his study was to "move science educators and researchers toward an agenda where the focus is increased understanding of science among students without influencing belief systems" (p. 22). The goal of this present research, only slightly different from Hermann's, is increased science understanding among students *in conjunction* with *modification of* their current belief systems. From a world view constructivist perspective, it is not likely that religious students will develop increased science understanding without a coincidental adjustment in their belief systems. Thus, to say that students' science understanding will increase without any change in their belief systems does not fall within the theoretical assumptions of this study.

Hermann contends that there is an important distinction between world view assumptions (presuppositions), world view perspectives, and a person's ultimate world view. For example, the theistic and scientific world views described earlier would be, in Hermann's opinion, world view perspectives which contribute, in part, to an overall world view. He argues that it is these perspectives that allow us to talk about the very different world views of individuals and yet still compare the world views of groups as a whole. While world views vary from person to person, the characteristics of a scientific world view perspective or a theistic world view perspective provide a common platform for discussion, as is the case in this study.

For religious students, a holistic presentation of the scientific enterprise contextualized within discussion of the theological implications of that enterprise might result in a greater degree of concordance between students' beliefs and scientific ways of thinking. Yet despite discussion that supports the potential effectiveness of this method (Cobern, 1991; 1996; Nelson, 2005; Schroeder, 2006; Smith and Scharmann, 1999), no studies have been located that investigate the effect of teaching science within a theistic world view context on the scientific compatibility of religious students' world views.

Conclusion

The nature of Christian scholarship emphasizes the integration of a Christian theistic world view with all of life and learning (Thiessen, 2007). While this goal is explicitly stated by most Christian universities, variations of this same goal exist at secular universities as well. The University of Southern Mississippi's website declares the university's goal of educating the *whole* student (University of Southern Mississippi, 2008). Educating the whole student means providing students with opportunities to form a coherent view of life in light of their experiences, beliefs, and the study of their individual disciplines. In many science classes, the emphasis on science as objective, naturalistic, unbiased, and empirical means that students' beliefs and assumptions about the nature of the world are either guided along naturalistic pathways or, in the case of religious students, disregarded as wrong-headed misconceptions. This compartmentalization of students' beliefs and world views from science content seems "indefensible on pedagogical grounds" (Anderson, 2007, p.), particularly in light of constructivist learning theory. Stephen Jay Gould an advocate of the independence (NOMA) view of religion

and science admitted that "many of our deepest questions call upon aspects of both [science and religion] for different parts of a full answer..." (Gould, 1997, n.p.).

University students are attempting to find answers for many of life's deepest questions and this search necessarily involves finding coherence between their religious beliefs and their scientific understandings. Anderson argued that "understanding how major concepts relate to one's world view and the shaping of this world view are part of acquiring an authentic and complete education" (p. 668). Hence, the research question in this study is framed around the effectiveness of teaching an introductory science course in the context of a theistic world view, wherein the methodological and epistemological presuppositions underlying science will be examined in light of the presuppositions underlying a Christian theistic world view. The goal is for students to achieve scientific literacy within a coherent world view framework.

CHAPTER III

METHODOLOGY

The purpose of this study was to investigate the effect of an introductory science course that intentionally contextualized instruction about the nature of science within a Christian theistic world view on the scientific compatibility of religious college students' world views. For the purposes of this research, the scientific compatibility of students' world views was indicated by the students' understanding of the nature of science, their affective attitudes toward science, and their beliefs about creation. This chapter discusses the methodology of the study.

Research Design

This study was a repeated-measures quasi-experimental design, with non-random assignment of the participants. The sampling technique was cluster sampling. Participants' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation were measured with three different instruments at the beginning and end of an introductory science course that intentionally contextualized instruction about the nature of science within a Christian world view. The completed instruments were analyzed to determine if there were any statistically significant differences between sample means on the dependent variables and to identify any statistically significant relationships among the dependent variables. The participants, instruments, data-collection procedures, and statistical analyses of the data are described below.

Participants

Introduction to the Natural Sciences (see syllabus, Appendix A) is a required, core-curriculum, introductory science course at a private, Christian university located in southeastern Pennsylvania. The university is an independent institution and is not affiliated with any church or denomination. The 194 students enrolled in this course during the 2008-2009 academic year were solicited for voluntary participation in this study. About half of the students (98) were enrolled in three sections of the course during the fall 2008 semester; the rest were enrolled in three sections during the spring 2009 semester. All students signed a statement of Christian faith as a condition of acceptance to the university, so it was assumed that all participants had a theistic world view. Demographic data was collected to determine participants' gender, age, denominational affiliation, and college major (Appendix B).

Instruments

Understanding of the Nature of Science

Participants' understanding of the nature of science was measured using the second version of the Student Understanding of Science and Scientific Inquiry Questionnaire (SUSSI, Liang, et al., 2006, Appendix C); the revised instrument used in this study took 10-15 minutes to administer. Permission to use this instrument was obtained from the primary author via email correspondence (Appendix D). The original SUSSI was a dual-response instrument that organized the respondents' understanding of the nature of science around the following themes: (a) observations and inferences; (b) change of scientific theories; (c) social and cultural influences on science; (d) imagination and creativity in scientific investigations; and (e) method-

ology of scientific investigations. For each of these themes, the instrument contained one open-ended response question and several statements with which participants' indicate their degree of acceptance on a five-point Likert-type scale (1 = strongly disagree, 2 = disagree more than agree, 3 = uncertain, 4 = agree more than disagree, and 5 = strongly agree). For the purposes of this study only the 18 Likert-type statements were used due to the large number of participants. Statements 1A, 1D, 2A, 2B, 2C, 3B, 3C, 4A, and 4B described the nature of science as reflected in science reform documents; these questions were coded according to the given scale. The remaining statements were worded to reflect common naïve misconceptions of the nature of science and were coded oppositely. Scores were summed; the lowest possible total score was 18 and the highest was 90. Higher scores indicated greater (informed) understanding of the nature of science; lower scores indicated lesser (naïve) understanding of the nature of science.

Face validity and content validity for the questionnaire were established by a panel of nine experts—two scientists and seven science educators—who taught and/or were experts in the nature of science (Liang et al., 2006). The authors also triangulated between the pilot study participants' scores on the Likert-type statements, their open-ended responses, and interviews to verify content validity. The overall instrument had satisfactory reliability (Cronbach's alpha = 0.72; Liang et al., 2006). Although questions were grouped by theme, four of the five theme subscales did not demonstrate satisfactory construct validity (Cronbach's alpha values below 0.70) and were not used in this study.

Affective Attitude toward Science

The participants' affective attitudes toward science were measured with the Affective Attitude towards Science Scale developed by Francis and Greer (1999; Appendix E). Permission to use this instrument was obtained from the primary author via email correspondence (Appendix F). The scale took 5-10 minutes to complete. This scale was chosen because of its homogeneous, uni-dimensional nature as determined by content analysis, exploratory factor analyses, and item analyses; that is, the scale measured the affective dimension of attitude toward science apart from the behavioral or cognitive domains (Francis & Greer). Twenty items were arranged on a three-point Likert-type scale (1 = disagree; 2 = uncertain; 3 = agree). Items 1, 7, 8, 11, 12, and 14 were scored oppositely. Scores for each item were summed to arrive at an overall attitude score. The lowest possible score was 20, indicating a less positive attitude toward science; the highest possible score was 60 indicating a more positive attitude toward science.

Content validity for this scale was established in several ways. First, it was "supported by the observation that the items recording the largest item rest-of-scale correlation are clearly central to the domain of affective science-related attitudes" (Francis & Greer, p. 222). Second, construct validity was supported by the correlation ($r = 0.38$, $p < .001$) between students' scores on the instrument and the number of science-related courses taken during secondary school. Mean scale scores for males and females showed that males had a more positive attitude toward science, which is supported by the research literature. Likewise, mean scale scores for younger students were higher than those for older students, a result also supported by the research

literature. The Cronbach's alpha reliability coefficient for the scale was 0.89 indicating good reliability (Francis & Greer, 1999).

Beliefs Regarding Creation

The Online Origins Survey (Tenneson & Badger, 2007, Appendix G) was used to measure the participants' beliefs regarding creation. Permission to use the survey was granted by the authors via email (Appendix H). The survey took 10-15 minutes to complete and was taken in class rather than online. This survey determined students' beliefs regarding creation and identified responses as being typical of a belief in young earth creation (YEC), old-earth creation (OEC), or evolutionary creation (EC). For the purposes of this study, a YEC position was considered less scientifically compatible than an EC position, with an OEC position falling between the other two. The original survey consisted of 62 items arranged on a five-point Likert-type scale (1 = strongly disagree, 2 = disagree, 3 = uncertain, 4 = agree, 5 = strongly agree). The option "I decline to answer" was also available to the participants. An additional question asked the participants' to identify their position regarding creation as being closest to one of the following: atheistic evolution, deistic evolution, evolutionary creation, old earth creation, young earth creation, other, or "I decline to answer." Brief descriptions of each position accompanied the survey.

Content validity for this survey was established by a panel of five experts based on their confidence that each item was descriptive of one of the conceptual definitions intended to be measured by the survey. The content validity for this instrument was high, with 80% agreement between experts and a mean confidence for each item of 2.5 on a 3-point scale (Tenneson & Badger, 2009). Overall, survey

reliability was good (Cronbach's alpha = 0.853; Tenneson & Badger, 2009). Construct validity was high as determined by exploratory factor analysis. Five factors were identified, three of which (EC, OEC, and YEC) were used in this study. The EC factor included eight survey items (1-coded negatively, 2, 3, 11, 12, 15, 17, and 21); the OEC factor included nine survey items (4, 5, 6, 8, 10, 16-coded negatively, 18, 23-coded negatively, and 25); the YEC factor included ten survey items (1, 7, 9, 13, 14, 16, 19, 20, 22, and 24). The reliability of individual factors was good (Cronbach's alpha values: EC = 0.865; OEC = 0.892; YEC = 0.797; Tenneson & Badger). For the purposes of this study, only the questions loading on the factors EC, OEC, YEC and the self-reported creation position were used for a total of 26 items.

Procedure

Before the study began, permission to conduct this research was requested from and granted by the University of Southern Mississippi's Institutional Review Board. Potential participants in the study were the 194 students enrolled in the course *Introduction to the Natural Sciences* during the fall 2008 and spring 2009 semesters. The procedure described here was used during both semesters. Because the researcher was also the instructor of the course, a proxy was used for all interactions with study participants to avoid the perception of coercion or bias on the part of the researcher. The proxy solicited the students' voluntary, anonymous participation in the study during the first class meetings of both semesters. The study was described as an investigation of the effect of enrollment in the course on factors related to the participants' views about science. After a brief oral presentation (Appendix I), written consent was obtained from the participants (Appendix J) explaining the parameters of

the study. At no time did the researcher have access to the students' informed consent forms, preserving the participants' anonymity. Participants were allowed to withdraw from the study at any time without prejudice.

After the study was explained and student consent was obtained, participants completed the pre-instruction instrument packet. The first page of the packet contained four simple questions which created an individualized code number for each student based on their responses to the questions. This alpha-numeric number became the student's code for the duration of the study. The questions were of such a nature that although the researcher saw each participant's code number, it was not possible to link the number to a specific participant based on information available to the researcher. The same four questions accompanied both pre- and post-instruction instrument packets, which made pairing of instruments possible. This ensured that the scores of participants who dropped the course or who entered the class after pre-instruction data were collected were eliminated from statistical analyses.

Of 194 possible study participants, 171 students completed pre- and post-instruction instrument packets. Demographic information including age, gender, denominational affiliation and college major was collected and participants then completed each of the instruments described previously in this chapter. The total time of instrument administration, including reading of instructions and obtaining informed consent, was thirty minutes. The fifteen-week introductory science course served as the treatment in this study and is described in detail below. At the end of the semester, the same three instruments were administered by proxy during the final

week of classes. Students were reminded that they could withdraw from the study without prejudice.

Instructional Treatment

Introduction to the Natural Sciences was a one-semester, core-curriculum introductory science course required of all sophomore students at the university where the study was conducted. This course was offered for the first time during the fall 2008 semester. The researcher designed and instructed the course. Since space was available in some course sections, students other than sophomores took the course for elective credit and participated in the research study as well. The university does not grant science degrees, so all students were non-science majors. This section describes the structure of the course in general, and then explains how it was contextualized within a Christian theistic world view framework.

General Course Overview

This course was an introduction to the nature, history, philosophy, and methodologies of the natural sciences. The focus of the course was on the development and nature of scientific thinking along with an exploration of the assumptions and limitations implicit in scientific endeavors. Students were encouraged to evaluate the nature and claims of science in light of their Christian world view and to integrate science and their beliefs into a cohesive whole. The specific objectives of the course and a schedule of topics in the order they were covered are found in an abbreviated course syllabus (Appendix A).

The course was divided into five units of instruction: the nature and purpose of science, the cultural context of science, the content of science, the integration of

faith and science, and current issues in science. A variety of pedagogical approaches designed to appeal to multiple learning styles and modalities were utilized including: interactive lectures supplemented by video and audio clips; small group discussions, projects, and case studies; whole-class discussions; and interaction with three guest professors. Constructivist learning theory guided the planning for the course, beginning with the assumption that students brought scientific preconceptions to the course that might not have been correct, along with world view presuppositions that might interfere with their acceptance of scientific epistemology. These preconceptions and presuppositions were exposed and explored through a variety of activities, case studies, assignments, and discussions. For example, during the unit on the nature of science, students participated in The Great Fossil Find, a simulation of paleontologists' discovery and reconstruction of fossilized bones. This activity, in conjunction with assigned readings, discussions about the nature of science, and a writing assignment, exposed the misconceptions students held about the epistemology of science and the process scientific inquiry.

Misconceptions about scientific ways of thinking, the validity of scientific evidence (particularly dealing with the age of the earth and biological evolution), and the perceived conflict between religion and science were explicitly and repeatedly addressed throughout the course. Students analyzed their own conceptions through written assignments and class discussions. Student assessment took several forms: students were graded on class participation, group work, individual assignments, four exams, and three quizzes.

Contextualization of the Course

The contextualization of this course within a Christian theistic world view makes this course unique and will be described here in some detail. Efforts to provide a Christian context fall into three main areas: readings and instructional resources, class discussions and guest professors, and written assessments will each be addressed.

Readings and resources. The required text for this class was *Origins: A reformed look at creation, design, and evolution* (Haarsma & Haarsma, 2007). The authors are professors in the Department of Physics and Astronomy at Calvin College, a Christian university in Michigan; both profess a Christian theistic world view and the text is written from this perspective. As an introduction to the science, philosophy, and theology of origins (creation, in this research), this text "...explains the science—what is well-established and what is speculative....focusing on areas where Christians agree, while sympathetically presenting the strengths and weaknesses of positions when Christians differ" (Haarsma & Haarsma, 2007, back cover). Written for non-scientists and non-theologians, this text received excellent reviews for presenting a balanced, accurate, and fair approach to science and religious beliefs and for a respectful attitude toward all creation positions, even those that are not well supported scientifically. The textbook emphasizes the foundational presuppositions of a Christian theistic world view, examines questions about creation and human origins in light of these presuppositions, and analyzes the strength of scientific support for each creation position. Students were expected to read assigned chapters from this book at various points during the semester.

