Abstract

Title of Document: CULTURAL BORDER CROSSING: THE INTERACTION BETWEEN FUNDAMENTAL CHRISTIAN BELIEFS AND SCIENTIFIC EXPLANATIONS

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The purpose of this study is to investigate the interaction between people's fundamental Christian beliefs and scientific explanations. When people with fundamental Christian beliefs encounter scientific explanations, such explanations may interact with their deeply rooted beliefs in a way that is likely to produce tensions. It is expedient to understand the classroom/professional experiences of such individuals and how they

manage these tensions. I will apply Jegede's collateral learning theory as a lens to look at how individuals manage the tensions between their religious and scientific worldviews. Gaining insight into people's experiences in the classroom/work place and how they manage these tensions will potentially inform classroom instruction and ways by which we can help students with fundamental Christian beliefs maintain their pursuit of science related careers by easing the nature of the borders they cross. Sources of data will include participant reported perspectives of how they manage the tensions and observations of real-time resolution of potentially conflicting explanations from their religious and scientific worldviews.

CULTURAL BORDER CROSSING: THE INTERACTION BETWEEN FUNDAMENTAL CHRISTIAN BELIEFS AND SCIENTIFIC EXPLANATIONS

By

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Outline of Report

According to Yin (2014), case study reports follow a variety of compositional formats. Merriam (2009) concurs by maintaining that there is not standard format to report a qualitative study. Reports therefore vary according to the audience and the purpose of the research. I wrote the report with the mindset that my dissertation committee is my primary audience, with science education researchers, teachers, and curriculum developers as a broader secondary audience. In reporting the findings of this case study, I present the findings to each research question and subquestions in two chapters. The first chapter presents the findings of research question 1, the second chapter presents the findings to research question 2.

Within each chapter, a selection of three to four cases is presented in a detailed manner in response to the research question the chapter answers. After a detailed presentation of the findings from these individual cases, a cross-case analysis is presented within the same chapter, this cross case analysis includes evidences from both the cases that are detail described in the chapter and other cases that are not described in the chapter, but which add meaning and clarity to the explanations being provided. In the paragraphs that follow, I give a brief overview of what the different chapters of this final report contain.

Chapter One: What I am Doing and Why

This chapter, addresses questions about the purpose of the research, the problem statement, significance of the study, researcher positionality, and theoretical perspectives.

Chapter Two: Review of the Literature

This chapter examined the current literature in three directions. First, I reviewed the current literature on cultural border crossing to gain insight into the different approaches that researchers have used to address cultural border crossing in science. Second, I examined comprehensively, the current literature that specifically addresses cultural border crossing in science with an emphasis on religious beliefs, specifically the interaction between religious beliefs and scientific explanations. This second category of literature enabled me develop research questions that were grounded in the literature. Finally, I examined the literature on religious beliefs and representations to gain insight to potential explanations as to why religious beliefs may influence how people respond to scientific explanations. From the literature reviewed so far, researchers have mostly placed individuals into categories according to their approach to handling the tensions between their religious beliefs and scientific explanations. Through the lens of Jegede's collateral learning theory, these categories seem to fit into multiple collateral learning.

Chapter Three: Methodology

This section of the report presents issues related to methods, study design, sample selection, data collection, data analysis, and validity and reliability. This chapter has described what was actually done in the course of the research study.

Chapter Four: The Classroom experiences, Resilience strategies, and Resources of people with Fundamental Christian beliefs

The report in this chapter will seek to respond to the following research question:

1. How do people with fundamental Christian beliefs manage to maintain their pursuit of science related careers in spite of the potential alienating experiences

due to the conflicts that arise between their deep Christian beliefs and scientific explanations?

- What are the experiences of people with fundamental Christian beliefs in the world of science?
- What coping mechanisms/resilience strategies do they employ to enable them traverse hazardous borders
- What are the resources (social, cognitive, etc.) people appeal to, to help them manage the effects of such tensions and maintain their pursuit of science related careers?

Here also, the report will be presented at two levels, the individual cases- a selection of four cases that provide the richest information in response to the above research question, and a cross-case report that looks at the differences and similarities of the individual cases and what general conclusions can be made about the cases as a whole.

Chapter Five: The Shifting Contextual nature of the interaction between people's fundamental Christian beliefs and scientific explanations.

The report in this chapter will seek to answer the following research question:

Can people be squarely placed in different categories as to how they manage the tensions that arise between their deep Christian beliefs and scientific explanations?

- What justifications do people provide pertaining to their approach to managing the tensions between their fundamental Christian beliefs and scientific explanations?
- What types of collateral learning theory do people employ to deal with such tensions?

Chapter One: What I am Studying and Why

Introduction

Religious beliefs that students hold form part of their home or life-world culture. Such beliefs may affect how they interpret classroom instruction as relevant to their lives, and may form part of the lens through which students interpret the world and make sense of new knowledge. Cobern and Aikenhead (1997) maintain that "within every culture there exist subgroups that are commonly identified by race, language, ethnicity, gender, social class, occupation, **religion**, etc." (p. 4, emphasis mine). Therefore people's religious beliefs form an integral part of their culture, and shape their worldview and identity. In the same way people are classified respecting their race, gender, SES, or ethnicity, people can be classified according to the religious beliefs they hold (Muslims, Christians, Hindus, etc.) and within the different religious groups, subgroups exist with respect to the extent of their held religious beliefs.

Enormous efforts have been made to render science teaching and learning relevant and responsive to different aspects of the spectrum of cultural diversity including race, ethnicity, language, and socio-economic status (Aikenhead, 2000; Aikenhead & Jegede, 1999; Tan, 2011; Thijs & Van den Berg, 1995; van Eijck & Roth, 2011). However little has been said to address religious beliefs as an aspect of cultural diversity in the ongoing culturally relevant science instruction dialogue among science educators (Dager & BouJaoude, 1997; Fish & Lucas, 1998; Taber et al., 2011). Religious beliefs as part of cultural diversity have been neglected in the decades-long discussion on culturally relevant pedagogy (Celgie, 2013; Dager & BouJaoude, 1997; Fish & Lucas, 1998; Stolberg, 2010; Taber, Billingsley, Riga and Newdick, 2011).

In order to advance culturally relevant science teaching, science educators must be aware of their students' cultural values and beliefs—especially students from underrepresented groups (Tan, 2011). In the context of science education, this includes the need for awareness of the perspectives of students with deep Christian beliefs, and how such beliefs interact with scientific explanations. We need to understand their experiences and look for ways to make such experiences to bolster their pursuit of science related careers rather than alienate them.

Statement of the problem

Some researchers maintain that religious beliefs held by people curtails the supply of scientists, and therefore a detriment to national productivity (Granger & Price, 2007). The question that should be asked is whether it is the religious beliefs in themselves that curtails the supply of scientists or the manner in which such beliefs and those who hold them dear are treated in the science classroom or scientific enterprise. Some have argued that it is the hostility, and feeling of alienation that may deter some students from pursuing science studies (Celgie, 2013; Dodick, Dayan & Orion, 2010).

With such a problem of shortage of scientists, and potential reason being the feelings of alienation that students with deep Christian beliefs face in science classroom, it is expedient for science education research to look at the classroom experiences of people with deep Christian beliefs, and the coping mechanisms and resilience strategies that those with such beliefs have employed to help them navigate a potentially hostile environment and maintain their scientific pursuits. Such an insight into their experiences

and coping mechanisms will inform educators on how to help others without such skills maintain their pursuit of scientific careers.

Purpose and Significance

The purpose of this study is to examine the interactions between students' deep religious beliefs and scientific explanations through the lens of Jegede's (1995) Collateral Learning Theory and the categories in which people have been placed by researchers with respect to their handling of potential conflict between their religious and scientific worldviews. I situate people's deep religious beliefs in the context of cultural diversity and examine the experiences and the tensions, if any, that arise when students' deep religious beliefs interact with scientific explanations. In this study I investigate the extent to which people's deep Christian beliefs form a lens through which they accept or reject new knowledge, including scientific explanations. I also investigate the experiences, resilience strategies and resources of people with fundamental Christian believes in their pursuit of science related careers.

The interaction of fundamental/deep Christian beliefs (by deep Christian beliefs, I mean belief in the Bible as the literal inerrant word of God) with scientific explanations may produce cognitive and emotional tensions for some students. Such students with deep Christian beliefs may employ different mechanisms to make sense of the interaction between their scientific and religious worldviews. I further investigate whether people can always be categorized with respect to how they manage their religious and scientific worldviews. That is, do people always resolve the tensions between their religious and scientific worldviews in the same way irrespective of the issues at stake? Specifically, I

investigate whether people can be classified as compartmentalizing science and religion, integrating science and religion, or choosing one over the other. I also investigate the mechanisms people may deploy for negotiating the tensions between science and religion, depending on the situation at hand.

With increasing calls to render science education culturally relevant to ease the borders that students from diverse cultural groups need to cross to make sense of scientific explanations (Aikenhead, 2000; Aikenhead & Jegede, 1999; Tan, 2011; Thijs & Van den Berg, 1995; van Eijck & Roth, 2011), it is important for educators to understand the classroom experiences of different cultural groups, including those with fundamental Christian beliefs, in the world of school science. Religious beliefs are an important aspect of some people's culture, and most often the central lens into people's cultural world, but relatively very little has been done to address how this aspect of culture affects students learning of science, compared to other cultural issues like language, identity, ethnicity, SES, and race.

With an increasing African immigrant population in the United States and West-African immigrants making up to a third of the population (American Community Survey, 2010), most of them holding very fundamental Christian beliefs, it is expedient to include such a group in our efforts to meet the supply of scientists with the forecasted demand. This study may also potentially inform how other cultural characteristics, peculiar to West Africa may interact with their religious beliefs to influence how they manage the tensions between their beliefs and scientific explanations.

Further, this study fills a gap in the research, as students with deep Christian beliefs have not been researched as a cultural group, and such neglect does not afford justice to the push for multicultural science education. While it may be necessary to study people with fundamental Christian beliefs as a whole, the challenge can be very enormous. Because Christians with fundamental Bible beliefs are themselves a very diverse group of people, I seek to focus on those of West-African origin because I am particularly and intrinsically interested in helping individuals from this region cross barriers into the world of school science. This helps narrow the gap in the available literature on this broad group of people by solving part of the problem. Knowledge and understanding of part of the problem will likely develop interest to look at how other parts of this cultural group of people with fundamentalist Christian beliefs.

This study will potentially inform science instruction in terms of creating a safe place for students with deep Christian beliefs. Understanding the experiences of students with deep Christian beliefs in science classrooms can help instructors ease the borders the students have to cross from their life-world to the world of school science. As Celgie (2013) puts it, "it is important for secondary science teachers as well as college science instructors to develop a stronger regard and to gain a better understanding about religion's influences on student motivation, academic achievements, and interest in science careers" (p. 58). Such an understanding may also help ease the tensions that some students experience when their deep Christian beliefs interact with scientific explanations thereby increasingly the supply of scientists and consequently economic productivity, by retaining those with fundamental Christian beliefs in the field of science.

In broad terms, I seek to explore the following questions: what happens when people's deep religious beliefs interact with scientific explanations? How do people manage tensions that arise between their deep religious beliefs and scientific explanations? Can people be placed in singular categories of how they manage these tensions or are their approaches dependent on the tension under consideration and possibly other contextual factors? What are the resources (social, intellectual, or cognitive) they employ to maintain their pursuit of scientific knowledge and science related careers in spite of such tensions between their beliefs and scientific explanations?

Theoretical/Conceptual Framework

I approach this study from a constructivist epistemology, Jegede's (1995) Collateral Learning Theory, and the categorizations of people's perceptions of interaction between scientific and religious worldviews that exist in the current literature. Constructivism as an instructional style can play a very important role in helping to demystify science and improve border crossing for students into the world of school science, their sense-making and participation in science lessons, their construction of science knowledge, and its application in their life-worlds. Through a constructivist approach to science education, students can be made to understand that science is, as Einstein puts it, "the refinement of everyday thinking."

Constructivism as an epistemological framework has several variations, each laying emphasis on different premises, but the common aspect about each of the variations is that human knowledge and the different methods and processes used in inquiry are not discovered but constructed; all human knowledge is a creation of human

culture or cognition (Crotty, 1998; Guba & Lincoln, 2005; Philips, 1995). The different knowledge disciplines are all human constructs and not "naturally occurring" subject matters. Unlike positivism which posits that scientific knowledge is purely empirically discovered and free from human values (Crotty,1998), constructivism posits that "knowledge is produced by humans, in processes that are unconstrained – or minimally constrained – by inputs or instructions from nature" (Philips, 1995 p8), i.e. it is impossible for human knowledge to be free from the values and perspective of the scientist nor can it be free from social, cultural or natural influences. I posit that the learning of science is both cognitively and socially influenced by the religious beliefs student come with into the science classroom. It is from such a perspective I approach this study.

I discuss the different categories of how people have been classified in accordance with how they manage the tensions that arise between their religious and scientific worldviews in the current literature through the lens of Jegede's (1995), and Jegede's and Aikenhead's (1999) Collateral learning theory in the cultural border crossing literature. I will apply this collateral learning theory in analyzing my interview data, and use themes from both the theory and the categorizations that are in the existing literature of people's perceptions of the interactions of religious and scientific worldviews. Because people build new knowledge on previous knowledge and experiences, these can interact in different ways. Collateral learning theory was coined by Jegede (1995) to explain what is likely to happen when students from non-Western or Western cultures encounter scientific explanations. There are four related possibilities in a continuum, as used by Aikenhead and Jegede (1999):

Parallel collateral learning occurs when conflicting schemata from the two cultures are placed side-by-side with no interaction, that is, they are allowed to co-exist without producing any cognitive disequilibrium. Simultaneous collateral learning occurs when schemata from two worldviews are considered to be the same, viewed by the learner as supporting each other, or a schema from one worldview supports the learning of a related schema from another worldview. Dependent collateral learning occurs when a schema from one worldview challenges a schema from another worldview, forcing the learner to modify the old schema to accommodate the new without radically reconstructing the old. Finally, secured collateral learning occurs when the learner securely resolves the conflict between schemata from different worldviews in favor of one, or is convinced of reasons to hold on to both.

There are four common categories, as synthesized from the literature, that researchers have placed participants respecting how they approach the science-religion border namely compartmentalization where people place their different worldviews in separate compartments of their life, integration/complementarity where people look for ways to merge the two worldviews, religious dominance where individuals subscribe to the religious worldview over scientific, scientific dominance where individuals subscribe to scientific explanations over religious beliefs. I will examine these categories through the lens of Jegede's collateral learning theory as part of the literature review to show which type of collateral learning people may be applying in the different categories.

Background and Positionality

I grew up in a nominally Christian home with a moderate attachment to religious beliefs. I attended a catholic elementary school where religious studies was taught and weekly mid-week services held in the church nearby. We often went to church on Sundays with my older siblings without our parents. While my parents did encourage us to go to church I don't remember ever going to church with either of them. My first experience of a potential conflict in the classroom was between the views of creationism and human evolution. Having been taught in my religious studies classes that man was created in God's image, I found it contradictory and disturbing to learn in a history class that we had actually evolved from the "early man" whose depiction was close to an ape. I remember even as a child I dismissed the scientific version of the origin of species and only made use of it to make fun of other students. I believe the contradictory schemata did not produce strong effects on me because I didn't have a strong attachment to religious beliefs and did not hold such as personal.

While in junior high school I again encountered this issue of origin of species in my Biology class. I remember the debate was very strong particularly for those students we considered to hold fundamental Christian beliefs. This time, my position had shifted to that of reconciliation between creationism and evolution. This is probably due to the influence of my teacher who held an "integration" position that there is a creator who created the universe over a period of several thousand years, during which evolution took place, figuratively depicted as seven days in the Bible. Needless to say while not everyone embraced his view, it helped to abate the heated classroom arguments from those who embraced strictly religious view of the origin of species.

It is possible that when teachers are honest about their views, students can be brought to reconsider their positions on the science/religion conflict. This position of reconciliation between creationism and evolution is one I held until my first year in college when I embraced fundamental Christian beliefs personally and found myself dismissing the evolutionary view of the origin of species. In retrospect I could now understand why those who held very strong Christian beliefs argued so sharply to defend their beliefs. My conversion from a nominal Christian to one who holds fundamental Christian beliefs made me to embrace the Bible and what it teaches at a very personal level I never did before, intricately viewing God and His word as inseparable and infallible.

As a first year college student studying physics at the university, I became a fundamentalist Christian. As I began reading my Bible, I began noticing some things that contradicted, others just apparent contradictions, with what I had studied in my high school physics and geography classes or to what I was now studying at college, namely the origin of the universe, the age of the earth, the nature of moonlight, the formation of rainbow etc. I found that I did not approach each of the contradictions exactly the same way and wondered how others would handle the same situation.

Having become a science teacher and a preacher, I found myself avoiding to engage in certain discussions about these contradictory schemata from the two worlds I lived in. I became interested to know why it was easier to resolve some of these tensions than others and wondered how the experiences would be for students who come into the science classroom with fundamental Christian beliefs from a home culture that considers

the teachings of the Bible as the standard to follow. As my dedication to spirituality and fundamental Christian values increased, being a science teacher, I became interested in understanding how the religious beliefs of students or practicing scientists influenced their lives as potential or practicing scientists, their experiences in the classroom, how they managed the tensions between their two life-worlds, and what resources were available to them to help them maintain their pursuit of science alongside their religious beliefs.

My position as one with fundamental Christian beliefs and a strong inclination toward science is both a strength and a potential weakness to this study. First is it a weakness in the sense that my personal experiences in crossing the borders between these two life-worlds may influence how I interpret the data. This potential limitation will be diminish through member check where participants will validate my interpretation of the data about them. It is a strength in the sense that people will be ready to talk about such deeply personal issues with one whom they can easily identified with, without fear of being judged, seeing that there has often been a backlash in certain milieu when people have voiced their perspectives or opinions on issues of contradictions between their religious beliefs and scientific explanations. Knowing that I am a preacher and also a science teacher will open the way for the collection of rich data.

Assumptions

I approach this study with a number of assumptions. Firstly, I assume that people with fundamental Christian beliefs come from homes in which the Bible is a part of their culture, and may likely hold a biblical worldview. Secondly, I assume that although all students are likely to experience some kind of discomfort in the science classroom, this experience is likely amplified for students with deep Christian beliefs. Thirdly, I assume that such students with fundamental Christian beliefs who pursue scientific careers are likely to have some successful coping strategies they use which could potentially inform science educators on how to help ease the borders for other students with similar beliefs into the world of school science and science related careers. These assumptions will be tested or validated when the respondents answer questions that solicit the role of the Bible and of science in their lives and describe their experiences in the science classroom.

Definition of terms

Fundamental/deep Christian Beliefs: the belief in the Bible as the inerrant word of God, a final authority on one's life choices, and in the literal interpretation of scripture.

Enculturation: when the transmission of the subculture of science occurs when a student's own culture resonates with that of school science, enculturation takes place and leads to enhancement of the person's everyday thinking with scientific thinking (Aikenhead & Jegede, 1999; Cobern & Aikenhead, 1997).

Cultural Assimilation: when cultural transmission is between the subculture of school science and a student whose everyday culture is disharmonious with the subculture of science, the student may be forced to abandon his/her own culture to embrace that of

science leading to cultural assimilation (Aikenhead & Jegede, 1999; Cobern & Aikenhead, 1997).

Acculturation: when students modify their existing ideas due to new ideas they learn, it is known as acculturation (Aikenhead and Jegede, 1999, Jegede & Aikenhead, 1999). Autonomous acculturation occurs when one borrows aspect from another culture and integrates then into his/her own culture (Cobern & Aikenhead, 1997).

Anthropological learning: anthropological learning occurs when students construct meaning from the subculture of science but without acculturation or assimilation (Cobern & Aikenhead, 1997).

Scope and Constraints

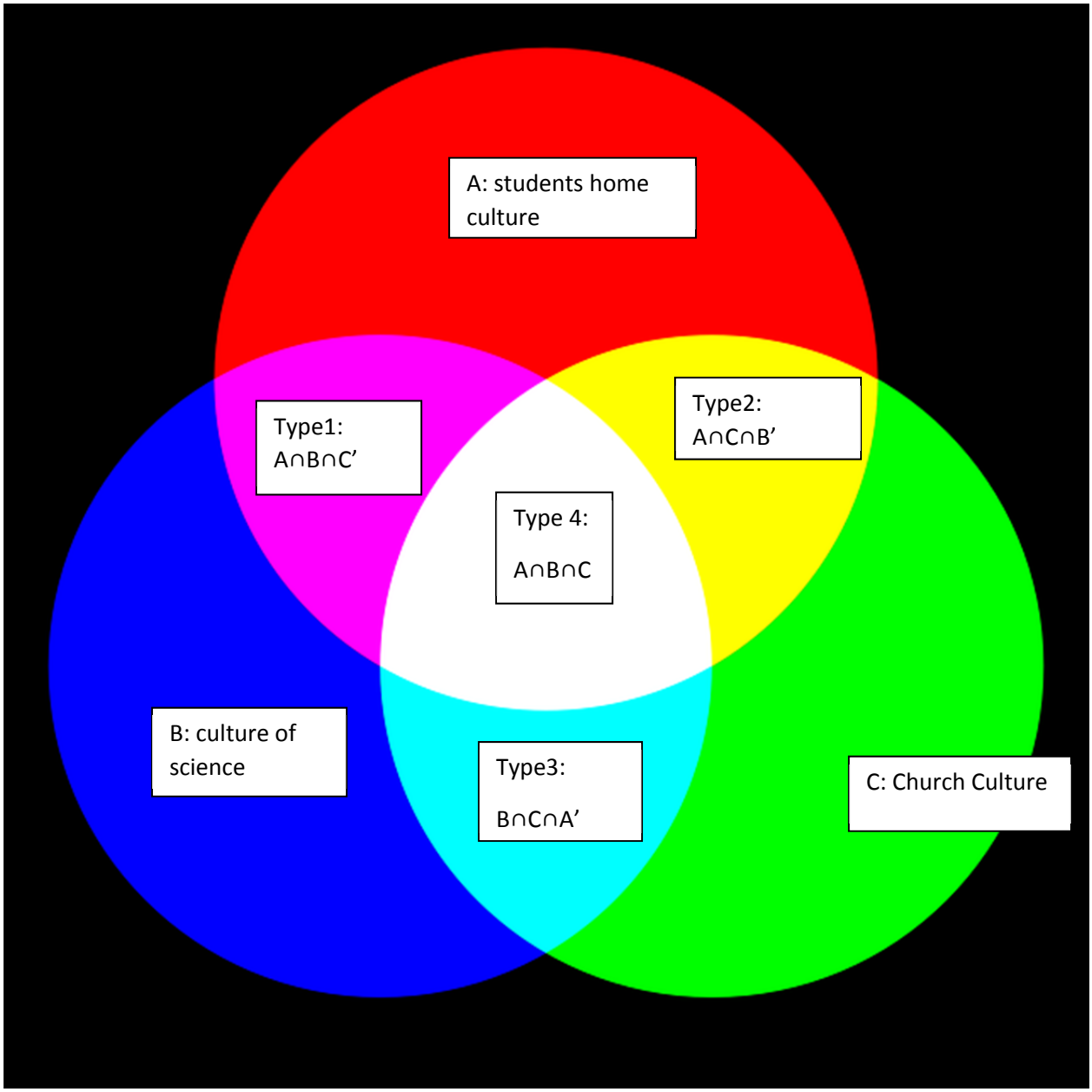

Figure 1: scope of participants' pool

Type1 students, A∩B∩C': students from homes where a science culture is encouraged but do not hold fundamental Christian beliefs are likely to experience little or no conflict.

Type 2 students, A∩C∩B': students who hold fundamental Christian beliefs and come from homes with fundamental Christian beliefs, with little or no exposure to science apart from science classroom are likely to experience severe conflict.

Type3 students, B∩C∩A': students with fundamental Christian beliefs studying science, but come from homes which do not hold such beliefs are likely to experience severe conflict because students who hold fundamental Christian beliefs from homes which are not inclined towards such beliefs will likely face "hostilities" from two fronts, lacking the support structure that those from homes with such beliefs may enjoy.

Type4 students, A∩B∩C: students with fundamental Christian beliefs whose home culture aligns with such beliefs but also encourages scientific practice are likely to experience conflict although not as severe as type2 and type3 students.

The above typology is adapted from that of Phelan, Davidson, and Cao (1991). However, it is not exactly the same as their Type IV students are assumed to face insurmountable barriers into the world of school science hence give up their pursuit. Another nuance between the two typologies is that their type II, III, and IV students can all be found within each type of students in my typology.

The scope of this study is limited to types 2, 3, and 4 students. The sensitive nature of this research study placed some constraints on who I can recruit to participate in the study. My focus on West-African students is due firstly to issues of access; as a West-African myself it is relative easy for me to have access to people whom I know as holding

fundamental Christian beliefs and are also pursuing/involved in science related careers, and who know me as someone who also holds fundamental Christian beliefs and is science inclined. The churches from which the participants will be recruited are ones I have either preached in or attended a conference in, hence am able to have a recommendation from the leaders to members of the congregation who I may not know personally. Secondly, the scope of this study is limited to West-Africans because I believe, individuals will be more likely to open up about such deeply private experiences of theirs when they are able to identify with the researcher as one who may have similar experiences and from relatively similar cultural backgrounds. As a novice researcher, I am relatively more versed with the West-African cultural group and those with fundamental Christian beliefs from this group than with any other group.

Chapter Two: Review of the literature

This chapter will examine the current literature in three directions. The first body of literature reviewed will be the current literature on cultural border crossing in order to gain insight into the different approaches that researchers have used to address cultural border crossing in science. The second body of literature reviewed will examine comprehensively, the current literature that specifically addresses cultural border crossing in science with an emphasis on religious beliefs, specifically the interaction between religious beliefs and scientific explanations. This second category of literature will enable me develop research questions that will be grounded in the literature. Finally, I will examine the literature of religious beliefs and representations to gain insight to potential explanations as to why religious beliefs may influence how people respond to scientific explanations.

In this review, I present what the current literature says about cultural border crossing in general and later narrow the focus to the pocket of literature that addresses the interaction between religious beliefs and scientific explanations. This can be viewed as a funnel, moving from a broader perspective to a more narrow focus of my research interest. I do this for two reasons; first the literature on the interaction of religious beliefs and scientific explanations is limited in scope hence the need to broaden to related concepts. The second reason was an unconscious "guide" into my research interest. As I began reading on cultural border crossing in science, after some very extensive reading on the topic, I noticed that although much had been done research-wise on many aspects of cultural border crossing relatively little work of this type has focused on religious aspects of culture, especially for fundamentalist Christians. In synthesizing the literature, I will argue that (i) many aspects of cultural border crossing have been explored, but little

work of this type has focused on religious aspects of culture, especially for fundamentalist Christians, (ii) the constructivist nature of religious thought and belief is such that we expect it to interact with students' learning of science in some ways and therefore there is need to explore the classroom experiences of people with fundamental Christian beleifs, (iii) the ways in which researchers of science/religion tensions categorize people and strategies align with Jegede's scheme for categorizing how students deal with tensions in cultural border crossing more generally; and therefore, in light of these three arguments stated above it is productive to use Jegede's scheme as a basis for exploring the nature and consistency of the ways in which students address potential tensions between religious beliefs and scientific explanations—not just for creationism/evolution conflicts addressed by almost all previous studies, but for other potential conflicts as well.

Cultural Aspects of Science

According to the National Research Council (2012), all science learning can be viewed as a cultural endeavor. "What counts as learning and what types of knowledge are seen as important are closely tied to a community's values and what is useful in that community context" (NRC, 2012, p. 284). This makes science teaching and learning complicated in today's society because with the world fast becoming a global village, today's classrooms are becoming increasingly diverse in every respect of the word. Homogenous student populations are becoming rare in most classrooms in the western hemisphere and it's easier to find heterogeneity in terms of race, culture, ethnicity, language, social status, beliefs etc.; multiracial, multilingual, and multiethnic classrooms have become the norm in educational settings.

Science and Worldview

Kawagley, Norris-Tull, and Norris-Tull (1998) defined Worldview as "a means of conceptualizing the principles and beliefs—including the epistemological and ontological underpinnings of those beliefs—which people have acquired to make sense of the world around them" (p. 134).

Science educators are increasingly confronted with the challenge to take into consideration alternate forms of knowing that result from cultural diversity (Kawagleyet al., 1998; Snively & Corsiglia, 2000; van Eijck & Roth, 2011), hence the need to approach science education from a cultural perspective. Tan (2011) explored the need for possible "reconciliation between the cultures of school, science, school science, as well as home" (p 559) and underscored the need for science teachers to be aware of differences in cultural values and belief systems of their students, especially those from underrepresented groups. This means there is a disparity that needs to be addressed between what students experience in their school science culture and what they experience in their homes and life-world.