Additional course readings consisted of articles that were uploaded to an electronic course website. A list of these articles is found in Appendix K. These articles were chosen based on their relevance to course topics and their explicit contextualization of each topic within a Christian world view. For example, "How science works: Foundations, methods, and teleology" (Boehlke, Knapp, & Kolander, 2006) analyzed the presuppositions of scientific and theistic world views for the purpose of determining if integration between them was possible. Students read this article in conjunction with class activities and discussion about the nature of science in order to gain a presuppositional perspective on scientific epistemology and their own theistic world views.

In addition to reading articles selected by the instructor, students were encouraged to use internet websites and peer-reviewed journals that discussed the interaction between science and religion from a variety of positions within a theistic world view (Appendix L). Some of these websites dealt specifically with creation issues, and some dealt with science and religion more generally. For one assignment, students were asked to research evidence related to the age of the earth on websites covering a spectrum of creation positions to see how differences within a theistic world view influenced the interpretation of the same scientific evidence. Students were also referred to secular websites about topics that were covered in class, particularly to learn more about the theory of biological evolution. The assumption was that these websites provided information from a scientific world view.

Class discussions and guest professors. Class discussions formed the pedagogical core of this course. Lectures were used when necessary, but students

were encouraged to interact with the material, the instructor, and one another during lecture sessions. Questions were encouraged and often provided the impetus for prolonged class discussions. The encouragement found in research to "teach less, better" (AAAS, 1989) was highly valued in this course, as were findings that class discussions were helpful in promoting critical thinking among students about their own world views (Alters & Nelson, 2002; Smith, 1994). Class discussions were used in order for the students' to analyze their own views and presuppositions and to hear and critique those of other students as well. The process of discussion was guided, but rarely directed toward an intentional end. Students were asked to clarify their thinking with repeated use of the questions "Why?" and "What do you mean by that?"

Although all topics were discussed to some degree in the course, those topics for which class discussion was the main pedagogical tool were: (a) reasons why some Christians are resistant to science and scientific methodology; (b) theistic implications of the big bang theory; (c) accepted interpretations of Genesis by biblical scholars; (d) implications of human evolution relative to theological issues such as the image of God, sin, and the fall and redemption of humans; (e) the age of the earth and varied interpretations of scientific evidence; (f) implications of quantum mechanics for scientific determinism and a Christian world view; (g) biological evolution as a perceived threat to a theistic world view; (h) scientific evidence versus textual authority; (i) the role of human error in interpreting scientific evidence and scripture; (j) stem cell research, genetic engineering, and the consequences of scientific advances—gifts from God or tinkering by mankind?

Guest professors led three discussions, bringing interdisciplinary viewpoints to bear and helping students realize that many of the questions being discussed in the course were connected to other epistemologies. During the unit on the cultural context of science, a history/social studies professor addressed the far-reaching and long-lasting world view implications of the change from a geocentric to heliocentric model of the solar system. Two class sessions guided by an Old Testament/Hebrew professor encouraged discussion of the breadth of scholarly interpretations of the accounts of creation and Noah's flood in Genesis. The goal of these sessions was to open students' minds to consideration of the validity of viewpoints other than their own with respect to interpretation of the Bible. Finally, a physics professor from a nearby university gave an evening lecture on the topic "The big bang and Genesis," presenting his hypothesis that the creation account in Genesis parallels the stages of the big bang as currently understood by scientists. This professor held a Jewish theistic perspective which added diversity to the discussion of theistic world views and science.

Student assessment. Three types of written student assessments were used in this course: quizzes, exams, and think pieces. Three multiple choice, summative quizzes were used to determine students' comprehension of basic terms and concepts related to atomic theory and quantum mechanics, plate tectonics, and microevolution and speciation. Exams combined formative and summative goals and, in most cases, included essay questions designed to extend students' thinking and analysis and multiple choice questions to verify comprehension and retention of facts and concepts. Several exams required the students to resolve, or at least reflect upon,

cognitive and affective disequilibrium brought about by the lectures, discussions, and readings prior to the assessment.

The first exam evaluated students' understanding of the nature of science, its presuppositions, and the purpose of examining these presuppositions in light of their own theistic world view. The second exam assessed students' comprehension of the terms and concepts associated with atomic theory, quantum mechanics, plate tectonics, and the big bang, and asked them to explain how they were integrating these theories with their world views. The third exam asked students to respond to an article entitled "Believing scripture but playing by science's rules" about a doctoral student with a self-identified theistic world view who believed in young earth creation, but whose dissertation gave evidence that a certain species of marine fossil was hundreds of millions of years old. The fourth exam, the culmination of a week-long group case study about stem cell research, was the composition of a position paper on stem cell research incorporating students' scientific understandings and their world views. Sample questions from each exam illustrating the contextualization of material within a theistic world view are reproduced in Appendix M.

Written assignments called "think pieces" were assigned to promote individual reflection in response to a given prompt. The prompts were designed to cause intentional reflection upon or resolution of discomfort or disequilibrium that had been provoked during prior classes. These brief (one or two page) papers were opportunities for students to "think out loud" without research or reference citations. Students were asked to respond honestly and in the first person. Students earned ten points for completing a think piece and zero points if they did not; grading was not

based on content so students didn't feel like they had to guess what the professor wanted to hear. Five think pieces were assigned during the semester on the following topics: 1) the presuppositions of science and of a theistic world view; 2) the students' own misconceptions about the nature of science; 3) the role of science with respect to social issues; 4) age of the earth research and interpretations of scientific evidence by people with different beliefs about creation; and 5) the theological implications of biotechnology. The prompts for each think piece are found in Appendix N; samples of student work are found in Appendix O.

Data Analysis

All statistical procedures in this study were performed using version 15.0 of the statistical package SPSS (SPSS, Inc., 2006) at an alpha level of .05. Fall 2008 and Spring 2009 data were combined before statistical analysis. Since each research sub-problem required a different type of statistical analysis, the sub-problems and hypotheses are repeated here for clarity.

Understanding of the Nature of Science

Sub-problem 1. Are there statistically significant mean differences in students' understanding of the nature of science before and after instruction of the contextualized science course?

*Hypothesis 1.*There are statistically significant mean differences in students' understanding of the nature of science before and after instruction of the contextualized science course.

The SUSSI instrument resulted in a total score for each participant. The highest possible score was 90, indicating an informed understanding of the nature of

science. The lowest possible score was 18, indicating a naïve understanding of the nature of science. Sample means and standard deviations were calculated for pre-instruction and post-instruction scores. A two-tailed paired samples *t* test was used to determine if there was a statistically significant difference between the means of the two groups. Effect size was also calculated. In this analysis, the independent variable was the pre-instruction vs. post-instruction grouping; the dependent variable was the score on the understanding of the nature of science instrument.

Affective Attitudes toward Science

Sub-problem 2. Are there statistically significant mean differences in students' affective attitudes toward science before and after instruction of the contextualized science course?

Hypothesis 2. There are statistically significant mean differences in students' affective attitudes toward science before and after instruction of the contextualized science course.

The affective attitude toward science scale resulted in one score for each participant. The highest possible score was 60, indicating a more positive affective attitude toward science. The lowest possible score was 20, indicating a less positive affective attitude toward science. Sample means and standard deviations were calculated and a two-tailed paired samples *t* test was used to determine if there was a statistically significant difference between the means of the two groups. Effect size was also calculated. In this analysis, the independent variable was the pre-instruction vs. post-instruction grouping; the dependent variable was the score on the Affective Attitude toward Science Scale.

Beliefs Regarding Creation

Sub-problem 3. Are there statistically significant mean differences in students' beliefs regarding creation before and after instruction of the contextualized science course?

Hypothesis 3. There are statistically significant mean differences in students' beliefs regarding creation before and after instruction of the contextualized science course.

The Online Origins Survey contained three factors of interest for this study: young earth creation (YEC), old earth creation (OEC), and evolutionary creation (EC). Responses for items loading on each factor were summed. The highest possible YEC score was 50 and the lowest was 0; the highest possible OEC score was 45 and the lowest was 0; the highest possible EC score was 40 and the lowest was 0. Sample means and standard deviations were calculated and a two-tailed paired samples *t* test was used for each factor to determine if there was a statistically significant difference between the means of the two groups on each of the three factors of interest (YEC, OEC, EC). In this analysis, the independent variable was the pre-instruction vs. post-instruction grouping; the dependent variables were the mean scores for each of the three factors. Changes in the frequency distributions of participants' self-identified positions regarding creation before and after instruction were investigated using a chi-square contingency table.

Relationships among Dependent Variables

Sub-problem 4. Is there a statistically significant relationship between students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation before instruction of the contextualized course?

Hypothesis 4. There are statistically significant relationships among students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation before instruction of the contextualized course.

Sub-problem 5. Is there a relationship between students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation after instruction of the contextualized course?

Hypothesis 5. There are statistically significant relationships among students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation after instruction of the contextualized course.

Pearson *r* correlation coefficients were computed to determine relationships among the dependent variables (students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation before and after instruction.) A Bonferroni adjustment was needed to account for Type I errors across three correlations, thus a *p* value of less than .017 (0.05/3) was required for significance.

CHAPTER IV

ANALYSIS OF DATA

Introduction

The purpose of this research was to determine the impact of a contextualized science course on the scientific compatibility of religious college students' world views. The scientific compatibility of students' world views was indicated by students' understanding of the nature of science, students' affective attitudes toward science, and students' beliefs about creation. Paired-sample *t* tests were conducted to determine whether there were significant differences in students' understanding of the nature of science, students' affective attitudes toward science, and students' beliefs about creation before and after contextualized instruction. A chi-square contingency table was developed based on students' self-identified beliefs regarding creation before and after contextualized instruction. Pearson correlations examined the relationship among students' affective attitudes toward science, understanding of the nature of science, and beliefs about creation before and after contextualized instruction.

Description of Sample

Of 194 students enrolled in *Introduction to the Natural Sciences,* a core curriculum course at a Christian university in southeastern Pennsylvania, 178 students completed pre-instruction instruments. Of these, seven students dropped the course resulting in a total of 171 students who completed both pre-instruction and post-instruction testing. Eighty-six participants (50.3%) were enrolled in the course during the fall 2008 semester; 85 participants (49.7%) were enrolled during the spring 2009 semester. The participants were divided among three class sections each semester. The

same instructor taught all sections during both semesters. The frequencies and percentages of initial participants by gender, denomination, and age are presented in Table 1.

Table 1

Frequencies and Percentages of Participants by Gender, Denomination, and Age

	n	%
Gender:		
Males	62	34.8
Females	116	65.2
Denomination:		
Baptist	44	24.7
Lutheran	2	1.1
Methodist	3	1.7
Non-denominational	81	45.5
Pentecostal	11	6.2
Presbyterian	11	6.2
Other	26	14.6
Age:		
18-19	99	55.6
20-21	65	36.5
22-25	8	4.5
26-30	3	1.7
31 or older	2	1.1
not reported	1	.6

The initial participants' academic majors are given in Table 2. All students at the university graduate with a bachelor of science in biblical studies; some students choose a concentration within the biblical studies major. Other students receive a second bachelor of science degree in another academic discipline.

Table 2

Frequencies and Percentages of Participants by Academic Major

	n	%
Primary Major		
Biblical Studies	178	100
Concentration within Biblical Studies		
Camping Ministry	1	0.5
Missions	2	1.1
Pastoral Ministry	3	1.7
Youth Ministry	12	6.7
Secondary Major		
Business	15	8.4
Counseling	12	6.7
Early Childhood Education	5	2.8
Elementary Education	34	19.1
Secondary Education	24	13.5
Education-Other	6	3.4
Music	16	9.0
Social Work	26	14.6

Females made up 65.2% of the initial sample. Because all students sign a statement of Christian faith upon enrollment at the university, it was assumed that all students accepted a Christian theistic world view; this makes this sample a unique subset of the general population of university students. The greatest number of participants indicated that they were non-denominational (45.5%) followed by Baptist (24.7%). Of 14.6% of participants who indicated a denomination other than those explicitly listed, the majority said they were Mennonite, not a surprising result given the geographic location of the university in southeastern Pennsylvania. No participants were Episcopal, Anglican, Orthodox, or Roman Catholic although these choices were available on the demographic form. A majority of participants (55.6%) were 18 or 19 years old; 7.3% were above age 21.

Participants completed the Student Understanding of Science and Scientific Inquiry (SUSSI) questionnaire, the Affective Attitude toward Science Scale (AATSS), and the Origins Survey before and after instruction of the contextualized course. Means and standard deviations for each of these instruments are given in Table 3. The SUSSI questionnaire measured students' understanding of the nature of science. The students' pre-instruction mean score (M = 68.15 out of 90 points) signifies a more informed understanding of the nature of science than similar samples of undergraduate students from United States, China, and Turkey who piloted the questionnaire (Liang et al., 2006) and undergraduate students in an introductory chemistry course for non-science majors (Borda, Kriz, Popejoy, Dickinson, & Olson, 2009). This inference is based on percentages of students with informed versus naïve understandings of the nature of science in each sample.

Table 3

Comparison of Descriptive Statistics for Nature of Science Understanding, Affective Attitude toward Science, and Creation Position

Variable	Pre-instruction		Post-instruction	
	Mean	SD	Mean	SD
Nature of Science (SUSSI)[a]	68.15	6.70	70.96	6.86
Affective Attitude (AATSS)[b]	44.57	6.02	45.63	6.23
Young Earth Creation (Origins)[c]	34.63	6.58	29.81	7.00
Old Earth Creation (Origins)[d]	17.73	6.35	20.22	6.53
Evolutionary Creation (Origins)[e]	16.11	5.66	19.34	5.96

Note: $N = 171$.
[a]Maximum score = 90. [b]Maximum score = 60. [c]Maximum score = 50. [d]Maximum score = 45.
[e]Maximum score = 40.

Students who agreed or strongly agreed with informed statements about the nature of science and also disagreed or strongly disagreed with naïve statements about the nature of science were considered to have informed understandings of the nature of science. Students' views were classified as naïve if they agreed or strongly agreed with naïve statements and also disagreed or strongly disagreed with informed statements about the nature of science. Students who were not classified as naïve or informed were considered transitional (Liang et al., 2006). A greater percentage of students in this sample had informed pre-instruction understandings of the nature of science than did undergraduate students in the two other studies (Borda, 2009; Liang et al., Table 4). Using the same method for determining naïve versus informed understandings of the nature of science, the percentage of participants in this study

with an informed understanding of the nature of science increased in every SUSSI category after contextualized instruction (Table 5).