Mvé-Ondo (2008) argued for a "worldwide space for science that is shared and built on diversity"(p 98); that science activity feeds on the culture where it is developed, that scientific interpretations come with an element of culture embedded in them, and that cultural diversity is important to 'decolonize' and 'de-westernize' science. Language, ethnicity, identity, gender, and other cultural factors like sense-making, reasoning styles, teaching and learning styles have a strong bearing on the science learning process (Barton & Yang, ; Brand, Glasson & Green, 2006; Franklin, 1995; Gaskell, 2003; Taconis & Kessels, 2009;Thijs & Van den Berg, 1995). Rosebery and Warren (2008) concluded that

everyday experience is an important intellectual resource in science learning and teaching, but are often misunderstood and undervalued. These everyday experiences originate from home and community cultures of students.

There is science that develops from one's observation of and experience with nature, and there is another science that develops from rational perceptions of reality (Cobern & Loving, 2001). Therefore science has multiple origins and multiple ways of developing scientific knowledge. Scientific practices are both global, local, and context dependent (Franklin, 1995). There are scientific practices which are nearly universal while others are practiced within specific local communities. Therefore we cannot ignore the role of culture when talking about the construction, propagation, and acquisition of scientific knowledge.

Cultural Boarder Crossing in Science

How I view Culture

Although culture has been viewed and conceptualized differently by researchers in different fields of study, I approach culture in the way it has been used by researchers who have explored the different "worlds" a student interacts with and how these "worlds" might influence learning in the classroom. Culture is "an ordered system of meaning and symbols, in terms of which social interaction takes place" (Geertz, 1973, p. 5, quoted in Cobern & Aikenhead, 1997, p. 3). Attributes of culture include, but not limited to:

> "Communication (psycho and sociolinguistic), social structures (authority, participant interactions, etc.), skills (psycho-motor and cognitive), customs, norms, attitudes, values, beliefs, expectations, cognition, conventional actions, material artifacts, technological know-

> how, and worldview…Within every culture there exist subgroups that are commonly identified by race, language, ethnicity, gender, social class, occupation, religion, etc." (Cobern & Aikenhead, 1997, p. 4)

Students cross borders when they move between different life worlds. Understanding the nature of the boundaries students are required to cross between their life worlds, and how they negotiate or fail to negotiate such borders and are impeded by them (Snively & Corsiglia, 2000) is expedient for educators and science educators in particular. Such an understanding of "students' multiple worlds and boundary crossing behavior is vital in a world where barriers continue to block understanding and obstruct attempts to develop and implement policies to ensure the success of all students in today's schools" (Phelan et al., 1991, p. 226) and especially in today's science classrooms.

Aikenhead (2000) points to the border crossing that students need to make from their home cultures into the culture of school science in order to make sense of science lessons. There is a degree to which school science appears foreign due to differences between students' everyday culture and the culture of school science irrespective of whether the students come from Western or non-Western backgrounds. The science classroom is a subculture of its own with ways of doing, values, codes of conduct, expectations etc. that are different from those students bring from their real life worlds (Barton, Tan, & Rivet, 2008). How people make meaning of what they encounter depends on the culture of the communities they live in, people they interact with, and the roles they play in such communities (Lemke, 2001). Because meaning-making is subjective and depends on the culture of an individual, cultural differences between the different life-worlds of the student will require him/her to cross cultural borders.

In the sections that follow, I describe briefly, the different ways border crossing into science has been approached, and then I discuss the different approaches to help students cross borders. I am not presenting a comprehensive review of all the different kinds of barriers students might face in the science classroom, rather I will seek to relate these barriers to issues of culture, and how students may be helped to cross these borders.

Ethnic/Racial Borders

Minorities face several challenges and borders they must cross in order to learn science, from differences in worldview, language, identity, religion, everyday experiences, to attitudes and practices of teachers. These all tend to reinforce the hazardous nature of the borders that students need to be negotiate. The enthusiasm and out-of-school science experiences of minority and low SES students are hardly noticed, acknowledged or encouraged in the science classrooms (Barton & Yang, 2000). There is a strong relationship between the attitudes of students towards science and their performance within classroom science with the similarity between the school science subculture and the student life-world (Krogh & Thomsen, 2005). Classroom science has been presented to students in a way that is not only different from their culture, but may also be alienating to some, likely limiting how well they perform in science classroom.

Because science has been presented in classrooms as purely rational and value free, context and culture independent, static, lacking connections in everyday life of students, it has helped marginalized minorities (Barton & Yang, 2000). Solomon (2003) maintains that "the school is at best strange, like a place in another land and another culture, and at worst threatening" (p. 229). This statement paints a vivid picture of the experiences of minorities in school science. The culture of school science present ideas

and representations that may discourage students from crossing the border; the monocultural and Eurocentric focus of school science alienates minority students as evident in the fact that minorities persistently underachieve in science (Barton & Yang, 2000; Brand, Glasson, & Green, 2006). For example in subcultures where spiritually and the physical are treated as an inseparable whole, it is difficult for students to cross such borders into the world of western science (Cobern & Aikenhead, 1997).

Teachers tend to reinforce minority students' poor habitus with respect to schooling and especially with science. Even when they have a proclivity for science, some have been actively counseled out of science by teachers, school counselors and administrators (Barton & Yang, 2000). Such passive and sometimes active hostility towards minorities have caused minority students to view science classrooms as arenas of cultural conflict (Barton & Yang, 2000) that require lots of effort and skill to navigate. The absence of minority role models, negative stereotyping, low expectations, and negative perceptions are barriers to student achievement in science. Hence, there is need to encourage minority students pursuing science through support programs, minority role models, and community mentors (Gaskell, 2003).

Language Borders

Language is another border that students need to cross in order to fully participate in the culture of science and school science. Therefore, language can potentially limit the ability to learn scientific concepts for those who do not master its use, especially in the context of science (Moore, 2007). As one researcher puts it, "Science is nothing more nor less than a very effective vocabulary for coping . . . . The point is not to get trapped into thinking that science is the only vocabulary available to us or that it limits the possibility

of inventing new vocabularies . . .” (Bernstein, 1983, p. 203, cited in Moore, 2007, p. 321). Students’ participation and performance in science classroom is therefore a function of their mastery of the language of science and its associated discursive practices (Lemke, 1990). Classroom science uses language which is foreign to most students, or at least difficult to grasp, and minorities find it hazardous to cross language boundaries to obtain the language of power used in Eurocentric discourses in the science classroom (Moore, 2007).

The language and discursive practices of students from minority groups have been delineated as deficits that must be abandoned, hence narrowing the range of what is considered scientific language. Moore (2007) argues that “In not accepting diverse, varied, and multiple ways of expressing meaning through language and cultural representations, this reinforces dominant language and discourses and standard ways of knowing, speaking, and writing. What is considered legitimate and standard ways of writing thus establishes it as dominant, hegemonic, and most acceptable.” (p. 334). Thus, the other ways people from other cultures may describe scientific phenomena only appears deficits because those in power have established boundaries of what should be considered acceptable scientific language.

Gender Borders

Girls face barriers within school and from broader societal attitudes depicting science as masculine and girls as incompetent of meeting its rigorousness, to a lack of curricula that promote equity, teaching strategies that do not suit, or even hamper, girls’ way of learning, and impede their commitment with and success in school science (Barton et al., 2008). Growing up, we often regarded girls pursuing science as having

special prowess, extremely intelligent, and somehow anti-social. Underscoring the importance of a gender-conscious approach to science education, Brickhouse, Lowery, and Schultz (2000) argue that "We need to understand how students are constructed and construct themselves as girls, as members of a particular racial of ethnic group, as a "good" girl, as an athlete, and how these identities overlap in important ways with students' views of scientific identities" (p. 444). Educators should harness the productivity of out-of-class girls' identities and direct such in the productive learning of science.

In discussing the science subculture traits, Taconis and Kessels (2009) described the following traits as typical of science: a certain kind of masculinity (or more precisely, non-femininity), a preference for the conveying of content rather than the process of communication, a tendency to be rational and to put emphasis on rational explanation over emotional aspects of communication, a tendency to make things technically objective wherever possible, a tendency to refrain from placing emphasis on personal presentation, dull, authoritarian, abstract, theoretical, fact-oriented and fact overloaded; little room for fantasy, creativity, enjoyment, and curiosity', and hard and difficult to understand. Such traits are not commonly associated with girls who are known for their "softness", pragmatism, and creativity. Therefore, girls are required to cross borders into a field that is characteristically masculine and are sometimes required to adopt masculine characteristics in order to participate in school science, a demand which can be very hazardous.

Identity Borders

Students' experiences in school science are defined not only by their cognitive abilities but their emotional predilections and changing personal identities that they enact as warranted by different circumstances (Kozoll & Osborne, 2004). Two characterizations of identity make it particularly salient in understanding how to help students smoothly cross the borders into school science. Identity "as fractured, contradictory, and shifting in such a way that accounts for the student's inner and outer diversity" (Hird, 1998, cited in Kozoll & Osborne, 2004, p. 168) and "as fluid and changing depending upon the surrounding circumstances and mode of discourse therein (Heilman, 1998, cited in Kozoll & Osborne, 2004, p. 168). Hence identity can be shaped or influenced in positive ways by educators to enable students acquire science compatible identities.

Identity development, as has been used by researchers in the border-crossing literature, is an individual endeavor yet it is socially situated; it influences and is influenced by social structures and actions (Brickhouse, et al., 2000). Students form their identities from the families, communities, social classes, ethnicity, and race in which they are brought up. The different life worlds people participate in determine their individual or collective experiences and the identities, personalities and roles that develop and are assumed from such experiences (Kozoll & Osborne, 2004). When students perceive their identity to be similar to what they believe to be science identities, they are likely to incline towards science subjects. On the other hand when they believe that their self-identities are very different from what they perceive to be science identity, they tend to distance themselves from science subjects. The degree of "scienceness" of a student's identity will determine their border crossing experience into school science. One

important reason why students turn away from science is a mismatch between their perceived image of science and their self-identity (Taconis & Kessels, 2009). Therefore, students must develop identities that are resonant and harmonious with science identities in order to learn science (Brickhouse, Lowery, & Schultz, 2000).

To summarize, students face several borders they are required to cross from their real life-world into the world of school science and the scientific enterprise. These include, language borders, gender borders, identity borders, ethnic, and socioeconomic borders. How well students negotiate these borders determines whether they are alienated from or drawn to science, and how well they develop understanding of scientific knowledge. In the section follows I present suggestions from the research literature on cultural border crossing on how people can be helped to negotiate such borders.

Researchers' Suggestions for Easing Border Crossing into Science

Several suggestions and propositions have been made respecting how people can be helped to negotiate cultural borders into the world of science. I think it is necessary at this point before going into details to talk about the nature of school science in two broad domains: science instruction and science curriculum. Students' classroom experiences are mostly influenced by the nature of school curriculum and the approaches to instruction. Understanding how these affect students' border crossing experience will help us better understand the approaches that have been put forth.

The nature of school science with respect to culture

The cultural nature of school science can be viewed from two perspectives, from the viewpoint of science instruction and science curriculum.

Science Instruction

I begin this section with a quote from Maddock: “science and science education are cultural enterprises which form a part of the wider cultural matrix of society and that educational considerations concerning science must be made in the light of this wider perspective" (Maddock, 1981, p. 10; cited in Cobern & Aikenhead, 1997, p. 2). In regards to instruction, most teachers approach school science as though it is purely rational, idealistic, and free from cultural influences (Aikenhead 1997). Teachers have been exposed to a version of science that is culture-independent and hence do not consider a cultural perspective when teaching science (Tan, 2011). As a consequence they have failed to bring relevance to science lessons in terms of how they can be applied in students’ everyday life-world. Teachers need to consider the complex nature of the interaction between science, culture, school, and other factors of the equation for science teaching and learning to take a meaningful dimension of culture and diversity.

Needless to say this view of science teachers’ about science is diametrically opposed to that held by most of the students they welcome into their science classrooms. For the most part, students from different cultures view science differently with some students believing cultural factors like country of origin, politics, religion, education, and social factors have an influence on science and how scientists make conclusions (Aikenhead, 1997). If such a disparity exists between what teachers believe and what students believe about school science, then students’ needs cannot be adequately met by a science teaching devoid of cultural perspectives.

Different cultures have different ways of socially interacting with peers, family, and people in authority. Different cultures favor different teaching styles. Sometimes

cultural practices pose additional challenges when science culture fails to align with students' cultural understandings and practices (Meyer & Crawford, 2011). The western cultural teaching style favors participation of students in the classroom to a greater degree than non-western cultures. Hence students from western culture in a western science classrooms can more readily feel at ease with the inquiry/argumentation method practiced in most reform-oriented science classrooms than students from non-western cultures (Thijs & van den Berg, 1995). The level of teacher-initiated and student-initiated activities in any classroom varies according to culture. Teaching and learning styles are important cultural variables that affect the way students participate in science classroom, hence the way they develop scientific skills (Thijs &van den Berg). Having looked at how instructors contribute the cultural irrelevance of science education I will now look at the role of curriculum.

Science Curriculum

In regards to curriculum Mutegi (2011) argues that the curricular perspectives, goals, and assumptions of current science education curriculum fail to address the needs of minorities. He further argues that current curricular standards are biased towards western modern science (WMS) to the exclusion of other scientific values from other cultures. Aikenhead (2006) recognizing the issue as relates to Aboriginal Canadians, explored ways of amending the science education curriculum to meet the educational and societal needs of the Aborigines across Canada. There have been a lot of standardizations of scientific knowledge leading to the loss of historical and cultural components of science in curricular standards (Tan, 2011). This loss of historical and cultural content in science curriculum led to the false representation, for a long time at least, that science stands alone in its interpretation of natural phenomena.

Science curriculum in schools today fails to provide space for indigenous knowledge; at best it treats other ways of knowing from non-western cultures as things that have to be changed (Quigley, 2011) and such tries to assimilate students from other cultures into a western way of knowing (Cobern & Aikenhead, 1997; Gaskell, 2003), Keane, 2008). Mve-Ondo (2008) writes, "Scientific content is built up from materials emerging from different cultures and assimilated into rational constructions" (p 97). For the most part science education has focused on the rational constructs and content of scientific knowledge to the exclusion of the historical and cultural contexts from which the knowledge was constructed. Science education has concentrated more on transmitting knowledge divorced from the cultural and social processes of the scientists and how they came to their conclusions. Such an approach to science education curriculum enacts borders that some fine difficult to navigate.