Table 4

Comparison of Informed Understandings of the Nature of Science for Three Samples of Undergraduates before Instruction

SUSSI category	Percent of students		
	Research	Pilot	Chemistry
Observations and inferences	60	35	42
Tentative nature of scientific theories	55	40	44
Social and cultural influences	42	21	38
Creativity and imagination	30	15	0
Myth of single scientific method	26	13	13

Table 5

Informed Understandings of the Nature of Science Before and After Contextualized Instruction

SUSSI category	Percent of students	
	Pre	Post
Observations and inferences	60	68
Tentative nature of scientific theories	55	66
Social and cultural influences	42	52
Creativity and imagination	30	48
Myth of single scientific method	26	32

The Affective Attitude toward Science Scale (AATSS) measured students' affective attitudes toward science apart from cognitive or behavioral components. The lowest possible score on this scale was 20, indicating a less positive attitude toward science; a high score of 60 indicated a more positive attitude. The mean pre-instruction score on the AATSS for students in this study was 44.6, which was slightly above the instrument mean of 40. This indicates a somewhat positive affective attitude toward science. These results are slightly higher than those reported by Francis & Greer (1999) for the sample of 16 and 17 year old students who piloted the attitude scale (M = 41.7 for females; M = 44.0 for males). Because students' attitudes toward science tend to become more negative with age (Francis & Greer), the students in the research sample evidenced a slightly more positive attitude toward science than might have been expected when compared to the younger British students. Students' mean post-instruction score on the attitude scale was slightly higher (M = 45.63).

The Origins Survey measured students' beliefs about creation and yielded scores on three scales, each measuring the students' acceptance of different creation positions. The evolutionary creation (EC) position had a maximum possible score of 40 which indicated a response of strongly agree for each survey item loaded on the factor evolutionary creation. The average pre-instruction EC score was 16.11 (40.3%); the average post-instruction EC score rose to 19.34 (48.4%). The maximum possible old earth creation (OEC) score was 45 which indicated a response of strongly agree for each survey item loaded on the factor old earth creation. The average pre-instruction OEC score was 17.73 (39.4%); the average post-instruction

OEC score rose to 20.22 (44.9%). The young earth creation (YEC) position had a maximum possible score of 50 which indicated a response of strongly agree for each survey item loaded on the factor young earth creation. The average pre-instruction YEC score for this sample was 34.63 (69.2%); the average post-instruction YEC score dropped to 29.81 (59.6%). These percentages do not indicate numbers of students holding these creation positions, but indicate that students had greater agreement with statements supporting a young earth creation position followed by evolutionary creation and old earth creation before and after instruction. After instruction, however, students' acceptance of statements supporting a young earth position decreased, while acceptance of statements supporting old earth creation or evolutionary creation positions increased.

Based on students' self-identified creation positions, the sample in this study displayed a different distribution of beliefs about creation before instruction than a group of similar undergraduate students at a Pentecostal university where the survey was created (Tenneson & Badger, 2009, Table 6). The post-instruction distribution of students' self-identified beliefs showed a decrease in YEC positions, small increases in the OEC and EC positions, and a large increase in the undecided/other/no response category. Tenneson and Badger (2009) judged that students' survey responses were consistent with their self-identified creation positions if respondents agreed or strongly agreed with four or five of the top five survey items (based on factor loadings) within each position. For example, a YEC student was judged to be consistent if he/she agreed or strongly agreed with at least four of five survey items that factor loaded on the YEC position. More YEC students gave survey responses

consistent with their self-identified position than did OEC or EC students both before and after instruction (Table 7).

Table 6

Self-identified Creation Positions of Sample Students vs. Pentecostal Students

Self Identified Position	Percent of Students		
	Research (pre) (N = 171)	Research (post) (N = 171)	Pentecostal (N = 763)
Young earth creation	70.8	48.0	51.1
Old earth creation	8.4	11.1	17.6
Evolutionary creation	2.2	3.5	8.5
Undecided/other/blank	18.6	37.4	22.5

Table 7

Consistency of Self-identified Creation Position with Origins Survey Responses

Self-Identified Position	Percent of students	
	Pre	Post
Young Earth	46	27
Old Earth	15	0
Evolutionary	25	17

Tests of Hypotheses

Results from the tests of the research hypotheses are presented in this section. Each research sub-problem and hypothesis is restated for clarity.

Understanding of the Nature of Science

Sub-problem 1. Are there statistically significant mean differences in students' understanding of the nature of science before and after instruction of the contextualized science course?

Hypothesis 1. There are statistically significant mean differences in students' understanding of the nature of science before and after instruction of the contextualized science course.

There was a statistically significant mean difference in students' understanding of the nature of science before (M = 68.15) and after (M = 70.96) instruction of the contextualized course, $t(170) = 5.52$, $p \leq .001$. While this difference was statistically significant, a lower than expected effect size ($p\eta^2 = 0.152$) means the practical significance of this finding must be interpreted carefully in light of other information about this sample's performance on the SUSSI. The mean pretest score indicates a somewhat informed understanding of the nature of science (Liang et al., 2006). Pre-instruction and post-instruction means and standards deviations are given in Table 3.

Affective Attitude toward Science

Sub-problem 2. Are there statistically significant mean differences in students' affective attitudes toward science before and after instruction of the contextualized science course?

Hypothesis 2. There are statistically significant mean differences in students' affective attitudes toward science before and after instruction of the contextualized science course.

There were statistically significant mean differences in students' affective attitudes toward science before (M = 44.57) and after (M = 45.63) instruction of the contextualized course, $t(170) = 2.77$, $p = .006$, with a more positive affective attitude toward science after instruction. A small effect size ($p\eta^2 = 0.043$) means that the practical significance of this finding must be interpreted carefully. Pre-instruction and post-instruction means and standards deviations are given in Table 3.

Beliefs Regarding Creation

Sub-problem 3. Are there statistically significant differences in students' beliefs regarding creation before and after instruction of the contextualized science course?

Hypothesis 3. There are statistically significant differences in students' beliefs regarding creation before and after instruction of the contextualized science course.

This hypothesis was examined using two-tailed paired samples *t* tests to analyze students' responses to the Origins survey and with a chi-square contingency table to analyze changes in students' self-identified positions regarding creation. The results of the *t* tests are presented first followed by the contingency table.

There were statistically significant mean differences in students' acceptance of statements supporting young earth creation, $t(170) = 10.10$, $p \leq .001$, $p\eta^2 = .242$; old earth creation, $t(170) = 4.46$, $p \leq .001$, $p\eta^2 = .105$; and evolutionary creation, $t(170) = 7.36$, $p \leq .001$, $p\eta^2 = .375$ before and after contextualized instruction. Mean scores for the old earth creation and evolutionary creation positions increased indicating students were more accepting of statements supporting these positions after instruction. Mean scores for the young earth creation position decreased meaning

students were less accepting of statements supporting this position after instruction. Effect sizes for the changes in the evolutionary creation and young earth creation positions indicate that these changes are of practical as well as statistical significance. Pre- and post-instruction means and standard deviations are given in Table 3.

Students' self-identified beliefs regarding creation before and after instruction were displayed in a chi-square contingency table (Table 8). Four patterns observed in this table are noteworthy.

Table 8

Changes in Students' Self Identified Beliefs about Creation

	Before Instruction						
	YEC	OEC	EC	U	O	DTA	Total
After Instruction							
YEC	73	3	4	1	1		82
OEC	8	5		4	1	1	19
EC	1	1		4			6
U	33	2		7	6	3	51
O	5			1			6
DTA	2	1				2	5
Blank	1	1					2
Total	123	13	4	17	8	6	171

Note. YEC = Young Earth Creation; OEC = Old Earth Creation; EC = Evolutionary Creation; U = Undecided; O = Other; DTA = Decline to Answer; Blank = Question left unanswered

1. One hundred twenty-three students identified themselves with a young earth creation position before instruction; after instruction, 50 of these students (41%) changed their position. Of these, 33 students said they were undecided about their creation position after instruction, eight chose an old earth creation position, one selected an evolutionary creation position, five said their position was something other than the choices given, and three participants did not state a position.

2. All four students who initially reported an evolutionary creation position changed to a young earth creation position after instruction.

3. After instruction, the young earth creation position gained a total of nine students from a variety of other positions. In contrast, the old earth position gained fourteen students from other positions after instruction, eight of whom were from the young earth creation position. The evolutionary creation position gained six students after instruction, four of whom were previously undecided.

4. More students who were undecided before instruction chose evolutionary creation or old earth creation positions after instruction (eight students) than they did a young earth creation position (one student).

Relationships among Dependent Variables

Sub-problem 4. Is there a relationship between students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation before instruction of the contextualized course?

Hypothesis 4. There are statistically significant relationship among students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation before instruction of the contextualized course.

Before instruction, statistically significant weak negative correlations were found between students' understanding of the nature of science and acceptance of old earth creation, $r(169) = -.255$, $p < .01$ and evolutionary creation, $r(169) = -.228$, $p < .01$. These correlation coefficients indicate that students' understanding of the nature of science and acceptance of statements supporting old earth creation or evolutionary creation are inversely related. A statistically significant weak positive correlation was found between students' understanding of the nature of science and acceptance of statements supporting the young earth creation position, $r(169) = .203$, $p < .01$. There was no statistically significant relationship found between students' affective attitudes toward science and any of the other dependent variables in this study before instruction.

Sub-problem 5. Is there a relationship between students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation after instruction of the contextualized course?

Hypothesis 5. There are statistically significant relationships among students' understanding of the nature of science, affective attitudes toward science, and beliefs regarding creation after instruction of the contextualized course.

There was a statistically significant weak positive correlation between students' understanding of the nature of science and acceptance of the young earth creation position, $r(169) = .303$, $p < .01$. The post-instruction relationship between these variables was slightly stronger than the pre-instruction relationship. The weak, negative relationships between students' understanding of the nature of science and old earth creation and evolutionary creation positions before instruction were still

negative, but much weaker, $r(169) = -.128$ and $r(169) = -.143$ respectively, and no longer statistically significant. There was no statistically significant relationship found between students' affective attitudes toward science and any of the other dependent variables in this study after instruction.

CHAPTER V

CONCLUSIONS AND DISCUSSION

Summary

A world view is an implicit cognitive structure based on socio-culturally generated presuppositions that determines how a person interprets and understands the world (Cobern, 1991). World views influence everyone, all of the time, usually without explicit recognition of the effect or structure of those views. World views of teachers color how and what they teach; world views of students color how and what they learn. Conflicting world views make teaching and learning difficult as extensive science education research on creation and evolution reveals (Alters, 2005; Dagher & Boujaoude, 1997; Lawson & Weser, 1990; Sinclair & Pendarvis, 1998; Sinclair et al., 1997). The participants in this study held acknowledged theistic world views, believing in a reality beyond that which can be empirically verified and in revealed knowledge beyond that which can be obtained through sensory observation or data. These world view presuppositions make it difficult for religious students to accept scientific epistemology when science, based solely on what can be observed or measured, is taught as the only correct way of knowing about reality (Cobern, 1991; Eisen & Westmoreland, 2009; Kilbourn, 1984).

This study examined the effect of an introductory science course contextualized within a Christian theistic world view on the scientific compatibility of religious college students' world views. Religious students tend to have negative attitudes toward science when the topic is biological evolution (Verhey, 2005), and to hold non-scientific beliefs regarding creation even in light of contradictory scientific evidence (Lawson & Weser,

1990; Sinclair & Pendarvis, 1998; Sinclair et al, 1997). Researchers have speculated that these characteristics may be causally connected to students' lack of understanding of the nature of science and scientific inquiry (Alters & Nelson, 2002; Schroeder, 2006; Smith, 1994). Thus, this study examined changes in students' affective attitudes toward science, their beliefs regarding creation, and their understanding of the nature of science as indicators of possible changes in the scientific compatibility of their world views.

Based on the logico-structural model of world view theory (Kearney, 1984) and on recommendations for science teaching in light of world views (Cobern, 1991, 1996; Kilbourn, 1984), the treatment in this study was to contextualize the instruction of an introductory science class within a Christian theistic world view framework in order to reveal the presuppositions implicit in the students' theistic world views and the world view presuppositions of scientific epistemology. Decisions about the selection of course readings and discussion topics and the content of written assignments and exams were predicated upon the goal of exposing, analyzing, and integrating two seemingly contradictory world views. Students' understanding of the nature of science, affective attitudes toward science, and beliefs about creation were measured at the beginning and at the end of the course to determine statistically significant changes in these variables and to reveal correlations among these indicators.

Conclusions and Discussion

Understanding of the Nature of Science

Students' understanding of the nature of science before instruction was more informed than that of two other samples of undergraduate students and showed a slight increase at the end of the course. The practical importance of this modest gain in

understanding was emphasized by the increased numbers of students with informed understandings of the nature of science after instruction on every category of the SUSSI questionnaire. This indicated a shift toward a more scientifically compatible world view and supports research literature which suggests that explicit instruction of the nature of science is necessary for student knowledge gains in this area (Abd-El-Khalick et al., 1998; Khishfe & Lederman, 2007).

Understanding of the nature of science showed a weak positive relationship with students' beliefs in young earth creation both before and after instruction. The suggestion found in the research literature that students' willingness to retain non-scientific beliefs in the face of scientific evidence to the contrary might be related to their understanding of the nature of science is not supported by these results. Instead, these findings show that the less scientifically compatible position (young earth creation) was positively related to students' understanding of the nature of science and that this relationship became stronger after instruction, despite modest gains in understanding of the nature of science. Koul (2006) speculated that students often accept contradictory evidence based on respect for the authority of the sources: students may have accepted science as having authority, but also retained young earth beliefs based on the authority they give to the Bible. For students with a young earth creation position in this study, these findings may signify compartmentalization, where students' understanding of the nature of science has had little influence on their acceptance of creation positions. This also suggests a less scientifically compatible world view.

There was a weak negative relationship between students' beliefs in old earth creation and evolutionary creation and their understanding of the nature of science before

instruction, but this relationship was no longer significant after instruction. Given that old earth and evolutionary creation positions are considered more scientifically compatible than young earth creation, the inverse relationship with understanding of the nature of science for these students was somewhat unexpected. It would be possible, however, for a student to hold an old earth or evolutionary creation position, yet still have naïve views about the role of culture in the practice of science or the creativity displayed by scientists, for example. Not all of the tenets of the nature of science were necessarily tied to factors that would influence a student's position on creation. Of interest would be the relationship between students' scores for individual SUSSI categories and their creation position to see if understanding of a particular aspect of the nature of science is associated more strongly with certain creation positions. This analysis was not possible during this study because the SUSSI sub-scales had not been validated as individual constructs. The lessening of the negative relationship between students' understanding of the nature of science and old earth or evolutionary creation beliefs before and after instruction may indicate more integration between students' new-found understanding of the nature of science and their beliefs regarding creation, suggesting that a more scientifically compatible world view had been developed.

Affective Attitude toward Science

Students' affective attitudes toward science improved slightly over the course of this study. To the extent that a more positive attitude toward science reflects a scientifically compatible world view, this change in attitude indicates a shift in the desired direction. Cautious interpretation of the practical significance of this finding is required, however, because of the small effect size and research literature which ties

changes in students' attitudes toward science to a multitude of variables such as the influence of the instructor (Oliver-Hoyo & Allen, 2005; Osbourne et al., 2003), gender (Schibeci, 1984), and the type of science being taught (Schibeci). Any or all of these could have contributed to the results obtained in this study.