Approaches to Helping Students Cross Borders into Science

Having looked at some of the borders that students are required to cross into the world of school science, in the next sections, I will present a brief overview of some of the different approaches that have been presented to help students navigate these cultural borders into the world of school science.

Critical Instruction

To diminish this cultural divide in multiethnic classrooms, explicit instruction about the nature of science coupled with instructional congruency will help facilitate border/boundary crossing for underrepresented student groups (Meyer & Crawford, 2011). Tan (2011) argues that there needs to be explicit discussions about the differences and commonalities between students' cultural ways of practice and knowing, and those of WMS. Teachers and students involving in identifying dominant cultural values of

different groups will help adapt instructional practices that will facilitate boundary/border crossings for students from minority groups (Tan, 2011). Opportunities should be created for critique in the classroom. Students should be given the opportunity to reflect on the activities in relation to their cultural perspectives (Quigley, 2011).

Students should be given opportunities to discuss how their home cultures are similar to or different from the WMS, and be given the opportunity to accept or reject WMS depending on whether they think the differences may work to their advantage or disadvantage (Tan, 2011). Bringing students to analyze the differences and similarities between indigenous science and WMS can help promote multicultural science education (Snively & Corsiglia, 2000).

Cultural Brokerage

To help students cross borders, teachers need to act as culture brokers for students crossing the border into school science culture. Aikenhead (2001) remarks that "Crossing the culture border between Western science and Aboriginal science involves more than simple translation. A culture brokering teacher must be sensitive to the culturally embedded meanings of words in both cultures" (p. 345). "As a culture broker, the teacher clearly identifies the border to be crossed, guides students across that border, and helps students negotiate cultural conflicts that might arise" (Aikenhead, 1997, cited in Aikenhead, 2001, p. 346). Thus teacher expertise at tour guiding and cultural brokerage is indispensable in making science relevant to students. Such a need places extreme demands on teachers to be conversant with multiple cultures in order to effectively tour-guide students on how to bridge the gaps between science and their culture.

Funds of Knowledge

Funds of knowledge approach to science education looks at ways to take into consideration the knowledge, ideas, and concepts that students bring into the classroom from the cultures of their homes and community, and guide students to make connections between school science and their everyday lives (Carlone & Johnson, 2012). According to Basu and Barton (2007),

> "Funds of knowledge refer to the historical and cultural knowledge of a community… [and also] experiences and knowledge that may be more particular to a given family within the context of a community. . . . Funds of knowledge therefore include knowledge, action, and disposition or habitus with a recognition of how each of these domains are culturally constructed and refined" (Basu & Barton, 2007, p. 468; quoted in Carlone & Johnson, 2012, P. 152).

Science educators need to tap into the funds of knowledge of students from underrepresented groups, using it as an asset instead of viewing it as a liability to scientific knowledge (Carlone & Johnson, 2012; Quigley, 2011). One aspect of funds of knowledge that students come with into science classroom, other than everyday ways of speaking and knowing and cultural beliefs, is their preconceptions. Students' alternative conceptions and preconceptions have been found to influence how they interpret scientific knowledge (Bransford et al., 2000; Posner et al. 1982; Smith et al., 1984).

As Thijs & van den Berg (1995) argued, cultural factors influence students' alternative conceptions and are important in science learning and teaching process. Therefore, for science lessons to effectively build on students' prior knowledge, teachers

will have to activate and work with students' prior conceptions (Bransford et al., 2000; Posner et al. 1982; Smith et al., 1984). Teachers need to view students' preconceptions, everyday experiences, sense-making practices, and common sense knowledge as continuous and constructive in the learning and teaching of science (Rosebery & Warren, 2008). Students from underrepresented groups are disadvantaged when their everyday knowledge and preconceptions are viewed as unproductive and discontinuous from scientific knowledge. Instead teachers should use these prior knowledge and out of school experiences to build new scientific knowledge with their students (Rosebery and Warren).

Empathy

Güney and Şeker (2012) suggest that teachers can use the aspect of empathy through the history of science in the classroom to bridge cultural borders between students' everyday culture and the culture of science. They discussed two types of empathy: affective empathy which is the sharing of others' feelings and cognitive empathy which is the sharing of others' understanding or perspectives. Affective aspects of empathy include personal connections, imagination, identification and humanization. Cognitive aspects of empathy include understanding the events that led to certain scientific developments and theories, understanding different perspectives scientists have taken on an issue, understanding the tentativeness of the conclusions that were arrived at, and critical thinking (or perspective taking).

Biases towards science can be reduced and barriers removed when students are brought to make personal connections and identify with scientists, imagining themselves in the situations of those who took certain decisions or developed certain theories.

Students' understanding of NOS can be improved by using the tool of empathy as they interacted with the history of science (Güney and Şeker, 2012). Teachers' taking interest in students as persons and listening to them with empathy and understanding is positively related to students' interest in science (Krogh & Thomsen, 2005). As another researcher puts it, "by acknowledging Western science's historical roles in the colonisation of Aboriginals, a teacher can address Aboriginal students' conflicting feelings toward the culture of Western science, thus making a student feel more at ease with learning and with appropriating that subculture's content without accepting its values and ideologies" (Aikenhead, 2001, p. 341).

Third space/ Hybrid Space

Quigley (2011) suggests the creation of a third space in science classrooms to meet the growing challenge of increased complexity of classroom demographics to incorporating all students in the acquisition of scientific knowledge. She argues that for all students to succeed in science, all the diverse views of science need to be included in the research base. This third space, she argues, should consist of home and school complimenting one another, making room for the funds of knowledge students bring from their family, home, communities, languages, and cultural backgrounds. It should be a place of discourses: instructional, scientific, and everyday discourses. In this third space, teachers' use of instructional discourse and students' everyday discourses will help support scientific discourse.

Gutiérrez (2008) describe a collective third space as a "particular social environment of development [in which] students begin to reconceive who they are and what they might be able to accomplish academically and beyond" (Gutiérrez, 2008, p.

148, quoted in Tan & Barton, 2010, p. 40). In a related dimension, Carlone and Johnson maintain that "a third space or hybrid space is created when classroom members bring together elements of school culture and home culture to create something new" (Carlone & Johnson, 2012, p. 155). Moje et al. (2004), describe third space as 'a bridge, a navigational space, or a space for critical understandings of the relationship between science and students' ''everyday worlds''' (p. 54 cited in Carlone & Johnson, 2012, p. 155). Barton et al., define a third space as a space where students and teachers engage in "cultural production" (Barton et al., 2008), where 'cultural production' is "a set of symbolic and material forms, affected but not determined by history and structure, actively appropriated or ''produced'' in groups to bring order and satisfaction to experiences" (Eisenhart 2001a, p. 212-213, cited in Barton et al., 2008).

Multiscience Teaching

If modern science is considered an ethnoscience, that is an approach to science of a particular group of people in this case those from a Eurocentric worldview, then science classes should be opened up to explore other ways by which other cultures come to understand and build their knowledge of the natural world (Gaskell, 2003). Multicultural science education can act as a pedagogical scaffold into science for students from multicultural backgrounds (Snively & Corsiglia, 2000). Multi-science teaching involves incorporating different types of sciences like personal and indigenous science in the teaching of WMS. When students meet their personal science and indigenous science in the classroom, their learning of WMS will be facilitated and enhanced. Incorporating indigenous knowledge and worldview in local science curriculum will promote student participation and understanding hence the goals of scientific literacy (Kawagley et al., 1998).

Scientific literacy should include opportunities for a pluralistic teaching environment where multiscience perspectives are encouraged and brought into comparison with modern science to bring out the strengths and limitations of each (Gaskell, 2003). "Teachers pursuing a culturally responsive approach to instruction will need to understand the sense-making practices of particular communities, the science-related values that reside in them, and the historical relationship that exists between the community and local institutions of education" (NRC, 2012, p. 284).

Frequent opportunities for students to engage in discussions about science in relation to their culture can help bridge the gap between modern science and local cultures (Gaskell, 2003). We should move from the idea that some knowledge is right while some other is wrong to the idea that some knowledge is more useful or makes more sense in certain contexts than others (Gaskell, 2003). Incorporating traditional knowledge in the science classroom will increase minority students' self-esteem and bridge the gap to modern science (Snively & Corsiglia, 2000).

Capacity Building

Capacity building is when instruction is tailored such that minority students' language, lived experiences, and other cultural capital are affirmed in such a way that their full intellectual capacity can be attained in the learning of science. "A capacity building perspective can empower and equip minority students by affirming their life world languages, their lived experiences and their prior knowledge in their learning of science" (Chigeza 2011, cited in Wilson & Alloway, 2013, p. 197). Capacity building ensures that curriculum content is tailored into students' interest, community values and needs, and the extent to which lessons are related to their experiences, interest and

attitude towards learning science can be greatly improved (Wilson & Alloway, 2013). It ensures that there is equal teacher and student status with respect to questioning in the classroom and broadens the boundaries of classroom science dialogue (Wilson & Alloway, 2013).

Capacity building focuses on democratic and relational aspects of science learning and will "enhance interest in science in a way that a) respects social and cultural diversity and gender equity; b) promotes personal and social relevance; c) empowers the learner for democratic participation and citizenship" (Wilson & Alloway, 2013, p. 151). Students are given the opportunity to express themselves creatively, demonstrate their talents and make informed decisions that affect them beyond the classroom into their life-worlds. Science teaching should lay emphasis on improving the capacities and abilities of students and helping non-mainstream students attain their full intellectual potential (Wilson & Alloway, 2013).

Linguistic Scaffolding

Linguistic scaffolding is another method to help students understand and use the language of science by helping students find connections between their everyday language and standard scientific language. Teachers should explicitly help students develop and use scientific vocabulary. Talking science is another strategy that teachers could use in multicultural science education. In talking science, students are given the opportunity to (learn how to) use scientific language. Linguistic scaffolding will help student move smoothly between using everyday language and scientific language in the classroom (Meyer & Crawford). Making use of everyday language and sense-making to build scientific knowledge will bridge the gap that exists between popular culture and the

scientific subculture (Warren et al., 2001). Code-switching is when teachers teach their students how to switch between using everyday language and the language of science or academic language. Teachers should use diverse cultural experiences and materials to help student cross borders. The use of everyday languages and discourse in the classroom, especially for students whose primary language is not the language of instruction, will boost participation and deepen understanding of scientific phenomena.

To summarize, several potentially helpful strategies to aid in smooth border crossing of students into the world of science have been proposed. These different approaches to helping people cross borders into science classroom can be used depending on classroom demographics, the topic under consideration, and other factors determined by the practitioner. They can be used as stand-alone strategies or as combinations of strategies depending on the expertise of the practitioner.

Religious beliefs and Border Crossing in Science

Having looked at the different borders that students need to cross into the world of school science, and the different approaches and recommendations to bridge those borders as treated in the literature, I now provide a more detailed and comprehensive look at religious border crossing in science, focusing on another dimension of cultural border crossing in science, namely the interaction between deep religious beliefs and scientific explanations. I review the literature on religious border crossing into science. I also examine the literature on religious representations, thinking, and beliefs as this may provide an understanding into why religious beliefs seem to persist in the mind of people.

How students conceptualize and navigate the religion/science border

Cobern and Aikenhead (1997) maintain that "within every culture there exist subgroups that are commonly identified by race, language, ethnicity, gender, social class, occupation, *religion*, etc." (p. 4, emphasis mine). Therefore people's religious beliefs form an integral part of their culture, and shape their worldview and identity. In the same way people are classified respecting their race, gender, SES, or ethnicity, people can be classified according to the religious beliefs they hold (Muslims, Christians, Hindus, etc.) and within the different religious groups, subgroups exist with respect to the extent of their held religious beliefs.

Religious beliefs as part of cultural diversity have been neglected in the decades-long discussion on culturally relevant pedagogy (Celgie, 2013; Dager & BouJaoude, 1997; Fish & Lucas, 1998; Stolberg, 2010; Taber, Billingsley, Riga and Newdick, 2011). In this section, I situate people's deep religious beliefs in the context of cultural diversity. Through the lens of Jegede's (1995) and Jegede's and Aikenhead's (1999) collateral learning theory, I review what current literature says about the interaction between people's fundamental religious beliefs and scientific explanations. What happens when people's deep religious beliefs interact with scientific explanations? How do people manage tensions that arise between their deep religious beliefs and scientific explanations? Can people be placed in singular categories of how they manage these tensions or are their approaches dependent on the tension under consideration? What are the resources they employ to maintain their pursuit of scientific knowledge and science related careers in spite of such tensions between their beliefs and scientific explanations?

Paying attention to students' religious beliefs

According to Hanley, Bennett, and Ratcliffe (2014), a dogmatic approach to science teaching only further alienates students who find difficulty reconciling their home culture/religious beliefs and school science. Ignoring religious beliefs in the science classroom can potentially limit rewarding and creative discussions in the science classrooms. If we must help students reconcile the interactions between their religious worldview and science, then we must take into consideration cultural and religious contexts (Hanley et al., 2014). Woolnough (1996) argues that a multidimensional, multifaceted world like ours requires multiple equally valid, and sometimes compatible, ways of viewing the world. Inappropriate application of science leads to conflict with other ways of knowing, especially religion.

Different forms of knowledge, all true, useful, valid, and compatible, may be suitable for different contexts, therefore, students should be encouraged to see science in its multiple contexts of the social, the historical, and the cultural just like religion is viewed (Woolnough, 1996). This is an argument to which Maddock concurs by arguing that "science and science education are cultural enterprises which form a part of the wider cultural matrix of society and that educational considerations concerning science must be made in the light of this wider perspective" (Maddock, 1981, p. 10; cited in Cobern & Aikenhead, 1997, p. 2).

The religious beliefs that students hold can no longer be treated as unimportant to their learning of science. Southerland, Sinatra, and Matthews (2001) argue that to relegate beliefs to the peripheries of science teaching and learning is to fail to explore and comprehend the reasons students hold beliefs, strips instruction of its dynamism, and may

be counterproductive to students' acceptance of science and the knowledge it produces. Celgie (2013) argues that science educators need to consider the role religious beliefs have for students pursuing a science career or science related career. Religion contributes to acquisition of social capital and academic motivation (Antrop-Gonzalez et al., 2007; Barrett, 2010, cited in Celgie, 2013), and religious beliefs are a form of cultural capital for some students (Celgie, 2013).

Religiosity supports student engagement and achievement (Liou et al., 2009, cited in Celgie, 2013) and acts as a source of resilience (Javanmard, 2013). In one study, African-American and Hispanic students who have strong religious beliefs and engage in church activities outperform their counterparts (Jeynes, 1999, cited in Celgie, 2013). Woolnough (1996) remarks that belief in a rational, personal Christian God encourages people to seek to understand the order in the world and that many past and current scientists find their religious faith a motivation for studying and gaining an understanding of the world around them.

Before delving into previous research on the interaction between people's religious beliefs and scientific explanations, it is expedient to discuss what religious beliefs and representations are, how they are developed and transmitted, why there are persistent, and why they may or may not interfere with the learning of science.

Religious representations, beliefs, and thinking

When students with deep religious beliefs encounter scientific explanations, they are likely to experience "cognitive dissonance" (Jegede & Aikenhead, 1999) depending on the nature of their beliefs and the scientific explanations they encounter.

What is religion and what are religious representations?

Religious beliefs, concepts, and representations can be found in nearly every culture, with some of these beliefs, concepts, and representations being culture independent and others depending on the culture in question (Bjorklund, 2012). What is religion and why are religious representations, concepts, or beliefs so prevalent regardless of the culture under consideration? How do these religious concepts develop? How stable are these concepts compared to scientific concepts? Do people require a set of cognitive resources for religious representations different from those used in non-religious representations?

According to Barrett (2000), 'Religion' designates a shared system of beliefs and actions concerning superhuman agency" (p. 29). A plethora of phenomena that cannot be readily explained using human logic is often attributed to superhuman influence and become a shared system of beliefs in a given culture or across cultures. This shared system of beliefs is an accumulation of human phenomena transmitted and controlled by natural human observation and cognition. Religious representations and concepts "deal with detection and representation of animacy and agency, social exchange, moral intuitions, precaution against natural hazards and understanding of misfortune" (Boyer, 2003; p. 119). That is, religious concepts deal with how people represent the natural world, interpret human actions and intentions, and provide explanations to that which will otherwise not be explained. Religious concepts are products of supernatural imagination.

Types of religious beliefs

There are two broad kinds of religious beliefs discussed in the literature on religious concepts and representations: beliefs about categories and beliefs about causation (Blancke, De Smedt, De Cruz, Boudry, & Braeckman, 2012; Diesendruck & Haber, 2009). According to Diesendruck and Haber (2009), two sets of beliefs about categories characterize both adults and children; essentialism and teleology. Essentialism is defined as "the belief that members of certain categories have inherent and stable properties, which are causally responsible for more superficial properties, and which make members of one category fundamentally distinct from members of other categories" (Diesendruck and Haber, 2009; p. 100).

Teleology is defines as "the belief that things exist for a purpose, be it intrinsic to the organism, or extrinsic for the benefit of another agent" (Diesendruck and Haber, 2009; p. 100-101). People generally tend to see things as belonging to distinct non-overlapping categories and that such things whether living or nonliving exist for a particular purpose, both the individual parts and the whole thereof. For example, animals are different from plants, which are different from humans, and the parts of these organisms have different functions like the organisms themselves function differently from other organisms. Plants have a different function, animals have a different function, inanimate objects have a different function.

The second broad kind of religious beliefs are what have been termed causal beliefs. There are two types of causal beliefs: intuitive beliefs and reflective beliefs (Blancke et al., 2012; Diesendruck & Haber, 2009). Intuitive beliefs are beliefs that are automatically and subconsciously activated when one is exposed to the proper stimulus

domain for which the belief developed evolutionarily (Diesendruck & Haber, 2009). Intuitive beliefs are unconsciously passed down across generations as a result of biological evolution. Intuitive beliefs constrain reflective beliefs and may act as default beliefs or determine which reflective belief is appropriate in a given situation (Blancke et al., 2012). They act as the basis and check for causal beliefs. Reflective beliefs are beliefs that we entertain at a conscious level and use them in our explicit reasoning (Blancke et al., 2012). Reflective beliefs are ones that while nested in an intuitive belief, are extrapolated through communication practices to different domains (Diesendruck & Haber, 2009).

How are religious concepts and representations developed and transmitted?

People naturally think along essentialist lines, mentally representing things according to their apparent categories thus, making inductive referencing possible in novel situations (Blancke et al., 2012). When people meet novel things, they are likely to represent them in terms of familiar ones in the same domain or category. For example, a child might refer to a horse as a big dog because he or she represents the unfamiliar horse in terms of a familiar dog, or refer to a millipede as a small snake because children often get to know about snakes before they get to know about millipedes hence they represent the unfamiliar millipede in terms of familiar snakes.

As Diesendruck and Haber (2009) explain, there are two approaches to explain potential domain-specific mappings of conceptual beliefs: “mild ontology” and “strong ontology”. In the mild ontology view, “essentialist-like beliefs result from both the causal structure and the communication practices used to refer to categories in a given domain” (p. 101), that is children will use both the structure of an object and acquired knowledge

from communication with other members of the community to place things in specific categories. In the strong ontology view it is argued that "there might be a set of innate causal beliefs that while varying in the extent to which they are domain-specific by definition, can nonetheless be extended to other domains" (p. 101), that is, people are born with causal beliefs which makes them categorize things, and possibly extend such categories where objects do not squarely fit.

Gottlieb (2006) argues that religious beliefs are a bi-product of human cognitive evolution and therefore are not a distinct conceptual domain with its own operational attributes. Instead religious thinking integrates concepts from other domains like the physical, biological, and psychological domains, a position supported by Barret (2000). Unlike previously held, cognitive resources required for acquiring and representing religious thoughts and actions are not different from those required to acquire and act on non-religious concepts. There is no need for a special domain of religious thought (Barrett, 2000). People simply make extensions of their ordinary cognitive resources of familiar situations to form representations of the supernatural. Religious concepts activate specific functional mental systems also present in non-religious contexts (Boyer, 2003). For example in some religious groups, natural horses are extended to religious horses with wings, natural trees are extended to supernatural tress with mouths that utter speech like humans.

Boyer (2003) argues that different religious representations activate distinct neural network or families of networks and that a mental machinery is activated in the process of acquiring and representing religious concepts based on three basic assumptions: 1) the greater part of people's religious thoughts and beliefs are not

consciously accessible, people's actual religious concepts often diverge from what they believe they believe, 2) religious thoughts naturally operate as a collection of distinct mental systems rather than unique, specific processes and 3) religious thoughts are a predictable by-product of normal cognitive function. Religious concepts are activated and transmitted because of their shared features with other supernatural concepts like dreams, folktales, and legends.

How do religious concepts relate to scientific concepts?

Boyer (2003) postulates that supernatural notions are noticeable because of two properties, 1. They meet some expectations held for the entire domain and 2. Specific features violate expectations held for the domain. For example the notion of a supernatural flying horse with wings meets the expectations of size and structure of a normal horse, but simultaneously its wings violate the expectation that horses do not have wings. This simultaneous occurrence of observable inferences and strong violations may constitute an optimum in memory and hence better recall than standard concepts or anomalies that do not involve violations of domain concepts. Even young children have been shown to possess the capacity to imagine supernatural agency by activating and modifying natural conceptions (Boyer, 2003).

In a similar vein Barrett (2000) argues that marginally counterintuitive concepts are easily represented and remembered by both adults and children. Concepts that mildly violate category-level assumptions are easily remembered and transmitted than concepts that fit the assumptions or strongly violate basic assumptions. Concept with too many counterintuitive features will be reduced to fit intuitive forms (Barrett, 2000).

Children easily adopt religious/supernatural concepts using ordinary conceptual resources to reason about such concepts. Their less developed conceptual systems make is easy for them to accommodate properties of religious agency. Though Boyer (2003) and Barrett (2000) agree that there needs to be violation for there to be better recall, they differ in the extent of the violations, Boyer argues for strong violations while Barrett argues for mild violations. I think, any degree of violation will lead to easy recall but with the intensity of "memory optimum" inversely related to the degree of violation until at maximum violation, where the individual reduces the novel concept to fit existing ones.

Blancke et al. (2012) argue that religious beliefs have a stronger appeal than scientific concepts by confirming people's expectations derived from their intuitions about living things and manmade objects from the natural world. Particularly, teleological beliefs are a mental default setting for understanding and explaining the natural world. Although schooling may change people's teleological beliefs, under certain constrains they resort to teleological explanations/reasoning. People are also inclined towards a design stance, where they consider artefacts to have been constructed with a particular purpose in mind because of their strong teleological beliefs. Such a stance makes it difficult for people to accept scientific explanations which often run counter to their default understanding of the natural world.

Scientific explanations often require people to change their conceptions which they derive from experience and common sense interpretations of the natural world. Because scientific explanations highly disrupt people's intuitive beliefs it is unlikely that such violent disruptions of the "naturalness" of their thinking will be accommodated. For example, it is easy for people with deep religious beliefs to resist the theory of evolution

and the Bug Bang theory because both run counter to their belief that everything is designed and placed in the universe by the creator for a purpose; life on earth is not mere chance.

There is a connection between religiosity and cognitive biases in representing the natural world. The more intense one's religious beliefs are held to, the stronger the beliefs influence their intuitions about the natural world. Such deep religious representations pose cognitive constraints to students' understanding of scientific concepts (Blancke et al., 2012). Supernatural concepts are informed by domain concepts like persons, living things, and man-made objects while scientific concepts often need extensive abstract thinking or representations which children may not possess thereby giving religious concepts an edge over scientific concepts in terms of assimilation and accommodation.

Religious beliefs and culture

Religious beliefs have been shown to be in one sense stable across cultures and in another sense to vary across cultures. Gottlieb (2006) argues that religious representations differ considerably across cultures but the underlying assumptions, ontologically, from which these representations operate remain universal. For example, essentialism beliefs about animals seem to develop irrespective of parental input and are uniform across cultures. Hence essentialism is not a result of enculturation. Essentialism about social categories is present in all cultures but different cultures essentialize different categories hence may be a result of communication practices in the culture (Diesendruck & Haber, 2009).

Children are also said to hold stronger teleological and essentialist beliefs than do their parents irrespective of the cultural context (Barrett, 2000; Blancke et al., 2012).

Similarly, children from different faith practices hold very similar religious beliefs or concepts but cross-cultural differences emerge by the time they reach adolescence (Evans, 2001). This difference develops as a result of cultural input due to communication with the adults in their environment.

Across cultures, people subconsciously ascribe purpose to things, both individual structures and the whole as required, and satisfactory conditions to explain their existence. Hence religious beliefs can be viewed as stable across cultures. Particularly, the presence of teleology in religious beliefs is cross-cultural. Barrett (2000) argues that people possess a large number of frequently inferred, spontaneous assumptions about the properties of different things, based on ontological category to which they belong. Intuitive assumptions about the properties of objects based on their ontological categories appear to be largely similar across cultures, and allow for a fast categorization of new things, as well as generation of predictions and explanations (Barrett, 2000). Hence there is a sense of stability of religious representations across cultures. Such a stability is owed to the interaction between reflective and intuitive beliefs. When reflective beliefs are in resonance with intuitive beliefs they make more sense, appear more natural and therefore are easily represented, remembered and transmitted hence can easily become stable cultural representations.

On the other hand since information derived from nonreligious conceptual schemata constrains religious ontology, actions, modes of transmission, and beliefs (Boyer & Ramble, 2001), one may also argue that religious concepts are culture dependent. This argument is further strengthened by Barrett's (2000) postulation that the ordinary cognition that religious actions draw upon are social causal cognition. The social

context in which religious practices take place influence how they are transmitted and adhered to.

As Barrett (2000) argues, religious concepts are shared in the context of religious actions and that ordinary cognition underlies religious representations, and structures religious practices in the minds of participants and observers. This shows that religious representations are highly informed by the context in which the religion is practiced and that representations of religious actions depend on cognitive mechanisms of representations for actions in general. Hence religious representations can both be viewed as both culture independent and culture dependent. To summarize, "Much as language is naturally acquired as a result of cognitive preparedness plus exposure to a typical sociolinguistic environment, ordinary cognition plus exposure to an ordinary environment goes a long way towards explaining religion" (Barrett, 2000; p. 29). Religious representations are generated within cultures and transmitted through group and individual experiences.

The ever-present conflict between scientific explanations and deeply held religious beliefs will generate different effects on people with deep religious beliefs who also have a strong inclination towards science than it will for people without such deep beliefs. Depending on the faith tradition, age of the individual, the experience of the individual, and how much the scientific explanation deviates from the everyday experiences of the student, if the religious explanation does not so much deviate from the everyday experiences and belief system of the student, it is likely that the student will reject the scientific explanation to avoid strong cognitive dissonance.

Having looked at religious representations, thinking, and beliefs; how they develop, are transmitted, and why they may persist against scientific explanations, I now turn to the literature which has examined the interaction between people's fundamentalist religious beliefs and scientific explanations.

The Science versus Religion Debate

The relationship between science and religion has been approached as either "a dichotomy, a dualism or complementarity; as antithetical, as separate nonoverlapping spheres of knowledge, or as complementing each other" (Tang & Mietus, 2003), "cousinly, mutually respectful, non-overlapping, competitive, proximate-ultimate, dominant-subordinate, and opposing-conflicting" (Staver, 2010, p. 19). Hanley et al. (2014) state that "'Belief-based' knowledge systems privilege what is known by faith and expressed through personal experience and writings. 'Evidence-based' knowledge systems were described as those backed up by facts, observations, and experimental evidence." (p. 1218). Such an argument, that is, the distinction between knowledge and belief, made by some philosophers, educators, and researchers is one of the reasons for the lack of attention to religious beliefs as an aspect of diversity in the science classroom. That is, some belief that knowledge and belief address different aspects of life and therefore should be mutually exclusive.

However, Cobern (2000) argues, such a distinction is misguided. He argues that there is no clear separation between knowledge and belief, that both represent what an individual has reason to believe is true. Calling on educators to acknowledge the parallel structure of knowledge and belief, Cobern (2000) argues that separation of knowledge and belief does not stand within a constructivist framework of learning. There are rational

reasons behind people's knowledge and people's beliefs. The focus should shift from separation of knowledge and belief to reasons behind both people's knowledge and people's beliefs. Our focus should be the soundness and validity of the arguments people present for their beliefs or knowledge rather than rejecting some arguments because they are what some may consider religious, and therefore unscientific.