Two findings related to students' affective attitudes toward science were unexpected and are worth discussing in some detail. First, students in this study had more positive affective attitudes toward science before and after instruction than were expected based on comparison with the student sample that piloted the AATSS instrument. The literature indicated that attitude toward science was negatively correlated with gender (females have poorer attitudes toward science) and age (Barmby, 2008; Schibeci); a sample of college students, with females in the majority, would be expected to have less positive affective attitudes toward science than the sample of younger students, evenly distributed by gender, who piloted the attitude scale. It is difficult to speculate on reasons for this better-than-expected attitude because of the established relationships between attitude and so many other factors. Perhaps this sample of college students had particularly good high school science teachers or only took science classes they found interesting. For most students, this was their first science course since high school; negative associations with prior science courses may have dulled over time. The fact that the instructor was a female may have played a role in the change in attitude over time for female students.

The second unexpected finding was the lack of relationship between attitude and all other variables in the study. The researcher expected a significant negative relationship between affective attitude toward science and belief in young earth creation

and significant positive relationships between attitude and all other variables. This expectation was based on the researcher's classroom experience with theistic students, anecdotal input from other university professors, and application of the Expectation-Value model of attitude formation (Azjen, 2001). The lack of relationship between attitude and the other variables in this study contributes new information to the research literature about the affective attitudes toward science of religious students and indicates the importance of future research in this area.

Beliefs Regarding Creation

Students' acceptance of statements supporting a young earth creation position decreased after instruction, while their acceptance of statements supporting old earth or evolutionary creation increased after instruction. Similarly, students' self identified positions regarding creation changed after instruction; fewer students identified themselves with a young earth position and more students identified themselves with an old earth creation position, an evolutionary creation position, or as undecided. These results indicate changes in students' ideas about creation that lean toward a more scientifically compatible world view, although whether these changes indicate a true change in belief is difficult to determine.

Other results, however, give conflicting information and indicate that students are still confused about exactly what they believe. Examining students' self-identified creation positions and their responses to survey items revealed that fewer than half of all students responded to survey items in a manner consistent with their declared position. The consistency between survey responses and stated beliefs, no matter which creation position was espoused, was lower for this sample than for a similar

group of religious college students who piloted the survey (Tenneson & Badger, 2009). Before instruction, students may have held creation positions somewhat dogmatically and been unaware of scientific evidence either supporting or opposing their position. Hence, there was greater consistency between their survey responses and their self-identified positions before instruction because their responses were belief-driven rather than knowledge-driven. After instruction, however, students knew more about scientific evidence. Their responses to survey items became knowledge-driven, while their creation position remained belief-driven, creating a larger number of inconsistent responses. Consistency of responses declined after instruction for all creation positions, which was reflective of the uncertainty that students necessarily experienced during the process of conceptual change, particularly when dealing with belief-related issues (Hokayem & Boujaoude, 2008; Sinclair & Pendarvis, 1998). A large number of students also identified themselves as undecided with respect to a creation position after instruction rather than adopting a more clearly defined position.

Students' apparent confusion and the resulting data were not unexpected, and in the researcher's opinion, were what would be observed after a brief course of instruction during which students' prevailing world views and long-held, firmly established beliefs were challenged. It was difficult to arrive at conclusions about whether these students' world views were becoming more or less scientifically compatible based on this data. It can be concluded, however, that students were engaging with ideas that were causing cognitive dissonance.

Changing a world view takes time (Anderson, 2007; Cobern, 1991). Whether one subscribes to a conceptual change model or a world view theory framework, the process of change is predicated upon creating dissonance and disequilibrium within students so they are forced to evaluate a new concept or presupposition. This process is uncomfortable and unsettling, especially when it pertains to personal beliefs rather than to merely scientific misconceptions (Sinclair & Pendarvis, 1998). It is the researcher's contention that this study has taken a snapshot of religious college students as they existed in a state of uncomfortable disequilibrium at the end of the course. A willingness to accept ambiguity by declaring an undecided position regarding creation and a similar readiness to express agreement with scientifically compatible statements which oppose belief in certain creation positions indicated a degree of open-mindedness which is a valued component of a scientifically compatible world view (Reiss, 2008). Another semester of input and discussion similar to what students experienced in this course might resolve conflicts in the students' thinking, allowing a clearer picture of the effect of contextualized instruction to emerge.

Anecdotal Reflections

Asking students who attend a university whose mission includes preparing them for Christian service to examine world view beliefs that have been instilled from childhood and reinforced by family, friends, church, and school was asking quite a lot. In teaching this course, the researcher's goal was never to undermine students' beliefs, but to expose unexamined acceptance of ideas regarding both faith and science, and in the process, to help students understand the nature of science, to appreciate science more

fully, and to begin integrating parts of two different world views into one. Fifteen weeks was not much time in which to accomplish this goal, and the time taken to gain trust, establish dialogue, and encourage reflection narrowed the window of opportunity even more. The results of this study show that the contextual methodology employed in teaching this course did help students begin the integrative process toward a more scientifically compatible world view, but that the process was far from complete.

Students' comments during office visits, conversations after class, and on course evaluations strongly supported that the goals of this class were being met. Students reported that discussions begun in the classroom continued in the cafeteria over lunch and in dorm rooms after dinner. Comments such as, "This course made me think more than any other course I've taken" and "I don't see science as the enemy anymore" were encouraging. While disequilibrium is a necessary part of genuine education, the hope is that each new course and each campus interaction helps students build the coherent world view that they desire. The data collected in this study combined with anecdotal qualitative feedback encourages the researcher to continue refining and investigating this contextualized instructional methodology.

Limitations

1. Because this was not an experimental study, the researcher could not control influences on the dependent variables occurring outside of the science classroom. Bible courses, particularly those on Genesis or the Old Testament, and philosophy courses could have a significant effect on students' beliefs regarding creation and on their thinking about epistemological issues. Students' own studies of

the Bible outside of school might also have been influential in their thinking about the integration of science and their faith, particularly regarding creation.

2. A second threat to internal validity of this study was the probable maturation of college students over the course of this study. Perry (1970) placed college sophomores on the cusp between the dualist stage of cognitive development and the contextual relativist stage. A student in the contextual relativist stage would be better able to integrate differing world views. Since a majority of students in this study were college sophomores, it was difficult to know whether any changes in world view were due to the contextualized instruction or to changes in students' developmental levels.

3. The college students in this sample had self-reported Christian theistic world view. This study may not be generalizable beyond a similar sample.

Implications for Practice

This study provides support for the research literature which recommends that students' beliefs should explicitly be taken into consideration in the science classroom (Alters & Nelson, 2002; Esbenshade, 1993; Smith, 1994). Both quantitative data and anecdotal qualitative data indicate that making religious students' world view presuppositions and the presuppositions of a scientific world view an explicit part of the discussion in the science classroom was associated with the development of a more scientifically compatible world view for some students. Shipman et al. (2002) found that brief discussion of cosmological and belief-related topics in a secular astronomy course caused some students to engage in world view reflection and that no students were offended by such discussions. Together, these studies indicate that whether in a Christian

setting or a secular setting, students are interested in discussing world view issues, that scientific content provides appropriate starting points for such discussions, and that such discussions potentially result in increased science literacy as students integrate a scientific way of thinking into their personal epistemologies.

Because much of the research literature focuses on religious students' belief in young earth creation, teachers at religious institutions may begin to think of students' beliefs regarding creation as a monolithic whole. As this study shows, students are conflicted about the views they claim to hold about creation and the scientific evidence they accept related to those views. Instructors in religious settings should be aware that students hold a variety of positions regarding creation that they may not understand or be able to fully express. Teaching in such a way to uncover the presuppositions inherent in these varying world view beliefs along with teaching the presuppositions of science will help religious students clarify their thinking about the validity of scientific evidence relative to their unique positions regarding creation.

Proponents of constructivist education emphasize the importance of student-centered teaching and learning, particularly in the science classroom (Alters & Nelson, 2002; Smith, 1994). According to these researchers, students do not construct new knowledge unless they are engaged in the process of examining and evaluating new input in a meaningful way. This study provides support for developing science courses that employ less didactic and more student-centered pedagogy if the goal of instruction is indeed scientific literacy. Science literacy, as described by Cobern (1996), necessarily involves understanding the context of the scientific language; this context, which includes the epistemological and ontological presuppositions of

science, cannot be adequately apprehended by students in a lecture-style class or apart from discussion and activities that cause them to engage with the material on a personal level.

Finally, requiring an introductory science course that explores science and scientific inquiry from philosophical and sociological perspectives as part of every student's university experience would encourage the incorporation of scientific ways of thinking into students' currently existing world views. This course would be taken at a naturally appropriate stage in students' development (Perry, 1970), when they are better able to integrate several world view perspectives (Hermann, 2007) into one world view. As discussions center on controversial or contentious issues such as evolution or stem cell research, the ability of students to speak from a common understanding of the nature of science would limit irrelevant debate and guide the conversation within more productive channels. If the scientific literacy called for by science education reform documents is meant to truly incorporate scientific ways of thinking into American citizens' existing world views, then a much more robust and holistic understanding of science is required than can be achieved through a series of science content classes.

Recommendations for Future Research

1. The scientific compatibility of a world view (Cobern, 1991, 1996) has not been clearly defined in the literature and thus, is difficult to measure. The indicators used in this research were three of many that could have been chosen. The lack of correlation among the variables in this study indicates that they do not sufficiently represent a coherent scientific compatibility construct. Further research is needed to operationally

define what is meant by scientific compatibility of a world view and to delineate measurable constructs that contribute to such a world view. One promising area of investigation would be the scientific attitudes of religious students including open-mindedness, objectivity, and willingness to suspend judgment (LaForgia, 1988).

2. The attitudes toward science of religious students are not well documented in the research literature. Studies of religious students' affective attitudes toward science, controlling for the influences of age, gender, and other confounding variables, would contribute valuable new information to this field.

3. A continuation of this study is recommended with two modifications: (a) the study should become longitudinal and follow students over time to investigate the resolution and/or retention of changes to their beliefs regarding creation as being indicative of a more scientifically compatible world view; and (b) the study should incorporate qualitative components including interviews with students and evaluation of their written work to clarify the relationship between students' understanding of the nature of science and beliefs regarding creation and to examine the lack of consistency between their responses to survey items in light of their self-identified creation position. Such qualitative research would also allow the researcher to directly examine the students' ideas about the influence of the contextualized course on the dependent variables in this study.

4. While many studies reference world view as an important factor in science education, only one other study was located that explicitly examined the effect of teaching science in a world view context on students' world views and the integration of science within that world view. An array of possible studies awaits researchers who are

willing to develop lessons, units, or entire courses that incorporate science and world-view related topics and discussions. The effect of this instructional methodology on students' achievement, attitude, motivation, or interest in science at a variety of grade levels, in all educational settings, is rich source of future research questions.

APPENDIX A

ABBREVIATED COURSE SYLLABUS

I. Description of the Course: *Introduction to the Natural Sciences*

This course is an introduction to the history, philosophy, and methodologies of the natural sciences. The focus of the course is on the development and nature of scientific thought along with an exploration of the assumptions and limitations implicit in scientific endeavors. Emphasis will be placed on the integration of Christian faith and science.

II. The General Curriculum Objective(s) Addressed in this Course

As part of the Arts and Sciences curriculum, this course is designed to assist the student to achieve the following objectives of this curriculum:

A. Acquire basic knowledge from a broad spectrum of human learning.

B. Learn to think logically and critically, weighing issues with discernment and applying sound conclusions to life.

C. Increase knowledge of and care for the physical environment.

D. Gain an understanding of oneself and society that will enrich personal relationships and enhance social usefulness.

E. Develop a world view under the authority of Scripture through integration of general knowledge with biblical principles.

III. The Specific Objectives of this Course

Upon completion of this course, the student will be able to:

A. comprehend the nature of science, including the assumptions upon which science is based, the nature and limitations of scientific knowledge, the processes and methodologies of science, and the self-correcting nature of scientific inquiry.
B. understand that science is a relatively recent enterprise, tracing the development of scientific thought as influenced by the historical, cultural, religious, and philosophical contexts of the past four centuries.
C. recognize and discuss the influence of scientific thought on culture during the past four centuries
D. relate science, scripture, and a biblical world view, including the response of a Christian to science as an intellectual domain
E. describe significant turning points in the development of current scientific thought including Newtonian laws of motion and gravity; the theory of evolution and Darwinian natural selection; genetics, heredity, and the discovery of DNA; Einstein's theory of relativity; and theories of the atom and quantum mechanics
F. discuss the scientific basis for and ethical implications of current issues in science including stem-cell research and genetic engineering
G. judge the credibility of scientific information
H. utilize scholarly avenues for the continued exploration of science and faith integration

Tentative Course Schedule

Introduction to the course

Week 1	Read: Boehlke, Knapp, & Kolander

The Nature and Purpose of Science

Week 2	The Purpose, and Presuppositions of Science Read: Project 2061 and Allchin , D.
Week 3	The Nature of Science The Great Fossil Find
Week 4	The "Traditional" Scientific Method NPR interview: The Power of Prayer
	Assessment #1: The Nature and Purpose of Science

The Cultural Context of Science

Week 5	Geocentricity and Heliocentricity (Mr. Palladino)
	Francis Galton and Hereditary Genius: Science and Race
	The Tuskegee Study of Untreated Syphilis

The Content of Science

Week 6	Physics' Model of the Atom *The Five Biggest Ideas in Science (Chapter 1)*
Week 7	Quantum Mechanics
Week 8	Geology's Plate Tectonics *The Five Biggest Ideas in Science (Chapter 4)*
	Spring Break
Week 9	Astronomy's Big Bang Theory Guest Speaker: Mr. Tabachnick, Delaware Valley College *The Five Biggest Ideas in Science (Chapter 3)*
	Assessment #2: The Content of Science

The Integration of Science and Faith

Week 10	World Views and Genesis (Dr. Putnam) *Origins,* Chapter 5 and Chapter 6 World views and Science *Origins*, Chapter 2 and Chapter 4
Week 11	Views about the age of the Earth *Origins*, Chapter 8
	Easter Break
Week 12	The Basics of Evolution: Microevolution and Speciation *The Five Biggest Ideas in Science (5)*
Week 13	Macroevolution and Human Evolution
	Assessment #3: Faith, Science, and World View Integration

Issues in Science

Week 14	Introduction to Genetic Engineering Genetic engineering Case Studies
Week 15	Stem-cell research Case Study
	Final Assessment: Group Position Paper on Stem Cell Research

APPENDIX B

DEMOGRAPHIC INFORMATION FORM

Please supply the following demographic information by checking the appropriate box in each category.