Views on the science-religion relationship

When students with deeply held religious beliefs encounter scientific explanations, when schemata from the two worldviews are different, the result is competition for explanatory space which results to cognitive conflict (Blancke, De Smedt, De Cruz, Boudry & Braeckman, 2012; Glennan, 2009; Preston & Epley, 2009; Shipman,et al., 2002). For purpose of clarity, I will separate this section into two subsections. The first subsection will present arguments from those who think it is not possible to accommodate both religious and scientific worldviews, and the second will present arguments from those who think it is well possible.

Arguments for irreconcilability

Some researchers on the one hand have argued that, it is impossible for individuals to accommodate both scientific and religious worldviews. For example, Preston and Elpey (2009) argue that it may be impossible to hold alternate explanations to same degree simultaneously; ascribing to one automatically diminishes the other, hence the notion of an automatic repulsion between science and religion. Similarly, Blancke et al. (2012) postulate that

> "Religious beliefs make an appeal to our intuitions, whereas science typically flies in the face of those very same intuitions. On a

> cognitive level, religion and science are thus counteracting forces, pulling in opposite directions. Because they compete for the same "explananda", religious and scientific explanations are engaged in a cognitive zero-sum game: if one accepts one type of explanation, one is less likely to find the other type plausible" (p. 1176).

Some researchers have taken an extreme view that religious beliefs held by people curtails the supply of scientists, and therefore a detriment to national productivity (Granger & Price, 2007).

There is a connection between religiosity and the effect of cognitive biases on individuals' representations of the natural world (Blancke et al., 2012). Woolnough (1996) states that there is a sense in which science and religion are not compatible because they are different forms of knowledge, concerned with different fields of study, use different methodology, and use different criteria for truth. A similar argument is made by Staver (2010) that science and religion by their very definitions portray a focus on two different domains: science on the natural world and religion on the supernatural world. An argument which I believe is not entirely true because both science and religion try to explain the natural world, the origin of species, the health and optimal functioning of man. The reason for the existing tensions lies in the fact that these two spheres of knowledge often interact in some ways, otherwise there will be no place for competition. This mutual exclusivity between science and religion is not a view held by all.

Arguments for reconcilability of science and religion

Other researchers and on the other hand have argued that science and religion can be compatible. Einstein (1956) expressed this view by saying "Science without religion is

lame, religion without science, blind" (cited in Tang and Mietus, 2003, p. 472). Science is concerned with the what and how while religion is concerned with the why (Tang & Meitus, 2003). Thus, we cannot get a full picture of our natural environment until we embrace sound religious explanations of our world and the things therein. Stolberg (2010) argues that the scientific and religious habits of mind are similar. That is, the way people react to new religious or scientific knowledge, approach uncertainties, or arrive at their conclusions are similar in both religion and science.

Staver (2010) argues that "the empirical truth of science is compatible with the revealed truth of God's word in a constructivist perspective, because describing reality as it exists separate from, external to, and independent of humans is not the goal for either science or religion" (p. 37). That is, both science and religion, though using different methods or approaches to arrive at truth, seek to explain reality in terms of its relationship to people, how people relate with the tangible and intangible world around them. Empirical research on knowledge and beliefs show that they have related effects on comprehension, understanding, and learning, both are resistant to change; the emotional distinction between knowledge and beliefs is no longer considered valid (Southerland, Sinatra, & Matthews, 2001).

Woolnough (1996) argues that there are parallels in the ways that Christians and scientists seek meaning in the physical world

- both belief the world is understandable and seek to understand it
- both recognize that our human minds are limited to fully understand the world
- both use models and metaphors to understand abstract concepts

- both recognize that certain models will be useful in some situations but inadequate for others
- both recognize that apparent contradictions and inconsistencies are grounds for further investigation
- both experience intellectual and emotional satisfaction when fresh insights are achieved

Both science and religion are social institutions of how people relate to the world (Staver, 2010). Laszlo (2004) offers an argument for reconciliation between science and religion, a rapprochement of science with religion at least in some aspects, especially the merging of creationism and evolution. He argues that science and religion reach the same fundamental conclusion about the world, that there is a significant agreement between the new scientific worldview and the worldview of Christians. He seems to argue that science is no longer anti-Christian as there are many scientists who hold very deep Christian beliefs at the same time. Thiering (2002) concurs by saying, "…religion and science may continue to interact, to the lasting benefit of both" (p. 125).

Therefore, "it is important for secondary science teachers as well as college science instructors to develop a stronger regard and to gain a better understanding about religion's influences on student motivation, academic achievements, and interest in science careers" (Celgie, 2013, p. 58). In a similar vein, Lemke (2000) states, "Student interest in, attitudes toward, and motivation toward science, and student willingness to entertain particular conceptual accounts of phenomena depend on community beliefs, acceptable identities, and the consequences for a student's life outside the classroom" (p. 301).

I believe that arguing whether science and religion are compatible is a misguided argument. The fact remains that many practicing scientist and students hold both religious and scientific worldviews. Hence there is a great need to pay attention to the experiences of this group of individuals. Even the argument that religious beliefs curtail the supply of scientist is a misguided one. The question that should be asked is whether it's the religious beliefs themselves or the manner in which such beliefs and those who hold them dear are treated in the science classroom or scientific enterprise.

It is the hostility, and feeling of alienation that may deter some students from pursuing science studies (Celgie, 2013; Dodick, Dayan & Orion, 2010). That is why some have called for instructors to maintain an atmosphere of tolerance and respect for students' religious viewpoint (Shipman et al., 2002) and that educators must not require students to accept scientific explanations at the expense of their religious beliefs; understanding does not necessitate acceptance or belief (Southerland et al, 2001) in order not to alienate students with strong religious beliefs.

Increasingly, science educators and science education researchers are coming to terms with the fact that the religious beliefs students hold play a role in their attitude, interest, and achievement in science, consequently educators must both acknowledge and explore how religious beliefs can be used to promote science learning in these subgroup of students (Celgie, 2013). This leads us to the social and emotional nature of the science/religion interaction both within and without the classroom.

Beyond merely cognitive conflicts

I am certainly not taking the position that the interaction between science and religion will always lead to cognitive conflict, I wish to show where such conflicts arise, they are not merely cognitive, rather may produce other adverse effects.

The interaction between people's deep religious beliefs and scientific explanations can potentially produce effects beyond the cognitive conflicts that people experience. Religious beliefs of parents influence children's attitude towards evolution and the church culture in which children grow up exerts an influence on their view about evolution hence fundamentalist Christian students' acceptance of evolution could potentially create a rift in their family and other social relationships (Windslow, Shavar, and Scharmann, 2011). Lemke (2000) concurs to the ripple nature of the effects of this interaction. He argues that "Belief is more than the acknowledgment of bare facts or an assent to logical relationships; it is a felt commitment, a component of identity, and a bond with a community" (p. 312). Change of thinking or values or beliefs is not just an intellectual matter, but a spiritual, social, psychological and even emotional one for students who hold strong religious beliefs (Lemke, 2000). How people make meaning of what they encounter depends on the culture of the communities they live in, people they interact with, and the roles they play in such communities (Lemke, 2000; Tang & Mietus, 2003).

Humans are not intelligent computers where programs or data can be changed or modified without any emotional, psychological, or social effects. People attach emotions to their beliefs and consider some core beliefs as part of their personal and even relational identities which they may not want to change or fear to change because of the ensuing

consequences. It is impossible for students to change their worldview and ideas in relation to scientific explanations without adverse effect on their cultural identity, especially when the former is in dissonance with the latter (Lemke, 2000). For example, Lemke (2000) argues that

> "To adopt an evolutionist view of human origins is not, for a creationist, just a matter of changing your mind about the facts, or about what constitutes an economical and rational explanation of the facts. It would mean changing a core element of your identity as a Bible-believing (fundamentalist) Christian. It would mean breaking an essential bond with your community (and with your god). It could lead to social ostracism and the ruin of your business or job prospects. It could complicate your family life or your marriage chances" (p. 301).

Hence the conflict between religious beliefs and scientific explanations extends beyond just the cognitive domain to the emotional, social, financial, and even psychological domains of people's lives. Thus, it is important while examining the cognitive effects of these interactions to also, where possible, look at the emotional and social effects of these interaction for people with fundamental Christian beliefs.

Categorization of the Interaction between Religious Beliefs and Scientific Explanations

Many researchers in their approach to how people manage the tensions that arise between their deeply held religious beliefs and scientific explanations have resorted to classifying individuals into categories. So far, only one research report I have

encountered (Taber et al., 2011) seems to suggest the contextual nature of people's approach to managing the tensions between their religious and scientific worldviews.

Shipman, Brickhouse, Dagher, and Letts IV (2002) discussed three categories into which the students in the study could fit: Distinct- those who believe science and religion concern two different domains, Convergent- those who think science and religion can be integrated to explain the natural world, Transitional- those who showed some engagement with science and religion but consider different questions to belong to different domains; science and religion are different but closely related, and added a fourth category from the literature, Confrontational- those who believe that science and religion are always antithetical.

In a similar vein, Tang and Mietus (2003), though acknowledging the contextual nature of the science versus religion interaction, classified their participants in the following categories: "religious salient"- those whose worldviews is more of a religious orientation, "scientific salient"- those whose worldview is more of a scientific orientation, "contextual salient"- those whose worldview shifted between scientific and religious worldviews, and "anomic salient"- those whose worldview is in a state of uncertainty.

Hanley, Bennett, and Ratcliffe (2014) categorized their research participants into Resistors- prefer belief-based knowledge system and find science alienating, Confused- perceive science and religion as competing and risk being discouraged from pursuing science, Reconciled-home culture/religion perceived in harmony with science hence smooth transition, and Explorers- experience discord but relish inquiry, nonsmooth transition. In a study conducted in Lebanon, Dagher and BouJaoude (1997) placed

participants into the following four categories: "(1) Students Who Accepted Evolutionary Ideas Using Arguments from an Evolutionary or Reconciliatory Perspective, (2) Students Who Did Not Accept Evolutionary Ideas Presenting Arguments from a Creation or Antievolutionary Perspective, (3) Students Who Reinterpreted the Theory Arguing from a Compromise Perspective, (4) Students Who Were Neutral Espousing Either a Noncommitted or a Confused Perspective."

There appears to be some inconsistencies in Dagher's and BouJaoude's categorization of the students' acceptance of biological evolution. For example, the first category merges those who accepted evolution from scientific explanations perspective and those who tried to reconcile the theory with their religious beliefs, the latter of which seems to be similar to their third category. The second category also merges students who rejected evolution because of their religious beliefs with those who rejected evolution from a scientific perspective.

Thus, I believe the following categorization would have shown less inconsistence: (1)Students who accepted evolutionary ideas from a scientific perspective, (2) Students who accepted evolutionary ideas by reconciling scientific explanations with religious beliefs, (3) Students who rejected evolutionary ideas based on their religious beliefs, (4) Students who rejected evolutionary ideas based on scientific reasons, and (5) Students who were confused espousing a noncommitted or confused perspective. By reorganizing the categories as above, I am not suggesting that there are five ways that people will respond to the theory of evolution, but that the new categorization takes care of the inconsistencies noticed in the original categorization. For example, students who accepted evolutionary ideas and students who rejected evolutionary ideas based on

scientific reasons are both speaking from a scientific perspective, and therefore are giving scientific explanations priority over their religious beliefs.

In a study conducted in England among adolescents, Taber, Billingsley, Riga and Newdick (2011) placed participants into the following five categories: (1) Giving religion precedence: recognizing some problems in relating science and religion and deferring to religion where contradictions are perceived; (2) Open to science supporting faith: recognizing some problems relating science and religion, but taking the view that ultimately these can be reconciled, with science supporting a faith position; (3) Compartmentalizing science and religion: considering that science and religion concern different domains and so there is no need to relate them; (4) Multiple frameworks: recognizing that sometimes one has to choose between science and religion and making this decision according to context; (5) Choosing science over religion: recognizing contradictions between science and religion and choosing to accept the scientific viewpoint. Although the authors here appear to

In spite of the difference in the categorizations, all the above mentioned studies seem to assert that students can be placed into categories based on their perceptions of the interaction between scientific explanations and religious beliefs. I argue that such categorizations based only on a limited aspect (in this case evolution), in spite of the many areas where science and religion seem to be in conflict, does not paint a true and complete picture of the potential ways students might deal with the different conflicting scenarios that exist between scientific explanations and religious beliefs.

One of the studies (Fish and Lucas, 1998) did not categorize the participants and argued that personal worldviews are complex and difficult to categorize. Although Fish

and Lucas (1998) did not place students into categories, my opinion is that, they made a conscious effort to avoid categorizing students as implicit in their description of the different participants. In most of their description of students' positions, they intimate that such students they describe may fall in a particular category. For example, in describing Laura, the authors wrote, "Laura holds science and religion as two quite different ways of seeing the world. She subordinates the science she learns in class to her Christian faith…." Such a description clearly portrays Laura as belonging to the category of those who always give their Christian beliefs precedence over scientific explanations in conflicting situations. A similar argument can be made about how the authors described Alex's position:

"Alex believes strongly in the compatibility of science and religion and expressed his disappointment that so many people denied themselves access to the benefits of the Christian faith through their adoption of a conflict model between the two."

Again, just like in the case of Laura, Alex was portrayed as someone belonging to the category of those who reconcile science and religion. Although the authors argue that personal religious worldviews are idiosyncratic and resist attempts at categorizations, their description of the positions of their participants intimate categorizations, which I believe a great conscious effort may have been made to avoid.

Thus, in the literature I have examined so far, explicit or implicit categorization has been the practice of those who examined people's perceptions of the interaction between science and religion, albeit limited to the conflict between creationism and the theory of evolution.

An alternate approach: Categorizing strategies rather than individuals

Some researchers instead of categorizing their participants have resorted to explaining the possible ways by which the conflict or tension between scientific explanations and religious beliefs has been managed. Starver (2010) discusses some ways that the conflict has been resolved: religion dominates, science dominates, incompatibility, separate independent and non-communicative, and separate, independent, and communicative. Barbour (2001) discusses four typologies of the science/religion tension: Conflict- the model where science and religion are seen to be in an irresoluble tension, independence- the belief that the two fields cannot conflict because they deal with different domains, dialogue- the notion that science and religion can engage in constructive dialogue, and integration- the notion that science can religion can be integrated.

Haught, (1995) outlines four ways to approach science and religion interaction: "Conflict–fundamentally they cannot be reconciled; contrast–because each addresses distinct questions, they do not truly conflict; contact–a search for potential harmony through dialogue and interaction, with particular emphasis on how science may inform religion and theology; and confirmation–an in depth search to understand how religion sustains and nurtures science as an endeavor." (cited in Staver, 2010, p. 20).

To summarize, when we look at the different categorizations or approaches to managing the science religion tension, a reasonable synthesis is that there are five ways, as synthesized in the literature, through which people managing this tension: 1) Compartmentalization- compartmentalization of their religious and scientific worldviews such that there is minimal interaction between both, if any, 2) Integration- viewing

science and religion as complimentary and seeking to integrate explanations from the two worldviews, 3) Religious dominance- religious beliefs and explanations are given precedence over scientific explanations, 4) Scientific dominance- scientific explanations are given precedence over religious beliefs, and 5) Contextualization- any of the above four approaches may be employed depending of the particular conflicting situation.

Through the Lens of Collateral Learning Theory

Because people build new knowledge on previous knowledge and experiences, their prior culturally-derived schemata for understanding the world can interact with school-taught concepts and ways of thinking in different ways. Jegede (1995) sought to explain this interaction by formulating the collateral learning theory. Collateral learning is a process by which people resolve conflicts between schemata when they move from their life-world into school science culture (Jegede, 1995). In this situation of religious and scientific worldviews, I will consider people's life-world to be their religious beliefs and therefore I apply the collateral learning theory to the interaction of people's religious beliefs and scientific explanations.

Jegede and Aikenhead (1999) discussed four types of collateral learning in a continuum, ranging from parallel collateral learning to secured collateral learning. At one end of the continuum is parallel collateral learning in which conflicting schemata are placed side-by-side of each other with minimal or no interaction. At the other end of the continuum is secured collateral learning in which the conflict between schemata has been confronted and resolved. Between secured and parallel collateral learning is dependent collateral learning in which one may choose one schema over another when convinced of its advantages. Lastly, between parallel and dependent collateral learning is simultaneous

collateral learning which occurs when a schema or concept from one worldview supports learning of a similar or related schema or concept in another culture.

In our context of religious beliefs and scientific explanations, I seek to relate the various categorization schemes that scholars have applied to students' experience of tension between religion and science to Jegede's collateral learning theory, which was constructed to describe cultural border crossing more broadly. How do these categories appear when viewed through Jegede's collateral learning theory?

Collateral learning theory and categorization/approaches

In this section, I discuss the different categories in the current literature through the lens of Jegede's (1995), and Jegede's and Aikenhead's (1999) collateral learning theory.

Parallel Collateral Learning

Categories that fall under this collateral learning type will be those in which research participants found no intersection between their faith and their religion, they consider the two as dealing with two separate areas and therefore having no need to reconcile both. In the Dagher and BouJaoude (1997) study the students who were uncommitted to either direction could be considered as employing parallel collateral learning. It is also seen as being employed by those students in the Taber et al. (2011) study who compartmentalized science and religion and saw no need to relate both. In the Coll et al. (2009) study, the scientists who compartmentalized their faith and religion in order to avoid cognitive dissonance can be considered as also employing parallel collateral learning.

Parallel collateral learning can also be related to Barbour's (2000) independence category because here also, science and religion are considered independent of each other. In the Hanley et al (2014) study, the students who were classified as confused may be classified as employing parallel collateral learning because they seem not to confront and resolve the conflict. In the Shipman et al. (2002) study, three of the categories namely, Distinct, Transitional, and Confrontational seem to employ Parallel collateral learning because the underlying quality for all the groups is that science and religion are distinct fields that do not need to interact. Though the way each study categorizes their participants is a little nuanced, the essential component threading across the categories is that the schemata do not interact with each other.

Secured Collateral Learning

In secured collateral learning the conflict between schemata has been confronted and resolved. In the Fysh and Lucas (1998) study it appears none of the students employed this type of collateral learning in dealing with the two schemata. In the Dagher and BouJaoude (1997) study the students who rejected evolutionary ideas by using arguments from a religious perspective or by using arguments that portray problems with the theory of evolution from a scientific standpoint, and those who accepted evolutionary ideas using the theory of evolution or a reconciliation perspective seem to employ secured collateral learning . Both groups seem to have confronted the conflict and resolved it in favor of one schema or the other. None of the scientists in the Coll et al. (2009) study seem to employ secured collateral learning and none of Barbour's categories fall in this type. Those students who are explorers in the Hanley et al. (2014) study seem to employ secured collateral learning because in spite of experiencing the conflict, their likeness for inquiry seem to propel them in their learning of science.

Dependent Collateral Learning

In the Fysh and Lucas (1998) study, the two students who perceived science and religion as two different ways of seeing the world with one favorably disposed towards science and the other favorably disposed towards religion may be considered as employing dependent collateral learning because they choose to favorably view one worldview over the other due to its potential advantages over the other. In the Dagher and BouJaoude (1997) study, none of the students seem to employ dependent collateral learning. In the Taber et al. (2011) study, the students who gave religion precedence and those who gave science precedence whenever there was conflict are employing dependent collateral learning. They seem to choose one over the other based on the advantages they perceive.

In the Coll et al. (2009) study, the scientists whose religious beliefs overrode their scientific training, and those whose scientific training were given priority over their religious beliefs were both employing dependent collateral learning. Barbour's (2000) conflict category is also related to dependent collateral learning in that people may be forced to choose one schema over another in face of such conflict. The resistors in the Hanley et al. (2014) study have chosen religion over science hence are employing dependent collateral learning. A thread of "precedence" of either science or religion runs through the categories under dependent collateral learning.

Simultaneous Collateral Learning

In the Fysh and Lucas (1998) study, the student, together with the clergy and science teacher, who perceived science and religion as compatible with each other are employing simultaneous collateral learning. The students in the Dagher and BouJaoude (1997) study who reinterpreted the theory of evolution by presenting arguments from a

compromise perspective may be employing simultaneous collateral learning by using schemata from the two worldviews to support their understanding of the phenomenon or they may have firmly resolved this tension and therefore are employing secured collateral learning.

In the Taber et al. (2011) article, the students who took the view that science and religion can be reconciled and were open to science supporting their faith, are employing simultaneous collateral learning. The scientists in the Coll et al. (2009) study who accommodated both religious and scientific views may be considered as employing simultaneous collateral learning, though some may argue that it depends on whether the schemata support each other or they are accommodated separately without interaction, in which case it may be argued they are employing parallel collateral learning .

Barbour's (2000) Dialogue and Integration categories may also be placed under simultaneous collateral learning because dialogue or integration between the two schemata would imply one schema from either the religious or science worldview would support the other. The students under the reconciled category in the Hanley et al. (2014) study are employing simultaneous collateral learning since they reconcile schemata from the two worldviews. Only the convergent category in the Shipman et al. (2002) study employs simultaneous collateral learning. Thus a thread of mutuality or compromise can be seen running across the categories that fall under simultaneous collateral learning.

Having examined the categories from the different studies through the lens of the collateral learning theory, I want to acknowledge that the authors themselves may not have placed their categories as such. It is apparent that some categories placed under one

type of collateral learning may overlap into other types since we are dealing with a continuum.

The table below summarizes the different categories found in the literature and the possible type of collateral learning theory employed:

Table 1:Summary of categorizations in light of collateral learning theory

Categories found in the Lit.	Description	Lit. where found	Type of Collateral learning possibly being employed	Explanations
Compartmentalization/ Conflict/independence	**People who view science and religion as two different worldviews and therefore do not interact**	**Barbour (2000) Glennan (2007) Coll et al. (2009) Dagher and BouJaoude (1997) Taber et al. (2011) Fysh and Lucas (1998)**	**Parallel Collateral Learning**	**People compartmentalize schemata or threat them as conflicting or as dealing with independent domains hence no need for interaction**
Dialogue/Compatibility/ Reconciliation/integration	**People who see science and religion as reconcilable**	**Barbour (2000) Laszlo (2004) Coll et al. (2009) Dagher and BouJaoude (1997) Taber et al. (2011) Fysh and Lucas (1998) Shipman et el. (2002)**	**Secured Collateral Learning Simultaneous Collateral Learning**	**People resolve conflict using logical arguments by integrating worldviews or using schema from one world view in support of the other**
Choosing religion over science	**People who choose religious beliefs over scientific explanations when both are**	**Coll et al. (2009) Dagher and BouJaoude (1997)**	**Dependent Collateral learning Secured Collateral**	**People may choose one domain over another just by affinity or by**

	conflicting	**Taber et al. (2011) Fysh and Lucas (1998)**	**Learning**	**logical arguments in favor of religion**
Choosing science over religion	**People who choose scientific explanations over religion when both are conflicting**	**Coll et al. (2009) Dagher and BouJaoude (1997) Taber et al. (2011) Fysh and Lucas (1998) Shipman et al. (2002)**	**Dependent Collateral Learning Secured Collateral Learning**	**People may choose one domain over another just by affinity or by logical arguments in favor of science**
Multiple framework	**People who choose either science or religion depending on the context in which both are conflicting**	**Taber et al. (2011) Fysh and Lucas (1998)?**	**Dependent Collateral Learning Secured Collateral Learning**	**People may choose one domain over another just by affinity or by logical arguments to resolve tension**

Conclusions from Review of the Literature

A gap in the literature examined above centers on the fact that most of the studies have looked at the evolution versus creation arguments or science versus religion in a very broad general context. Looking at people's perceptions along very specific areas of apparent or actual tensions between science and religion stands to illuminate how these interactions and the ensuing tensions are managed. Another point of interest is that most of the studies have looked at religion in general or those attending a religious institution. Looking at a subset of Christians, those with fundamnetal Christian beliefs will likely yield different categories. I believe those who hold deep Christian beliefs (like the Bible is the inerrant eternal word of God to be taken literally) are most likely to encounter tensions between some tenets of the Christian doctrine and scientific explanations, hence

it is necessary to understand the nature of the tensions and how they manage such. Such an understanding will have implications for culturally relevant science teaching.

The studies above, while informative, do not explain the classroom experiences of students with deep religious beliefs. This can be understood because it was not part of their research questions and also, their studies included participants irrespective of the nature of their beliefs. A study to investigate the classroom experiences of students with deep Christian beliefs in science classrooms, will add to our knowledge base, thus filling a gap in this literature. The different studies mentioned above that looked at how people, from secondary school students and college students, perceived the interaction between their faith and scientific explanations, came up with different categories that are related across the groups. A longitudinal study of whether students' perception of the religious versus scientific worldviews are stable or changing, and reasons for such changes across the years may provide additional insight on how such perceptions evolve.

The review of the literature leads to develop the following research questions:

1. How do people with fundamental Christian beliefs manage to maintain their pursuit of science related careers in spite of the potential alienating experiences due to the conflicts that arise between their deep Christian beliefs and scientific explanations?

    - What are the experiences of people with fundamental Christian beliefs in the world of school science?

- What coping mechanisms/resilience strategies do they employ to enable them traverse hazardous borders

- What are the resources (social, cognitive, etc.) people appeal to, to help them manage the effects of such tensions and maintain their pursuit of science related careers?

2. How do people with fundamental Christian beliefs and with an inclination for science view the roles of both science and the Bible in their lives? How do they manage the tensions that arise between their religious and scientific worldviews?

    - What justifications do people provide pertaining to their approach to managing the tensions between their fundamental Christian beliefs and scientific explanations?

    - Can people be squarely placed in different categories as to how they manage the tensions that arise between their deep Christian beliefs and scientific explanations?

Chapter Three: Methodology

Purpose of the Study, Research Questions, and Methods

The purpose of this study was to examine the interactions between people's fundamental Christian beliefs and scientific explanations, how they manage the potential tensions that arise from these two worldviews, and the intellectual, cognitive, social, or emotional resources that people employ to enable them maintain their pursuit of science related careers in spite of the potential alienation from science that such tensions between their worldviews may pose. I employed qualitative methodology in this investigation, with an inclination towards case study inquiry in particular. The research questions and subquestions that this study sought to answer were:

1. How do people with fundamental Christian beliefs manage to maintain their pursuit of science related careers in spite of the potential alienating experiences due to the conflicts that arise between their deep Christian beliefs and scientific explanations?

    - What are the experiences of people with fundamental Christian beliefs in the world of school science?

    - What coping mechanisms/resilience strategies do they employ to enable them traverse hazardous borders

    - What are the resources (social, cognitive, etc.) people appeal to, to help them manage the effects of such tensions and maintain their pursuit of science related careers?

2. How do people with fundamental Christian beliefs and with an inclination for science view the roles of both science and the Bible in their lives? How do they manage the tensions that arise between their religious and scientific worldviews?

    - What justifications do people provide pertaining to their approach to managing the tensions between their fundamental Christian beliefs and scientific explanations?

    - Can people be squarely placed in different categories as to how they manage the tensions that arise between their deep Christian beliefs and scientific explanations?

Research Design

This study was designed as a qualitative multiple case study investigation. I recruited several participants of west-African background who hold fundamental Christian beliefs and are in pursuit of science related careers. I explain below the reason for my choice of participants of West African origin.

Justification of qualitative and case study methodology

Bogdan and Biklen (2007) and Merriam (2009), maintain that there are five characteristics of qualitative research: it is naturalistic, it has descriptive data, is concerned with a process, inductive, and focused on meaning and understanding. This research is descriptive in the sense that, I assumed that nothing is trivial. I was interested in describing how the research participants manage the tensions that arise from the interactions between their fundamental Christian beliefs and scientific explanations, what effects, if any, does their experiences have on their choice of science related careers and their attitude towards science. The data collected were in form of words rather than

numbers, and I paid attention to details that the casual observer may have overlooked. This study was concerned with a process because I am interested in paying attention to how people, those with fundamental Christian beliefs with an inclination for science, negotiate meaning when their two worldviews interact. This study was inductive in the sense that I did not approach the study in order to prove or disprove a hypothesis; rather the data collected informed the abstractions that were generated. This study focused on meaning because I looked at people's perspectives on the tensions that arise between their religious and scientific worldviews, their experiences, and what these meant to them.

Why Case Study?

A case study is defined as "an in-depth description and analysis of a bounded system" (Merriam, 2009), "a detailed examination of one setting, or a single subject, a single depository of documents, or one particular event"(Bogdan & Biklen, 2007), "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-world context, especially when the boundaries between the phenomenon and context may not be clearly evident" (Yin, 2014), and "the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances" (Stake, 1995). From the different definitions we see that a case study involves an in-depth or detailed investigation of a phenomenon of interest within a defined boundary.