1. What is your gender?

□ Male
□ Female

3. What is your age group?

□ 18-19
□ 20-21
□ 22-25
□ 26-30
□ 31 or older

2. What is your denominational affiliation?

□ Baptist
□ Episcopal/Anglican
□ Lutheran
□ Methodist
□ Non-denominational
□ Orthodox
□ Pentecostal
□ Presbyterian
□ Roman Catholic
□ Other: _____

4. What is your major field of study? You may check more than one box.

□ Biblical Studies
□ Business
□ Camping Ministries
□ Children's Ministries
□ Counseling
□ Early Childhood Education
□ Elementary Education
□ Undecided
□ Secondary Education
□ Education-other
□ Missions
□ Music
□ Pastoral Ministry
□ Social Work
□ Youth Minister
□ Other: _____

APPENDIX C

STUDENT UNDERSTANDING OF SCIENCE AND SCIENTIFIC INQUIRY QUESTIONNAIRE (SUSSI)

Please read EACH statement carefully, and then indicate the degree to which you agree or disagree with EACH statement by circling the appropriate letters to the right of each statement. (SD = strongly disagree; D = disagree more than agree; U = uncertain or not sure; A = agree more than disagree; SA = strongly agree).

---

1. *Observations and Inferences*

A. Scientists' observations of the same event may be different because the scientists' prior knowledge may affect their observations.	SD	D	U	A	SA
B. Scientists' observations of the same event will be the same because scientists are objective.	SD	D	U	A	SA
C. Scientists' observations of the same event will be the same because observations are facts.	SD	D	U	A	SA
D. Scientists may make different interpretations based on the same observations.	SD	D	U	A	SA

2. *Change of Scientific Theories*

A. Scientific theories are subject to on-going testing and revision.	SD	D	U	A	SA
B. Scientific theories may be completely replaced by new theories in light of new evidence.	SD	D	U	A	SA
C. Scientific theories may be changed because scientists reinterpret existing observations.	SD	D	U	A	SA
D. Scientific theories based on accurate experimentation will not be changed.	SD	D	U	A	SA

3. *Social and Cultural Influence on Science*

A. Scientific research is not influenced by society and culture because scientists are trained to conduct "pure" unbiased studies.	SD	D	U	A	SA
B. Cultural values and expectations determine *what* science is conducted and accepted.	SD	D	U	A	SA
C. Cultural values and expectations determine *how* science is conducted and accepted.	SD	D	U	A	SA
D. All cultures conduct scientific research the same way because science is universal and independent of society and culture.	SD	D	U	A	SA

4. *Imagination and Creativity in Scientific Investigation*

A. Scientists use their imagination and creativity when they collect data.	SD	D	U	A	SA
B. Scientists use their imagination and creativity when they analyze and interpret data.	SD	D	U	A	SA
C. Scientists do *not* use their imagination and creativity because these conflict with their logical reasoning.	SD	D	U	A	SA
D. Scientists do *not* use their imagination and creativity because these can interfere with objectivity.	SD	D	U	A	SA

5. *Methodology of Scientific Investigation*

A. Scientists follow the same step-by-step scientific method.	SD	D	U	A	SA
B. When scientists use the scientific method correctly, their results are true and accurate.	SD	D	U	A	SA

APPENDIX D

PERMISSION TO USE THE SUSSI QUESTIONNAIRE

Dear Paula,

You are welcome to use the SUSSI instrument - it's free with proper citation. The instrument is not perfect but my colleagues and I found it more user friendly... feel free to modify it as needed. For the past two years, I worked on a couple of different projects and did not continue the SUSSI study. The instrument is now published online at http://www.ied.edu.hk/apfslt/v9_issue1/liang/ (Volume 9 Issue 1 of the Asia-Pacific Forum on Science Learning and Teaching). The international comparison part is in a separate paper (accepted) and will be published at the International Journal of Math and Sci. Education. I am attaching the instrument & paper below. Let me know if you have further questions. Perhaps we'll see each other at NARST? Or since we're neighbors, you are most welcome to visit La Salle :-)

Take care and good luck!

Ling

==========

Ling Liang, Ph. D.
Associate Professor of Science Education
Department of Education, La Salle University
1900 West Olney Avenue
Philadelphia, PA 19141 - 1199
Tel: (215) 951-1174, Fax: (215) 951-5029

APPENDIX E

AFFECTIVE ATTITUDE TOWARD SCIENCE SCALE

Please read EACH statement carefully, and then indicate the degree to which you agree or disagree with EACH statement by circling the appropriate letters to the right of each statement. (D = disagree; U = uncertain; A = agree).

---

1. Science has ruined the environment.	D	U	A
2. Working in a science laboratory would be a very interesting way to earn a living.	D	U	A
3. Science is very important for a country's development.	D	U	A
4. Money spent on science is well worth spending.	D	U	A
5. In my future career, I would like to use the science I learned in school.	D	U	A
6. Science will help to make the world a better place in the future.	D	U	A
7. Scientific discoveries do more harm than good.	D	U	A
8. Science and technology are the cause of many of the world's problems.	D	U	A
9. Science is an enjoyable school subject.	D	U	A
10. The science taught in school is interesting.	D	U	A
11. Science is a difficult subject.	D	U	A
12. Science is difficult when it involves calculation.	D	U	A
13. Science is relevant to everyday life.	D	U	A
14. I do not have much interest in science.	D	U	A
15. More scientists are urgently needed.	D	U	A
16. Studying science gives me great pleasure.	D	U	A
17. I will seriously consider becoming a scientist when I leave school.	D	U	A
18. I look forward very much to science lessons in school.	D	U	A

19. I would like to understand more about scientific explanations for things.	D	U	A
20. I would like to study science more deeply than I do at present.	D	U	A

APPENDIX F

PERMISSION TO USE THE AFFECTIVE ATTITUDE TOWARD SCIENCE SCALE

Dear Paula

Of course I am pleased to give permission for you to use the scale, and I wish you well in your research. I hope that you may be willing to keep me in touch with your progress.

With best wishes

Leslie

The Revd Canon Professor Leslie J Francis
Professor of Religions and Education
Warwick Religions and Education Research Unit
Institute of Education
University of Warwick
Coventry CV4 7AL
UK

direct line: 024 7652 2539
e-mail: leslie.francis@warwick.ac.uk

APPENDIX G

THE ORIGINS SURVEY

Please read EACH statement carefully, and then indicate the degree to which you agree or disagree with EACH statement by circling the appropriate letters to the right of each statement. (SD = strongly disagree; D = disagree; U = uncertain; A = agree; SA = strongly agree; N = decline to answer).

---

1. Evolution (macroevolution) should be rejected for scientific reasons.	SD	D	U	A	SA	N
2. God used evolution to produce the various life forms (kinds).	SD	D	U	A	SA	N
3. Over time living things have changed from one life form (kind) to another life form (kind).	SD	D	U	A	SA	N
4. God created the various life forms in separate creative acts over millions of years.	SD	D	U	A	SA	N
5. The days of creation in Genesis refer to very long periods of time.	SD	D	U	A	SA	N
6. Each life form (kind) was specially created by God, but these creative acts did not happen in six consecutive 24-hour periods.	SD	D	U	A	SA	N
7. The scientific community cannot be trusted to investigate origins without bias.	SD	D	U	A	SA	N
8. God specially created Adam and Eve millions of years after He created plants.	SD	D	U	A	SA	N
9. Humans and dinosaurs lived on Earth simultaneously.	SD	D	U	A	SA	N
10. The universe is at least several billion years old.	SD	D	U	A	SA	N
11. Naturalistic macroevolution provides a complete and satisfying explanation of the origin of humans.	SD	D	U	A	SA	N
12. Macroevolution did not happen by chance; God guided it.	SD	D	U	A	SA	N
13. No solid scientific evidence exists that challenges a literal interpretation of the Genesis account of creation.	SD	D	U	A	SA	N

14. Noah's flood (in Genesis) explains the geological layers.	SD	D	U	A	SA	N
15. God is still using macroevolution to produce new life forms (kinds).	SD	D	U	A	SA	N
16. The earth is not more than 15,000 years old.	SD	D	U	A	SA	N
17. People should try to harmonize the Genesis account of creation with the fact of macroevolution.	SD	D	U	A	SA	N
18. Each life form (kind) was specially created by God, but the creation days of Genesis 1 generally correspond to geologic ages.	SD	D	U	A	SA	N
19. Evolution (macroevolution) should be rejected for theological reasons.	SD	D	U	A	SA	N
20. Evolutionary ideas are incompatible with the nature of God as revealed in the Bible.	SD	D	U	A	SA	N
21. Evolution (macroevolution) is a well-supported scientific principle.	SD	D	U	A	SA	N
22. Accepting evolutionary theory leads to the rejection of biblical values.	SD	D	U	A	SA	N
23. The creation account in Genesis should be understood as six consecutive 24-hour periods.	SD	D	U	A	SA	N
24. Christians who believe in theistic evolution have placed too much confidence in science and scientists.	SD	D	U	A	SA	N
25. The first human beings evolved millions of years after God first created life.	SD	D	U	A	SA	N

Read the descriptions of the basic origins positions below and check the box next to one description that comes closest to your own position.

□ **Atheistic evolution (Ateleological Evolution)**

Life arose from non-life and one kind of life changes into other kinds of life without divine intervention since God is thought to be non-existent.

□ **Deistic Evolution**

The physical realm is a superior and more trustworthy revelation of God than the Bible, which is rejected as neither inspired nor authoritative. If God created the physical realm, he left it to evolve on its own.

□ **Theistic Evolution (Evolutionary Creation)**

Evolution is the method God used to guide the development of existing life forms from the original life forms which he created. Evolution (macroevolution) can be harmonized with the biblical account of origins.

□ **Old Earth Creation (Progressive Creation)**

There are scientific evidences for a universe that is billions of years old, but God created everything, including life, by a series of creative acts that took place over a long period of time. There is disagreement about when each of these creative acts occurred. Macroevolution is generally rejected, and God directly created life in its various forms.

□ **Young Earth Creation (Scientific Creation)**

Both the Bible and scientific evidences support these conclusions: 1) God suddenly made the physical realm and life, 2) out of nothing, 3) in six consecutive 24-hour periods, 4) about 8.000 to 15,000 years ago. Thus, contemporary theories of evolution (macroevolution) are rejected.

Other, Undecided, and "I decline to answer" were also possible choices.

APPENDIX H

PERMISSION TO USE ONLINE ORIGINS SURVEY

Dear Ms Gossard:

We are happy to grant you permission to use our Online Origins Survey in your dissertation.
Below is more information in case you need it for a citation.

Sincerely,

Steve Badger, PhD
Mike Tenneson, PhD
Evangel University
1111 North Glenstone Ave
Springfield, MO 65802

badgers@evangel.edu
tennesonm@evangel.edu

417.865.2815

==========

Steve Badger, PhD
Professor of Chemistry

APPENDIX I

ORAL PRESENTATION FOR INFORMED CONSENT

You are being invited to participate in a research study investigating the effect of this course, *Introduction to the Natural Sciences*, on your views toward science and creation. This study is being undertaken to fulfill the dissertation requirements for the researcher's doctoral program. Your participation in the study will involve taking three surveys in class. The surveys will investigate three different areas: 1) your understanding of the nature of science; 2) your attitude toward science; and 3) your beliefs regarding creation. You will be asked to indicate the degree to which you agree or disagree with certain statements; there are no correct or incorrect answers on these surveys. You will take each survey twice; once at the beginning of the semester and once at the end of the semester. They will require about half an hour of your time each time you take them. Students who do not participate in the study will work quietly at their seats while the participants respond to the surveys.

There are no direct benefits to you from participating in this study other than benefits that may result from thinking about the survey questions or feelings of satisfaction from having helped with a research project. Similarly, there is little risk to you other than the inconvenience of taking time outside of class to respond to one of the surveys and perhaps a slight feeling of discomfort if survey questions are difficult or stressful for you to answer.

Your participation in this study is completely anonymous. The survey response sheets will each be coded with a random number; this number will never be associated with your name. All surveys will be shredded at the end of the study. Results will be made available to interested participants upon completion of the study.

This project has been reviewed by the Human Subjects Protection Review Committee, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research participant should be directed to the chair of the Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5147, Hattiesburg, MS 39406-0001, (601) 266-6820. Participation in this project is completely voluntary and participants may withdraw from this study at any time without penalty or prejudice. Any questions about the research should be directed to Mrs. Nancy Painter at (215) 702-4259.

_____ _____

Signature of person giving oral presentation Date

_____ _____

Witness to oral presentation Date

APPENDIX J

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

AUTHORIZATION TO PARTICIPATE IN RESEARCH PROJECT

Participant's Name: _____

Consent is hereby give to participate in the research project entitled "The effect of integrated instruction on the scientific compatibility of worldviews." All procedures to be followed and their purpose, including any experimental procedures, were explained by the researcher's proxy, Mrs. Nancy Painter. Information was given about all benefits, risks, inconvenience, or discomforts that might be expected.

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

Questions concerning the research, at any time during or after the project, should be directed to Mrs. Nancy Painter at (215) 702-4259. This project and this consent form have been reviewed by the Human Subjects Protection Review Committee, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research participant should be directed to the chair of the Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5147, Hattiesburg, MS 39406-0001, (601) 266-6820.

_____ _____

Signature of Participant Date

_____ _____

Signature of person explaining the study Date

APPENDIX K

COURSE READINGS

Unit 1: The Nature of Science

Allchin, D. (2004). Error and the nature of science. Retrieved from http://www.actionbioscience.org/education/allchin2.html

American Association for the Advancement of Science. (1989). *Science for all Americans.* Chapter 1: The nature of science. Retrieved from http://www.project2061.org/publications/sfaa/online/chap1.htm

Boehlke, P., Knapp, L., and Kolander, R. (2006). How science works: Foundations, method, and teleology. Putting presuppositions on the table: why the foundations matter. *Zygon, 41*(2), 415-425.

Unit 2: The Cultural Context of Science

Galton, F. (1869). *Hereditary genius: An inquiry into its laws and consequences.* London: MacMillan.

Holmes, J. (1927). *Opinion of the court: Buck v. Bell, Error to the Supreme Court of Appeals of the State of Virginia* Supreme Court of the United States, 274 U.S. 200.

Unit 3: The Content of Science

Faulkner, D. (2009). The big bang, multiverse, and other tales about outer space. *Acts and Facts,* 38(2), 28.

Gee, H., Howlett, R., & Campbell, P. (2009). 15 evolutionary gems. *Nature,* January, 2009. Retrieved from www.nature.com/evolutiongems

Newman, R. (n.d.). Scriptural evidence for an old earth. Retrieved from http://www.newmanlib.ibri.org/Documents/OldEarthScriptEvid.htm

Phillips, P. (2005). The thrice-supported big bang. *Perspectives on Science and Christian Faith, 57*(2), 82-96.

Ross, H. & Rea, J. (2000). The big bang: the Bible taught it first. *Facts for Faith, 3.* Retrieved from http://www.reasons.org/resources/publications/facts-faith/2000issue03#big_bang_the_bible_taught_it_first

Sinclair, J. (n.d.). The metaphysics of quantum mechanics. Retrieved from http://www.reasons.org/physics/constants-physics/metaphysics-quantum-mechanics

Theobald, D. (2004). 29+ evidences for macroevolution: The scientific case for common descent. *The Talk Origins Archive* vers. 2.83. Retrieved from www.talkorigins.org/faqs/comdesc/

Wynn, C. & Wiggins, A. (1997). *The five biggest ideas in science.* New York: John Wiley, Chapter 1, 13-30; Chapter 3, 47-64; Chapter 4, 65-80, Chapter 5, 81-106.

Unit 4: Science and Faith

Dean, C. (2007, February 12). Believing scripture but playing by science's rules. *The New York Times.* Retrieved from http://www.nytimes.com/2007/02/12/science/12geologist/html

Unit 5: Issues in Science

Hartling, D. (2005). The moral status of the early human embryo: Balancing reverence and integrity. Paper presented at the 2005 International Institute for Christian Studies Conference. Retrieved from http://www.iics.com/vision2005papers.html

APPENDIX L

WEBSITES AND JOURNALS

Websites (descriptions were taken from each website's purpose statement)

1. American Scientific Affiliation: www.asa3.org

The American Scientific Affiliation is a fellowship of men and women in science and disciplines that relate to science who share a common fidelity to the Word of God and a commitment to integrity in the practice of science.

2. Answers in Creation: www.answersincreation.org

Answers in Creation is an old earth creation science ministry providing rebuttals to the false claims of young earth creation science.

3. Answers in Genesis: www.answersisgenesis.org

Answers in Genesis feels called to proclaim the life-changing message of the gospel, beginning in the book of Genesis. Answers in Genesis is the largest apologetics organization in the world and is poised to challenge evolution on every continent and in every language (Answers in Genesis, 2009)

4. God and Science: http://www.godandscience.org/

God and Science provides evidence for the existence of God and the reliability of the Bible and provides answers for common questions and objections to Christianity.

5. Institute for Creation Research: www.icr.org

The Institute for Creation Research provides in-depth scientific and biblical information regarding the creation/evolution controversy from a young earth creation perspective.

6. Interdisciplinary Biblical Research Institute: www.ibri.org

The Interdisciplinary Biblical Research Institute is a group of Christians who see a need for men and women convinced of the complete reliability of the Bible who will: (1) get

training both in Biblical studies and in some other academic discipline, and (2) use this training to help other Christians deal with areas where non-Christian teaching is dominant today.

7. Reasons to Believe: www.reasons.org

The mission of Reasons to Believe is to show that science and faith are, and always will be, allies, not enemies.

8. Talk Origins: www.talkorigins.org

Talk Origins is devoted to the discussion and debate of biological and physical origins. Most discussions center on the creation/evolution controversy, but other topics of discussion include the origin of life, geology, biology, catastrophism, cosmology, and theology.

9. Understanding evolution for teachers:

http://evolution.berkeley.edu/evosite/evohome.html

Journals

Perspectives on Science and Christian Faith, journal of the American Scientific Affiliation

Zygon: Journal of Religion and Science, sponsored by the Institute on Religion in an Age of Science (IRAS) and the Center for Advanced Study in Religion and Science (CASIRAS)

APPENDIX M

SELECTED ASSESSMENT QUESTIONS

Assessment #1, Fall Semester: The nature of science

Students were asked to read a case study called "Prayer Study: Science or Not?" and then respond to questions posed by the instructor about the nature of science, the scientific method, and the following question aimed specifically at assessing students' thinking about the integration of science and faith:

Is the medical effectiveness of prayer an appropriate topic of scientific study? What are the implications of studies of this nature? Your answer should reflect an understanding of the definition, presuppositions, purpose, and nature of science as well as your thoughts about the relationship between science and faith.

Assessment #1, Spring Semester: The nature of science

Students were asked to choose one of the following questions and to write one paragraph in response:

A. Argue that it is important for students at a biblical university to take a class that explains the process of science and requires them to think about the integration of faith and science. Give at least three reasons for your opinion supported with scripture *and* with what you've learned in class so far this semester.

B. Is modern science inherently atheistic, agnostic, or neutral with respect to God, or is it none of these? Give at least three reasons for your opinion supported with what you have learned so far in class this semester about science (nature, purpose, presuppositions).

Assessment #2: The content of science

Students were asked to answer the first question below and then to choose one of the following three questions.

Mandatory question: For *each* of the theories we have studied so far (Atomic Theory; Plate Tectonics Theory; Big Bang Theory), discuss its integration (or lack thereof) with your biblical world view. If you feel that the theory *does* integrate well, explain why. If you feel that the theory *does not* integrate well, explain why not and discuss the questions you are still wrestling with. Your answer should reflect thoughtful consideration of this question and should include specifics about the theories themselves.

Choose one of the following three questions:

A. What is quantum mechanics? Thomas Young's double slit experiment caused scientists to confront the nature of subatomic particles. What did Young observe and why was it puzzling? Discuss two interpretations of subatomic "reality" that resulted from Young's experiment. In your opinion, can there be objective "reality" in light of this experiment?

B. Describe/discuss at least three lines of evidence supporting the theory of plate tectonics. At least one of these must involve paleo-magnetic data. Do you believe this is a well-substantiated theory? If so, what is the strongest evidence supporting the theory and why do you think so? If not, explain the weaknesses you perceive in the evidence.

C. Discuss our guest professor's oft-repeated statement, "Science tells us how or what; religion tells us why." What are the implications of this statement? Does this statement promote a relationship between science and religion that you are comfortable with? Why or why not? Discuss this statement in light of what you have learned in this class.

Assessment #3: Faith and Science

This assessment was a take-home assignment. Students were asked to read the New York Times' article *Believing scripture but playing by science's rules,* and then to answer the following questions. The students were encouraged to discuss the article and their responses with one another, but their writing was to be their own work.

1. Must a Christian scientist sacrifice his/her beliefs in order to gain respect in the scientific community? In other words, is it possible to be a Christian and still do "good science"? If not, what are the implications of this line of thinking? Be sure that your answer includes the characteristics of "good science."

2. Readers of the New York Times are invited to post their responses to articles via an online forum called "Share Your Thoughts." The question that was posed with this article was "Can a scientist produce intellectually honest work that contradicts deeply held religious beliefs?" Compose a one-paragraph response to the question, suitable for online posting.

3. Make a list of at least five questions you would ask if you were interviewing *one* of the following people mentioned in the article. Then explain *why* you chose the person *and* the questions that you did. Be sure that your questions are meaningful and relevant to the topic of the article and/or our class discussions. *Do not ask questions to which you could find answers with a simple internet search!* The people you may choose from are: Dr. E. Scott, Dr. K. Wise, Dr. J. Boothroyd, Dr. J. Baumgardner, or Dr. M. Dini.

4. Define the word "paradigm." Dr. Ross says he operates within two different paradigms. What are they? If you could have a conversation with Dr. Ross wearing your "theological hat" what would you like to discuss/ask/say? If you could have a

conversation with Dr. Ross wearing your "scientist hat", what would you like to discuss/ask/say? Why would it be necessary to wear two different hats to have a conversation with Dr. Ross?

Assessment #4: Issues in Science

Students spent one week in small groups of three or four students working on a case study about stem cell research called "Saving Superman," a reference to Christopher Reeves' devastating riding accident. After researching the medical background of stem cell research and discussing the ethical implications from their world view perspective, students met during the final exam period to compose a position paper on stem cell research in response to the following prompt:

From BBC News (http://news.bbc.co.uk/2/hi/americas)

9 March 2009

Today President Obama lifted restrictions on federal funding for research on new stem cell lines. Mr. Obama signed an executive order in a major reversal of US policy, pledging to "vigorously support" new research. [Former President George W. Bush had blocked the use of any government money to fund research on human embryonic stem cell lines created after 9 August 2001.] At this moment the full promise of stem cell research remains unknown and it should not be overstated," Mr. Obama said. "But scientists believe these tiny cells may have the potential to help us understand and possibly cure some of our most devastating diseases and conditions." Analysts say Mr. Obama's decision could also lead Congress to overturn a ban on spending tax dollars to create embryos. Correspondents say the policy change is part of President Obama's pledge to make clear that his administration wants scientific research to be free from political interference.

Announcing his decision, Mr. Obama described himself as a man of faith who had carefully weighed the implications of the decision, and said moving forward required a "delicate balance". Like Mr. Bush, President Obama has profound Christian beliefs but he has defined the issue in terms of integrity. To that end, he also signed a memorandum directing the White House's science and technology office to develop a strategy for restoring scientific integrity to government. And he vowed that only research meeting strict ethical guidelines would be allowed, stressing that under no circumstances would stem cells be used for research into human cloning. "It is dangerous, profoundly wrong, and has no place in our society, or any society," Mr. Obama said. Scientists say the research will lead to medical breakthroughs, but many religious groups are opposed to it.

Directions: Compose a letter to President Obama outlining your group's position(s) on stem cell research. Be sure that your letter discusses the different forms of stem cell research that were presented in the case study "Saving Superman." Your letter should include at least one reference to the article by Ruth Hartling and one reference to Scripture and/or the Christian beliefs that you share with President Obama. Your letter should be no longer than two double-spaced pages.

APPENDIX N

THINK PIECE PROMPTS

Think Piece #1

Are the four presuppositions of science discussed in class consistent with a biblical world view? Defend your opinion using scripture or with reference to biblical principles or concepts.

Think Piece #2

Based on your reading of Chapter 1 of Project 2061 and The Great Fossil Find activity, write a one-to-two page reflection on *either* of the following topics:

1) What misconceptions did you previously have about how scientists work and the nature of scientific understanding that were revealed by the reading and/or activity?

2) Describe at least eight ways that The Great Fossil Find activity illustrates the nature of science as described in Project 2061. Be specific.

Think Piece #3

Last week in class we discussed the cultural context of science. In doing so, we looked at examples of the following types of interaction:

1) Culture sometimes limits the acceptance and influence of valid and original scientific thinking (Galileo and heliocentric theory)

2) Culture uses valid scientific findings (the laws of genetics) to justify seemingly immoral social policies (eugenics)

3) Poor scientific methodology (craniometry) or pseudoscience (phrenology) are used to justify existing cultural beliefs and practices (racism)

4) Cultural norms influence the practice of science sometimes resulting in unethical scientific methodology (Tuskegee Study of Untreated Syphilis)

After some reflection on last week's topic, write one to two pages in response to the following questions. You do *not* have to specifically answer each question in the prompt; they are included only to encourage your thinking.

How will *you*, as a Christian, wrestle with the reliability of science and its applicability to important social issues. Is it right to become completely skeptical of *all* science just because we've looked at some specific abuses and misapplications? Will you be skeptical only about the science that is related to important moral issues such as abortion or stem cell research? Do Christians today respond to "uncomfortable" science the same way the church did in Galileo's day? Do you think valid scientific findings are ever inappropriately applied for political, social, or economic ends? Where did last week's topics lead you in your thinking about these issues?

Think Piece #4

After some preliminary reading, choose a *specific* part of the young earth-old earth conversation that interests you. It can be a theological point (the meaning of the Hebrew word *yom*, for example) or a scientific point (the thickness of dust on the moon, for example). Research the topic from a variety of theistic perspectives using the websites posted on e-Learning. Be sure to read each website's purpose statement so you clearly understand the perspective of the author(s). Write a one-to-two page summary of what you've learned about the topic and discuss how visiting multiple websites has impacted your thinking about the age of the Earth and the interpretation of scientific evidence in light of a pre-existing belief or world view. *Include citations for each website.*

Think Piece #5

1. How does (or how should) the nature of God as revealed in scripture inform our thinking about biotechnology issues?

2. What do we learn about the nature of man as we observe the quest to understand (and control) the very code of life itself?

APPENDIX O

EXAMPLES OF STUDENT WORK

Response to Think Piece Prompt #2: Based on your reading of Chapter 1 of Project 2061 and The Great Fossil Find activity, write a one-to-two page reflection on either of the following topics:

1) What misconceptions did you previously have about how scientists work and the nature of scientific understanding that were revealed by the reading and/or activity?

2) Describe at least eight ways that The Great Fossil Find activity illustrates the nature of science as described in Project 2061. Be specific.

Growing up, I gained the culmination of my scientific knowledge from elementary and high school textbooks--along with a healthy dosage of Bill Nye the science guy. Because of this, I soon came to realize that before performing "The Great Fossil Find" I had many presupposed misconceptions of science that I never before realized that I had. Among these were the realization of approximation, the room for rearrangement, and the infallibility of the facts. After gaining a basic understanding of the misconceptions that I was influenced by, one will be able to see how I overcame these presuppositions through scientific activities such as "The Great Fossil Find."

The first presupposition that I brought to the table was the "realization of approximation"—or that science is made up of rules, with very little room for hypothesis and "educated guesses". Previously, I believed that all scientists had a very firm idea of what they were looking at and knew exactly what they would need to discover in order to complete their scientific investigations. This proved to be false. In "The Great Fossil Find", for example (although we knew that we were looking at a fossil of an animal), it took us quite a while to "guesstimate" what type of animal it was. Even after the investigation was over, the different groups involved did not agree on the achieved end. Science was, in fact, much more of a "creative art" than I ever expected.

The second presupposition that I encountered was that of "room for rearrangement". Never before had I realized the intense debate that was raged over what the different pieces of bone, in actuality, were. The scientists involved in the experiment all came to the table with their own preconceived notions of what the fossil parts might be...thus leading to intense controversy. To our combined minds, a bone was a foot was a hand was a wing...and this did not settle well as we all strove to mesh our presuppositions into a small enough "data-strainer" to achieve facts. Never before had I realized just how much presuppositions affected the way people think with each other—especially in the field of science.

The third presupposition that I encountered was that of the "infallibility of the facts". Previously, I believed that once a scientific discovery was made and accepted, it

was parked away in the history books as a common "fact". This, however, is not true. Never before had I realized the intense debate that occurred even *after* the scientific experiment was completed. Scientists as a whole are consistently repeating, modifying, and revamping hypothesis, hoping to disprove or improve on an already well-distributed theory. Therefore, science was not as "stagnant" as I had previously considered it to be.

All in all, "The Great Fossil Find" helped me to see the importance of wiping out preconceived misconceptions, the value of working with others, and the fallibility of any "human" science. Never in this lifetime will we fully comprehend all that is involved in the scientific method when it comes to determining "facts", but we must keep trying. God calls us as His people to learn and grow in Him...and what better way to do that then to continue to study the wonderful world that He has created around us!

Response to Think Piece Prompt #3: How will you, as a Christian, wrestle with the reliability of science and its applicability to important social issues. Is it right to become completely skeptical of all science just because we've looked at some specific abuses and misapplications? Will you be skeptical only about the science that is related to important moral issues such as abortion or stem cell research? Do Christians today respond to "uncomfortable" science the same way the church did in Galileo's day? Do you think valid scientific findings are ever inappropriately applied for political, social, or economic ends? Where did last week's topics lead you in your thinking about these issues?

Due to the ever-changing nature of the scientific world, Christians often avoid studying and believing the reliability of scientific discoveries. As a believer in Christ, however, I have realized over the past few weeks, through analyzing various aspects and attributes of the scientific world, that science has a vast array of social implications that cannot be escaped. I, and other Christians, must wrestle with many scientific interpretations as they affect the society in which we live and are striving to be a testimony for Christ. Though skepticism in moderation is legitimate when forming opinions and conclusions, Christians cannot be so extremely skeptical of science that they cannot and will not evaluate and apply the clear reasoning and conclusions that have been made. Skepticism taken to an extreme causes Christians to be close-minded and ignorant; this is not helpful when striving to be a Biblically-based, intellectually-informed believer in the world today.

I think that the majority of aggression towards science stems from a fear of violating Biblical principles upon accepting the conclusions made by scientists. In a world of post-modern thought and moral uncertainty, Christians tend to lash out against the science that is related to important moral issues, such as abortion or stem cell research, without fully understanding what it is that they are lashing out against. While taking a stand against sinful policies and practices is clearly important, simply fixing one's self against the waves of apparent "corruption" is not enough. It is imperative that

we, as Christians, be grounded in the absolute truths that are found in God's Word. We must not only know **what** we believe about certain ethical issues; we must know *why* we believe it, and be prepared to defend our beliefs in an educated manner that displays the knowledge and character of God as being of supreme value and upmost importance.

The topics discussed in class last week were definitely thought-provoking. The basis behind my belief system in science (up until this point) has, essentially, been swallowing the things that have been taught to me, simply because they are what I have always known. This philosophy and basic frame of mind was broken down throughout different classroom discussions and my own individual research. I came to the conclusion that science is not something to be feared, and that "uncomfortable science" is not necessarily "bad science." The hypotheses, theories, and laws that have been formulated through science have not been created by imbeciles, and can therefore not be refuted or disproven by uninformed Christians who are afraid of finding out the truth about the world in which they live. I now realize that science is something that must be studied and understood as a complex ideology to be reckoned with, calculated, and deciphered within the parameters set forth in the Bible. God's Word has, and will, stand forever as the prevailing, absolute standard for truth. There will never be something "scientific" that disproves what God has said. Therefore, I know that I can study both science and the Bible with an open-mind and clear conscience, knowing that God's Word will never fail and that science has its worth in the world today.

Response to Think Piece Prompt #4: After some preliminary reading, choose a specific part of the young earth-old earth conversation that interests you. It can be a theological point or a scientific point. Research the topic from a variety of theistic perspectives using the websites posted on e-Learning. Be sure to read each website's purpose statement so you clearly understand the perspective of the author(s). Write a one-to-two page summary of what you've learned about the topic and discuss how visiting multiple websites has impacted your thinking about the age of the Earth and the interpretation of scientific evidence in light of a pre-existing belief or world view.

Age of the Earth in Relation to Human Evolution

I initially picked this specific aspect of evolution because I could not wrap my mind around the idea of man evolving from animals – especially apes. If this were true, it would seem that we are really no different than the animals; that we have no inherent value, and what does 'made in the image of God' really mean? I went to every one of the websites, and I found that the majority had information which was very disappointing. There was either an air of pride in their beliefs that overshadowed even the *possibility* of entertaining an opposite view point, or the information was just not well thought out. Obviously these are tough issues, but the information presented on these websites:

Answers in Genesis, Institute for Creation Research, Reasons to Believe, Talk Origins, and the Interdisciplinary Biblical Research Institute, seemed to be lacking. However, the remaining websites had some very intriguing articles and gave me some new things to think about.

I thought it was very helpful that the God and Science website included articles from various viewpoints. I read one article that talked about the uniqueness of man in regards to the animal kingdom (Deem) and two about evolution actually fitting right into the Genesis account (Bonnette). The latter two articles said that evolution could have only occurred using an old earth model of creation. An incredibly interesting thought concerning the age of the earth was a small rabbit trail concerning the word 'begot'. "'Begot' need not imply immediate generation of a son or daughter. Matthew 1:8 reads: 'And Joram begot Uzzi'ah.' It turns out that Uzzi'ah is not Joram's son, but his great-great grandson!" (Bonnette, July). However, Answers in Creation had an article that asserted the exact opposite, "...you can logically see that to accept the young-earth model, you must accept a rapid rate of evolution as truth, and you inadvertently have proven the very thing that you seek to disprove" (Neyman).

I think the other point that really rocked my world and made me go 'huh' was a question. "Could a process of creation by natural evolution be divinely guided by God, so humans would have all of the characteristics (physical, mental, emotional, social, moral, spiritual) that He wanted us to have?" (Rusbult). I will admit I am not fond of this idea at all. I think mainly it is because it is the opposite of everything I was taught growing up. I do not know where I stand on micro evolution and changes *within* kinds, but for man to evolve from animals really seems to diminish any value we as humans have and makes me wonder what really makes us different if this is how we came to be? I am unable to wrap my mind around that concept at the moment and I was curious to find fellow believers who truly believe that Genesis and evolution can go hand in hand.

I have come to no conclusions! The issues we are discussing are way out of reach in some aspects and I am completely mind boggled, but deep down (past the frustration and feelings of getting nowhere) I really think it is important to consider these various issues and to be open to different opinions and views. I am wrestling with the issue of human evolution and if God used evolution to bring us into being, where does that leave us? What now? Why were we given dominion over the animals if we are really just a notch above them? And again, what in the world does 'made in the image of God' *really* mean?

Response to Think Piece Prompt #5: How does the nature of God as revealed in scripture inform our thinking about biotechnology issues? What do we learn about the nature of man as we observe the quest to understand (and control) the very code of life itself?

The Bible talks about God as being the creator and sustainer of life. If God is the creator of life then believers in God face some issues in light of the fact that we humans are able to biotechnologically engineer human life. We do not in fact create the components necessary to form a life(an egg and a sperm) but we are able to harvest them and combine them inside a lab instead of a womb to "create" a living organism. The question we must ask is whether or not God is still the creator when we form life outside of the conventional methods God has put in place. Since man cannot create something from nothing but simply, in this case, combine the created elements in an unconventional way, I do not believe God ceases to be the creator. This does not mean that there are not scientists who view themselves as creators, as there most likely are. Not only does man desire to be creators but they are also trying to lay claim as sustainers of life. One of the main purposes of stem cell research and biotechnology is to improve the quality and prolong the longevity of human life. Although science and medicine have certainly made advances in these areas we still have not figured out a way to avoid the inevitability of death. God sustains life as long as He wills, at some point man must give up control.

We get into even more complicated issues when we read passages like Psalm 139 which says "For you created my inmost being; you knit me together in my mother's womb," and other passages which speak of God creating and forming life in the womb. How would this verse apply to a life that was not started in the womb? In the next verse the Psalmist states that he is "fearfully and wonderfully made," and praises God for that. The scriptures appear to show us that it is God's job to create and form life as He wishes. Scientists hope to use biotechnology to be able to design healthy babies free from disease or maybe even design a baby's physical appearance to the preference of the parents, giving them brown hair instead of blond. Imagine the implications this has on the verse, where one day it may be more accurate for some to say "a scientist knit me together in a test tube and placed me in my mother's womb." Even if God is the creator there is still the question of whose job or whose right it is to design the makeup of a life at its earliest stages.

There is also the big question of when life begins, or when the fertilized organism becomes a human being. Many of these organisms are terminated and there are important ethical implications based upon when human life beings, or even ethical issues surrounding the experimentation and termination of the "potentiality of life." God's words to Jeremiah may shed light on these questions. In Jeremiah 1:5 He says "Before I formed you in the womb I knew you,/before you were born I set you apart." God says Jeremiah is set apart before birth, but even more than that, God knew him even before he was formed in the womb. Our interpretation of this verse is important in our understanding of biotechnology. Is God speaking specifically of Jeremiah, or does he know every life before it is formed? At what point does the forming process take place, when an embryo has nerves? When the organism develops multipotent, pluripotent, or even totipotent cells? At conception or fertilization? The verse says that God knew him

(and I believe this applies to every life as well) before the forming process. God is eternal and omnipotent, therefore for the Bible believer we should assume that God knew him and had plans for him well before the act of being formed occurred. If God knows every life before it gets to the formation process before birth, should we then be playing around with these organisms that God *knows* even if they were not in fact human beings?

Another verse in the Bible about God forming life in the womb is found in Job 31:15 where Job says "Did not he who made me in the womb make them? Did not the same one form us both within our mothers?" This passage brings up the question of social equality. The 'them' he is referring to in the passage are his menservants and maidservants. Job talks about how he cannot deny justice to his servants and be innocent before God. The premise is that God made both Job and Job's servants and he made them through the same process, therefore both Job and his servants are intrinsically equal. If this is the rational as to why human beings are equal, then what is to be said of humans who are not conceived and formed of the same process? Could a test tube baby be considered less than human because of its origins? If scientists perfect the ability to alter genes at this stage and people are born with better than normal bodies would these people be considered a superior race?

These issues and the implications they may have are extremely important. There is so much that we do not know and cannot agree upon that if someone has faith in God and a defined set of moral standards such as the Bible to inform their thinking, there are more questions raised than there are answers to be found.

It is not hard to recognize man's desire to be God when we observe these issues. As stated above man longs to lay claim to the titles of creator and sustainer. Man's thirst for power is larger than simply subduing and having dominion over the earth as commanded by God. Man wants to have control of man. We want the production rights on human life, to design it as we see best. I also do not want to give it up and want the ability to prolong life as much as possible. It is the quest to control one's own destiny and the search for immortality, which is not new, we just have the technology today to be fairly good at it. If you go back to the Greeks we see the same ideas in their literature. Achilles desired immortality and sought it through sheer strength and reckless passion. Odysseus tried to control his fate through reason. Today we are looking for the same things and the most powerful tool we have to do it with is science.

Another thing we learn about the nature of man is that we buy into the Batman mentality. The thing about Batman, which is shown exceptionally well in the newest Batman movie *The Dark Knight*, is that he does whatever he has to do to fight crime. He believes that it is acceptable and even necessary to bend the rules, to commit a few small evils, in order to ultimately do what's right. In other words the end justifies the means. Our culture would generally agree with this statement. It is a theme that not only shows up in our movies and entertainment, but also in our ethics concerning scientific research.

It is very unclear and disputed when life actually begins, and many scientists are willing to push the date to the latest because of the end product. Stem cell research has the potential to greatly improve human life, cure and prevent diseases, and generally to help people. Although it is possible the research is killing thousands of pre-infant human lives, it is a risk that is worth taking because the end justifies the means. Even if we were able to establish that stem cells were legitimate life there would be many willing to sacrifice the few for the good of the whole.

When discussing these issues many ask whether or not we are "playing God." Personally I do not believe it is possible for humans to replace God. It is the nature of man and the nature of God that we cannot be God or come close to doing the things He does, so there really is nothing we can do to fill His shoes. It is not for lack of trying though and it is a dangerous thing to attempt. I would rather stay away than to cross the line in the attempt.

APPENDIX P

INSTITUTIONAL REVIEW BOARD APPROVAL

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Institutional Review Board

118 College Drive #5147
Hattiesburg, MS 39406-0001
Tel: 601.266.6820
Fax: 601.266.5509
www.usm.edu/irb

HUMAN SUBJECTS PROTECTION REVIEW COMMITTEE
NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Human Subjects Protection Review Committee in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

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

PROTOCOL NUMBER: **28072102**
PROJECT TITLE: **The Effect of a Non-Majors' Course Integrating the Nature of Science and a Christian Worldview on the Scientific Compatability of Students' Worldviews at a Christian University**
PROPOSED PROJECT DATES: **08/01/08 to 07/31/09**
PROJECT TYPE: **Dissertation or Thesis**
PRINCIPAL INVESTIGATORS: **Paula R. Gossard**
COLLEGE/DIVISION: **College of Science & Technology**
DEPARTMENT: **Center for Science and Math Education**
FUNDING AGENCY: **N/A**
HSPRC COMMITTEE ACTION: **Expedited Review Approval**
PERIOD OF APPROVAL: **09/15/08 to 09/14/09**

Lawrence A. Hosman, Ph.D.
HSPRC Chair

9-17-08
Date

REFERENCES

Abd-El-Khalick, F., Bell, R., & Lederman, N. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*, 417-436.

Allen, N., & Crawley, F. (1998). Voices from the bridge: Worldview conflicts of Kickapoo students of science. *Journal of Research in Science Teaching, 35,* 111-132.

Alters, B. (2005). *Teaching biological evolution in higher education: methodological, religious, and nonreligious issues.* Sudbury, MA: Jones & Bartlett Publishers.

Alters, B., & Nelson, C. (2002). Teaching evolution in higher education. *Evolution, 56*, 1891-1901.

American Association for the Advancement of Science. (1989). *Science for all Americans.* New York: Oxford University Press.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy.* New York: Oxford University Press.

American Scientific Affiliation. (2003). Rusbult, C. (Ed.) What is a world view?—A definition and introduction. Retrieved June 28, 2008 from www.asa3.org/ASA/education/views

Anderson, R. (2007). Teaching the theory of evolution in social, intellectual, and pedagogical context. *Science Education, 91*, 664-677.

Ausubel, D. (1966). An evaluation of the BSCS approach to high school biology. *The American Biology Teacher, 28*, 176-186.

Ayala, F. (2000). Arguing for evolution. *Science Teacher, 67*(2), 30-32.

Azjen, I. (2001). Nature and operation of attitudes. In S. Fiske, D. Schacter, & C. Zahn-Waxler (Eds.), *Annual Review of Psychology: Vol. 52.* (pp.27-58). Palo Alto, CA: Annual Reviews.

Barbour, I. (1990). *Religion in an age of science.* San Francisco: Harper Collins.

Barmby, P. (2008). Examining changing attitudes in secondary school science. *International Journal of Science Education, 30*, 1075-1093.

Blalock, C., Lichtenstein, M., Owen, S., Pruski, L., Marshall, C., & Toepperwein, M. (2008). A comprehensive review of science attitude instruments 1935-2005. *International Journal of Science Education,* 30, 961-977.

Blocher, M. (2004). Essential elements of the Christian world view. *Biblical Bioethics Advisor, 8,* 1-4. Retrieved June 8, 2009, from http://www.bfl.org/documents/BibBioAdv81.pdf

Boehlke, P., Knapp, L., & Kolander, R. (2006). How science works: Foundations, method, and teleology. *Zygon, 41*, 415-425.

Borda, E., Kriz, G., Popejoy, K., Dickinson, A., & Olson, A. (2009). Taking ownership of learning in a large class: Group projects and a mini-conference. *Journal of College Science Teaching, 38*(6), 35-41.

Brazelton, E., Frandsen, J., McKown, D., & Brown, C. (1999). Interaction of religion and science: Development of a questionnaire and the results of its administration to undergraduates. *College Student Journal, 33*, 623-628.

Brossard, D., Lewenstein, B., & Bonney, R. (2005). Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education, 27*, 1099-1121.

Cavanaugh, S. (2006). NAEP scores show few budding scientists. *Education Week, June 2, 2006.* Retrieved June 28, 2006 from www.edweek.org

Chinsamy, A., & Plaganyi, E. (2007). Accepting evolution. *Evolution, 62,* 248-254

Christian Apologetics and Research Ministry. (n.d.). *What are some elements of a Christian world view?* Retrieved June 8, 2009, from http://www.carm.org/christianity/christian-issues

Cobern, W. (1991). World view theory and science education research. *National Association for Research in Science Teaching Monograph No.3.* Manhattan, KS: NARST.

Cobern, W. (1994). Point: Belief, understanding, and the teaching of evolution. *Journal of Research in Science Teaching, 31,* 583-590.

Cobern, W. (1996). World view theory and conceptual change in science education. *Science Education, 80,* 579-610.

Committee on Undergraduate Science Education. (1997). *Science teaching reconsidered: A handbook.* Washington DC: National Academy Press.

Costu, B., Unal, S., & Ayas, A. (2007). A hands-on activity to promote conceptual change about mixtures and chemical compounds. *Journal of Baltic Science Education, 6*(1), 35-46.

Crano, W., & Prislin, R. (2006). Attitudes and persuasion. In S. Fiske, A. Kazdin, & D. Schacter (Eds.), *Annual Review of Psychology: Vol. 57.* (pp. 345-374). Palo Alto, CA: Annual Reviews.

Dagher, Z., & Boujaoude, S. (1997). Scientific world views and religious beliefs of college students: The case of biological evolution. *Journal of Research in Science Teaching, 34*, 429-445.

Demastes, S., Good, R., & Peebles, P. (1995). Students' conceptual ecologies and the process of conceptual change in evolution. *Science Education, 79,* 637-666.

Donnelly, J. (2006). The intellectual positioning of science in the curriculum and its relationship to reform. *Journal of Curriculum Studies, 38*, 623-640.

Downie, J., & Barron, N. (2000). Evolution and religion: Attitudes of Scottish first year biology and medical students to the teaching of evolutionary biology. *Journal of Biological Education, 34*(3), 139-146.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science.* Bristol, PA: Open University Press.

Eisen, A., & Westmoreland, D. (2009, May 1). Teaching science with faith in mind. *The Chronicle of Higher Education*, p. 23.

Elfin, J., Glennan, S., & Reisch, G. (1999). A perspective from the philosophy of science. *Journal of Research in Science Teaching, 36*, 107-116.

Ellison, C., & Musick, M. (1995). Conservative Protestantism and public opinion toward science. *Review of Religious Research, 36*, 245-262.

Esbenshade, D. (1993). Student perceptions about science and religion. *The American Biology Teacher, 55,* 334-338.

Fazio, R., & Petty, R. (Eds.). (2008). *Attitudes: Their structure, function, and consequences*. NY: Psychology Press.

Fishbein, M. (1963). An investigation of the relationship between beliefs about an object and the attitude toward that object. In R. Fazio & R. Petty (Eds.), *Attitudes: Their structure, function, and consequences* (pp. 137-142). NY: Psychology Press.

Francis, L., & Greer, J. (1999). Measuring attitude toward science among secondary school students: the affective domain. *Research in Science and Technological Education, 17,* 219-226.

Francis, L., & Greer, J. (2001). Shaping adolescents' attitudes towards science and religion in Northern Ireland: the role of scientism, creationism, and denominational schools. *Research in Science and Technological Education, 19,* 39-53.

Fulljames, P. (1991). Creationism, scientism, Christianity, and science: A study in adolescent attitudes [electronic version]. *British Educational Research Journal, 17*, 171.

Geraedts, C., & Boersma, K. (2006). Reinventing natural selection. *International Journal of Science Education*, *28*, 843-870.

Gould, S. (1997). Nonoverlapping magisteria. *Natural History, 106*(2). Retrieved July 11, 2009, from Academic Search Premier.

Haarsma, D., & Haarsma, L. (2007). *Origins: A reformed look at creation, design, and evolution.* Grand Rapids: Faith Alive.

Harrison, V. (2006). Scientific and religious world views: Antagonism, non-antagonistic incommensurability and complementarity. *Heythrop Journal, 47*, 349-366.

Hermann, R. (2007). Utilizing world view theory to determine the factors influencing the understanding of evolutionary concepts. Ph.D. dissertation, Morgan State University, United States—Maryland. Retrieved May 31, 2008 from ProQuest Digital Dissertations database. (Pub. No. AAT 3258441).

Hokayem, H., & BouJaoude, S. (2008). College students' perceptions of the theory of evolution. *Journal of Research in Science Teaching, 45,* 395-419.

Hutchinson, J. (1993). *Religion and the natural sciences: The range of engagement.* NY: Harcourt Brace.

Johnson, P. (1995). *Reason in the Balance: The case against naturalism in science, law, and education.* Downers Grove, IL: InterVarsity Press.

Kearney, J. (1984). *World view.* Novato, CA: Chandler & Sharp.

Kemering, G. (2006). *A dictionary of philosophical terms and names.* Retrieved June 21, 2009, from http://www.philosophypages.com/dy/

Khishfe, R., & Lederman, N. (2007). Relationship between instructional context and views of nature of science. *International Journal of Science Education, 29,* 939-961.

Kilbourn, B. (1984). World views and science teaching. In Munby, H., Orpwood, G. & Russell, T. (Eds.), *Seeing curriculum in a new light; Essays from science education* (pp. 34-43). Lanham, MD: University Press.

Kind, P., Jones, K., & Barmby, P. (2007). Developing attitudes toward science measures. *International Journal of Science Education, 29,* 871-893.

Koballa, T. (1988). Attitudes and related concepts in science education. *Science Education, 72,* 115-126.

Koul, R. (2006). Religious outlook and students' attitudes toward school science. *Journal of Beliefs and Values, 27*, 251-267.

Krough, L., & Thomsen, P. (2005). Studying students' attitudes toward science from a cultural perspective but with a quantitative methodology: border crossing into the physics classroom. *International Journal of Science Education, 27*, 281-302.

Kruglanski, A., & Stroebe, W. (2005). The influence of beliefs and goals on attitudes: issues of structure, function, and dynamics. In D. Albarracín, B. Johnson, & M. Zanna (Eds.), *The handbook of attitudes* (pp. 323-368). Mahwah, NJ: Erlbaum.

Laforgia, J. (1988). The affective domain related to science education and its evaluation. *Science Education, 72*, 407-422.

Lawson, A., & Weser, J. (1990). The rejection of nonscientific beliefs about life: Effects of instruction and reasoning skills. *Journal of Research in Science Education, 27*, 589-606.

Lawson, A., & Worsnop, W. (1992). Learning about evolution and rejecting a belief in special creation: Effects of reflective reasoning skill, prior knowledge, prior belief, and religious commitment. *Journal of Research in Science Teaching, 29,* 143-166.

Lee, Y. (2007). Exploring the roles and nature of science: A case study of severe acute respiratory syndrome. *International Journal of Science Education, 30*, 515-541.

Liang, L, Chen, S., Chen, X., Kaya, O., Adams, A., Mackin, M., & Ebenezer, J. (2006). *Student understanding of science and scientific inquiry: Revision and further validation of an assessment instrument.* Paper prepared for the annual meeting of the National Association of Research in Science Teaching. San Francisco, CA.

Liu, S., & Lederman, N. (2007). Exploring prospective teachers' world views and conceptions of the nature of science. *International Journal of Science Education, 29*, 1281-1307.

Matthews, M. (2002). Foreward and introduction. In K. Tobin (Series Ed.) & W. McComas (Vol. Ed.), *Science and Technology Education Library: Vol. 5. The nature of science in science education: Rationales and strategies* (pp. xi-xviii). New York: Kluwer Academic Publishers.

McComas, W. (2002). The principle elements of the nature of science: Dispelling the myths. In K. Tobin (Series Ed.) & W. McComas (Vol. Ed.), *Science and Technology Education Library: Vol. 5. The nature of science in science education: Rationales and strategies* (pp. 53-70). New York: Kluwer Academic Publishers.

McComas, W., Clough, M., & Almazroa, H. (2002). The role and character of the nature of science in science education. In K. Tobin (Series Ed.) & W. McComas (Vol. Ed.), *Science and Technology Education Library: Vol. 5. The nature of science in science education: Rationales and strategies* (pp. 3-39). New York: Kluwer Academic Publishers.

McComas, W., & Olson, J. (2002). The nature of science in international science education standards documents. In K. Tobin (Series Ed.) & W. McComas (Vol. Ed.), *Science and Technology Education Library: Vol. 5. The nature of science in science education: Rationales and strategies* (pp.41-52). New York: Kluwer Academic Publishers.

National Academy of Sciences. (2008). *Science, evolution, and creationism.* Washington DC: National Academies Press.

National Research Council. (1996). *National Science Education Standards.* Washington DC: National Academy Press.

National Science Teachers Association. (2008). U.S. students' science scores lag behind other developed nations. *NSTA WebNews Digest, Jan. 2, 2008.* Retreived June 28, 2008 from www.nsta.org/main/news/stories

Nelson, C.E. (2000). Effective strategies for teaching evolution and other controversial topics. In S.J. Skehan & D.E. Nelson (Eds.), *The creation controversy and the science classroom* (pp 19-50). Arlington, VA: National Science Teachers Association.

Oliver-Hoyo, M., & Allen, D. (2005). Attitudinal effects of a student-centered active learning environment. *Journal of Chemical Education, 82*, 944-949.

Osbourne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas-about-science" should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching, 40*, 692-720.

Palmer, D. (2004). Situational interest and the attitudes towards science of primary teacher education students. *International Journal of Science Education, 26*, 895-908.

Papanastasiou, E., & Zembylas, M. (2004). Differential effects of science attitudes and science achievement in Australia, Cyprus, and the USA. *International Journal of Science Education, 26*, 259-280.

Pepper, S. (1961). *World hypotheses: A study in evidence*. Berkeley: U.C. Press.

Perry, W. 1970. *Forms of ethical and intellectual development in the college years: A scheme.* New York: Holt, Rinehart, & Winston.

Pigliucci, M. (2007). The evolution-creation wars: Why teaching more science is just not enough. *McGill Journal of Education, 42*, 285-306.

Posner, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*, 211-227.

Proper, H., Wideen, M., & Ivany, G. (1988). World view projected by science teachers: A study of classroom dialogue. *Science Education, 72*, 547-560.

Reiss, M. (2008). Should science educators deal with the science/religion issue? *Studies in Science Education, 44,* 157-186.

Robinson, B. (2007). Definitions of the word religion: None are totally satisfying. Retrieved July 7, 2008 from http://www.religioustolerance.org/rel_defn.htm

Roth, W., & Alexander, T. (1997). The interaction of students' scientific and religious discourses: two case studies. *International Journal of Science Education, 19,* 192-146.

Ryan, A., & Aikenhead, G. (1992). Students' preconceptions about the epistemology of science. *Science Education, 76*, 559-580.

Ryder, J., Leach, J., & Driver, R. (1999) Undergraduate science students' images of science. *Journal of Research in Science Education, 36*, 201-219.

Scharmann, L. (1993). Teaching evolution: Designing successful instruction. *The American Biology Teacher, 55*, 481-487.

Schibeci, R. (1984) Attitudes to science: An update. *Studies in Science Education,11*, 26-59.

Schroeder, B. (2006). Science instruction in the context of Christian faith. Ph.D. dissertation, Walden University, United States—Minnesota. Retrieved May 31, 2008 from ProQuest Digital Dissertations database. (Publication Number AAT 3229902).

Schwartz, R., & Lederman, N. (2008). What scientists say: Scientists' views of the nature of science and relation to science context. *International Journal of Science Education, 30*, 727-771.

Scott, E. (2004). *Evolution vs. creationism: An introduction.* Berkeley: U.C. Press.

Shipman, H., Brickhouse, N., Dagher, Z., & Letts, W. (2002). Changes in student views of religion and science in a college astronomy course. *Science Education, 86,* 526-547.

Sinclair, A., & Pendarvis, M. (1998). Evolution versus conservative religious beliefs: Can biology instructors assist students with their dilemmas? *Journal of College Science Teaching 27*(3), 167-170.

Sinclair, A., Pendarvis, M., & Baldwin, B. (1997). The relationship between college zoology and students' beliefs about evolutionary theory and religion. *Journal of Research and Development in Education, 30*(2), 118-125.

Sire, J. (1976). *The universe next door: A basic world view catalog.* Downers Grove, IL: InterVarsity Press.

Skehan, J. (2000). Modern science and the book of Genesis. In S.J. Skehan and D.E. Nelson (Eds.), *The creation controversy and the science classroom* (pp 1-18). Arlington, VA: National Science Teachers Association.

Smith, M. (1994). Counterpoint: Belief, understanding, and the teaching of evolution. *Journal of Research in Science Teaching, 3*, 591-597.

Smith, M., & Scharmann, L. (1999). Defining versus describing the nature of science: A pragmatic analysis for classroom teachers and science educators. *Science Education, 83*, 493-509.

Suzuki, T., & Miura, A. (2001). *Words in context: A Japanese perspective on language and culture.* Tokyo: Kodansha International.

Tenneson, M., & Badger, S. (2008, March). *Teaching origins to Pentecostal college students and measuring the beliefs of Pentecostal students about origins.* Paper presented at the Society of Pentecostal Studies and Wesleyan Theological Society Joint Meeting, Durham, NC.

Tenneson, M., & Badger, S. (2009). Teaching Origins to Pentecostal Students. In Yong, A. (Ed.), *The spirit renews the face of the earth: Pentecostal forays in science and theology of creation.* Eugene, OR: Pickwick Press.

Thiessen, E. (2007). Refining the conversation: some concerns about contemporary trends in thinking about worldviews, Christian scholarship, and higher education. *Evangelical Quarterly, 79,* 133-152.

Tsai, C. (2001). Ideas about earthquakes after experiencing a natural disaster in Taiwan: An analysis of students' world views. *International Journal of Science Education, 23*, 1007-1016.

Turkmen, L. (2007). The influences of elementary science teaching method courses on a Turkish teachers college elementary education major students' attitudes towards science and science teaching. *Journal of Baltic Science Education, 6*(1), 66-77.

University of Southern Mississippi. (2008). Retrieved July 11, 2008 from http://www.usm.edu/admissions/parentsandfamily/abouttheuniversity/

Vanderlinden, D. (2007). Teaching the content and context of science: The effect of using historical narratives to teach the nature of science and science content in an undergraduate introductory geology course. PhD dissertation, Iowa State University, United States—Iowa. Retrieved June 26, 2008, from ProQuest Digital Dissertations database. (Publication No. AAT 3274879).

Verhey, S. (2005). The effect of engaging prior learning on student attitudes toward creationism and evolution. *BioScience, 55*, 996-1004.

Viadero, D. (2005). Panel urges U.S. push to raise math, science achievement. *Education Week, 25*(8). Retrieved June 18, 2009 from Academic Search Premier.

Vlach, M. What in the world is a Christian world view? Retrieved June 28, 2008 from www.theologicalstudies.org

von Glasersfeld, E. (1989). Constructivism in Education. In T.Husen & T. Neville Postlethwaite (Eds.), *The International Encyclopedia of Education: Research and Studies, Supplementary Volume 1* (pp. 162-163). Oxford: Pergamon Press.

Waldrip, B., Timothy, J., & Wilikai, W. (2007). Pedagogical principles in negotiating cultural conflict: A Melanesian example. *International Journal of Science Education, 29,* 101-122.