Most of previous research on border crossing that attends to aspects of religion has mostly categorized their participants instead of providing a thick, rich description of

the experiences of the respondents respecting the tensions that arise between their religious beliefs and scientific explanations, and the potential resources that these individual employ to help then navigate such hazardous borders between their religious and scientific worldviews. Also, since none of the previous studies has attended to individuals with fundamental Christian beliefs with a likeness for science as a group, this study took an exploratory approach to provide a thick, rich description of a potentially new terrain.

Case Study Protocol

Yin (2014), recommends the development of a case study protocol as a valuable tool for guiding data collection and increasing the reliability of case study research. I employed Yin's framework for the development of a case study protocol describing an overview of the case study, data collection procedures, data collection questions, and description of the eventual case study report.

Case selection and description

The phenomenon of study in this investigation is the interaction between people's fundamental Christian beliefs and scientific explanations of certain natural phenomena. The unit of analysis is the individual. This case study will be bounded in the sense that it is focused on people of West-African origin who hold fundamental Christian beliefs and have a likeness for science. This study is also intrinsic (Merriam, 2009; Stake, 1995) in the sense that I am particularly interested in gaining a deeper understanding of how people of a similar background as mine manage the tensions between their religious and scientific worldviews.

While I recruited multiple participants, I paid detailed attention to the individual cases because the uniqueness of the individual cases and the contextual nuances of the nature of their beliefs and backgrounds will provide a deeper understanding of each case. In other words I will be working towards particularizations rather than generalization (Stake, 1995). This case study seeks to provide understanding of the human experience of a cultural border crossing phenomenon rather than identifying a cause and effect relationship (Stake, 1995).

As someone from West-African background who holds fundamental Christian beliefs and a strong affinity for science, I think my experiences with the cultural and religious values of this group of people gave me a unique perspective in understanding how they manage the tensions between their religious beliefs and scientific explanations. It also gave me an advantage of access to such individuals who were relatively free talking to me about such deeply personal issues than they would someone from a totally different background.

According to Stake (1995), it is useful to select cases which are likely to maximize what can be learned about, gain understanding of, and lead to assertions about the phenomenon of interest. Sometimes it may be a typical case or one that is representative of other cases. Because I did not seek to draw any generalizations from this study, I chose cases that were typical examples of the phenomenon of interest within the boundary of those of West-African origin. My sample of participants was a non-probabilistic sample, that is, I selected a purposive or purposeful sample (Merriam, 2009) that could better inform the study and provide rich information for analysis. People I personally know as fundamental Christian believers who also have a strong likeness for

science as is evident in their pursuit of science related careers were such a sample. This purposive sample was augmented through the snow ball technique to recruit more participants who were recommended by other participants as potential candidates for the study.

Stake (1995) also recommends picking cases that are easily accessible and are hospitable to the subject of inquiry, what Merriam (2009) terms a convenient sample. Because I personally knew individuals from West-African background, with fundamental Christian beliefs, and with a likeness of science, and who also knew me as one with similar characteristics, I recruited such for the study who indicated a willingness to participate in the study. My contact with certain Pentecostal pastors with some student populations also likely gave me easy access to people who were potentially rich sources of information and increased the pool of research participants.

Setting and Study Participants

For this study I recruited two sets of participants from West Africa who have deep religious beliefs and are inclined towards or involved in science related careers. Four adults, specifically college students or recent graduates were recruited and interviewed here in the US and another four adults were recruited and interviewed in Germany. I recruited four participants from each "site" because my advisory committee suggested this will be a manageable number of participants for a qualitative study. Because I didn't know ahead of time to what extent the participants' views would be idiosyncratic or quickly "converge" into patterns, there was no a priori way to choose the precise number of participants. The eight participants, on the recommendation of the dissertation committee, were chosen to provide a kind of balance between being manageable and

exploring the terrain as fully as possible. It should be noted that these numbers were tentative and approximate in nature because I intended to collect data until I reach data saturation, that is, when the information I collect becomes redundant. There was no particular reason for recruiting participants from the US and Germany but for the fact that for the last three years I spent my time in either one of these countries and therefore came in contact with people whom I knew would be very good sources of information for this study.

West African indigenous Culture and Fundamental Christian Beliefs

Research participants recruited came from three different West African nations, hence there was a degree of diversity touching nationality. In terms of gender, there were six males and two females. Because gender was not a consideration in this study, this gender imbalance did not pose any issues; and besides, there were no noticeable differences along gender lines in terms of the experiences, strategies, resources, and management of the science-religion tensions. There was also diversity in age among participants. The ages of the participants at the time of the interview ranged from 23 yrs to 36 yrs. Each participant had received some form of college education and at least two had received some form of postgraduate education. The fields of study ranged across biological science, physics, engineering (mechanical and chemical), medical sciences (Nursing and Medicine), and computer science.

In spite of the above described diversity among the research participants, all of them held fundamental Christian beliefs. In West African communities, people are very aware of the supernatural. They hold beliefs of unseen forces which are at work in

communities whether they be of demonic origin or of divine origin. Many indigenous traditions and practices bring people in contact with the unseen. For example, it is very common for families to consult with witch doctors for protection from the power of witchcraft. Even those who are well educated consult "powers that be," to have an edge over their competitors, both at work, in business and even in schooling.

Life is viewed in many West African communities as a battlefield against demonic forces and familiar spirits that will go to any length to stop one from making reasonable progress economically, socially, professionally and otherwise. To emerge victorious in this battlefield, people understand that you can't be neutral, you would need to consult some higher powers to survive in the community. For many West Africans, this higher power resides with the fundamentalist Christian God; by establishing a relationship with God through His Son Jesus Christ, not only is one saved from the consequences of sin, but God's power affords deliverance from satanic strongholds that seek to prevent people from progressing in life, and protection from evil in general. Fundamentalist Christianity affords spiritual experiences and insight into the realm of the spirit which other forms of Christianity don't afford. People get to witness miracles through the power in the name of Jesus—something many of the participants referred to when describing their spiritual life and contrasting it with what science can provide.

When the Gospel of Jesus Christ is preached, in West Africa and elsewhere, people often identify the message with their personal experience and make a conscious commitment to follow Jesus. This commitment brings with it the benefit of eternal life in heaven after death, in addition physical, social, and material prosperity. So people find some form of security in subscribing to fundamental Christian beliefs, which they are not

willing to compromise for any reason. The strength and extent of one's belief may be viewed as the line between surviving in the battlefield of life and becoming a victim of the forces of evil.

Data collection

The interview method is commonly used by researchers investigating the interaction between religious and scientific worldviews (Fysh & Lucas, 1998; Taber et al., 2011). Each participant was interviewed using a semi-structured interview protocol (see Appendix A) to elicit their (classroom/professional) experiences of the interaction between their scientific and religious worldviews (Merriam, 1998). The interview method has the advantages in that it is targeted and insightful, that is, it provides explanations, meanings, perceptions, and personal views (Yin, 2014). I used semistructured interviews because it gave me the flexibility to be adaptive to the response of the individual to particular questions of the protocol without being stuck to the need to ask questions in any particular order (Merriam, 2009). However, all the interviewees got to respond to the same set of guiding questions soliciting their perceptions of the interaction between their two world views, and their approach to managing the tensions that arise between these worldviews. Participants had the freedom to bring in other issues where they may have experienced tension between their beliefs and scientific explanations. While there were guiding questions, the interviews were more conversational than interrogational.

The interview protocol was divided in two parts. One part of the interview protocol was designed to elicit respondents' view about the role of science and religion in their lives, their perception about the interaction between their fundamental Christian beliefs and scientific explanations, and their experiences in the classroom. The other part

of the interview protocol was designed to provide a "real time" experience of (apparent) tensions between their religious and scientific worldviews thereby providing an observer's perspective (Merriam, 1998; Stake; 1997; Yin, 2014). Other questions were asked the participants based on their responses to the questions on the protocol.

Each initial interview lasted between forty minutes and an hour and was videotaped and audiotaped for backup purposes. The first part of semi-structured interview helped me get the participants experiences from their own perspectives (Bogdan & Biklen, 2007), and the "real time" scenario some of the questions were designed to create an observer's view of how the participants manage the tension rather than just from what they said. These two perspectives – their explanation of how they manage the tensions and their real-time management of tension as observed by the researcher helped strengthen the conclusions that have been drawn (Bogdan & Biklen, 2007; Booth, Colomb, & Wiliams, 2008; Merriam, 1998; Yin, 2014). Follow-up interviews were also conducted where necessary to gain clarification in case of ambiguity or where further information was needed about an issue.

Data storage

The video files were stored in a password protected laptop which I alone have access to. The file names were stored under pseudo initials of the research participants. After transcription of interview data, the interview transcripts were also stored in the password protected computer and saved under pseudonyms to avoid revealing the identity of the participants. No one else has access to these files except those I chose to

share the data with, albeit using pseudonyms, without disclosing the identity of the respondent.

Human subject protection

Respondents' participation in this research was completely voluntary. They could have chosen not to take part at all or to withdraw in the midst of the interview without any liability on their part, thus continuous participation was voluntary throughout the study. If anyone decided not to participate in this study or if he or she stopped participating at any time, they were not penalized in any way. Respondents were free to take breaks from the interview as frequently as they chose. Interviews were conducted where the respondent thought he or she was most comfortable.

Data analysis

This study was approached as a multi case study (Merriam, 1998; Yin, 2014) of the classroom/professional experiences of people with deep religious beliefs, and how they manage the tensions that arise from the interaction of their Christian and scientific worldviews. The interviews were transcribed verbatim and analyzed individually using both predetermined codes from the Collateral Learning Theory and categories in the current literature and codes that emerged as I collected and analyzed the data from ground up. I sought to provide a thick, rich description of the experiences participants have, and the meaning they ascribe to these experiences. Although a verbatim transcription was time consuming and strenuous, it gave me the advantage of getting an intimate familiarity with the data in the course of transcribing (Merriam, 2009).

Data analysis was done at two levels, within-case analysis and cross- case analysis. Because the "case study is an intensive, holistic description and analysis of a single bounded unit" (Merriam, 2009), I sought to convey an understanding of the individual cases as comprehensive cases by their own right. After within-case analysis of each case was complete, I performed a cross-case analysis, looking for both similarities and differences across the cases. This cross-case analysis led to "categories, themes or typologies that conceptualize the data from all the cases" (Merriam, 2009).

Initial Analysis

Before applying any codes, I used memo writing (of reflections, ideas, speculations, tentative themes) to myself in the process of collecting my data, thus doing initial analysis in the data collection process (Merriam, 1998; Stake, 1997; Yin 2014). This helped me to notice any useful emerging concepts from the data and what aspects of the interview protocol needed more emphasis. I began my analysis by reading and rereading the interview transcripts while making notes on the margins (Merriam, 1998; Yin, 2014). This multiple reading of the transcripts and note-taking also enabled me to notice certain details and patterns about the data that could not have been noticed otherwise, and the notes I took represented my initial thoughts about the data and what patterns I had begun noticing. This initial exploration of some of the data I collected helped confirmed that the codes derived from the literature and the collateral learning theory could be applied to the data, and what additional codes needed to be developed from the data..

Coding Procedures

My overall strategy to analyzing this case study was both deductive and inductive. Although I had, and I made use of some predetermined codes developed from the literature, I mostly did work my data from the ground up, noticing useful concepts, relationships between different parts of the data, themes, or categories that emerged during the initial coding, that is, I conduct open coding on most of the data collected (Merriam, 2009). After this first round of coding, I performed a second round coding (Saldana, 2012) or axial coding (Corbin & Strauss, 2007) or analytic coding (Merriam, 2009) by grouping the open codes after careful reflection on the meaning of the initial open codes. This second round of coding enabled me to develop themes and categories from the coded data by grouping codes that were similar in meaning or fitted under a common umbrella term.

I planned to use a combination of values, emotions, and versus coding to analyze the data (Saldana, 2013) since my questions were designed to elicit the values, experiences, and beliefs of the research participants, which Bogdan and Biklen (2007) classify under situation codes. Although some of the codes used were provisional codes, that is, developed from the literature review before any field work started, I kept myself open during the entire data collection and analysis for the emergence of new codes from the data (Saldana, 2013). In this regard while examining the data, I decided to use different coding mechanism respecting the particular research question. For the question on students classroom experiences I decided to use emotional coding. According to Saldana (2013), “emotional codes label the emotions recalled and/or experienced by the participant or inferred by the researcher about the participant (p. 105) and are suitable to explore questions about intrapersonal experiences.

According to Saldana (2013) Value coding is applied "onto qualitative data that reflects a participants values, attitudes, and beliefs, representing his or her perspectives or worldview" (p. 110). Another coding scheme I used was versus coding. As I went through the data I realized the participants approached the science-religion interface in binary or dichotomous terms. Saldana (2013) posits that "versus codes identify in dichotomous or binary terms the individuals, groups. Social systems, organizations, phenomena, processes, concepts etc., in direct conflict with each other" and is appropriate for data sets that suggest strong conflicts.

The data was first coded on individual basis and then across cases. After the individual analysis, I performed cross-case synthesis (Merriam, 1998; Yin,2014) across the group to look for similarities and differences within and across individuals and for overarching themes, concepts or relationships.

Establishing Trustworthiness

The extent to which the qualitative researcher establishes credibility, transferability, dependability, and confirmability determines how trustworthy the research is (Lincoln & Guba, 1985). In the paragraphs that follow, I describe the methods I used to increase the trustworthiness of my case study, including maintaining a chain of evidence, using peer debriefing, member checking procedures, and confronting researcher bias.

Reliability and Validity

According to Bogdan and Biklen (2007) "qualitative researchers tend to view reliability as a fit between what they record as data and what actually occurs in the setting under study, rather than the literal consistency across different observations" (p. 40). Therefore, I tried as much as possible to present the record of the exact words of the

respondents by videotaping the interviews and real-time observations and providing dense evidence that will give the reader the possibility to form their own interpretation of the data.

Yin (2014) recommends documenting procedures followed and making as many steps operational as possible in order to achieve reliability. Merriam (2009) describes reliability as the extent to which the results are consistent with the data collected. To achieve reliability in this study, I asked the same basic questions to all the participants in the study and I provided a rich thick description of the different participants and the settings in which the interviews were conducted. I also documented each step of the research process and provided an "audit trail" (Guba and Lincoln, 1985; quoted in Merriam, 2009 p. 222) of the decisions, methods of analysis and why such were made during the study.

Internal validity was achieved through member checks; the findings arrived at from analyzing interview transcripts were provided for validation by the respondents (Maxwell, 2005; Merriam, 1998). Peer examination by colleagues and members of my dissertation committee was an additional strategy for ensuring internal validity (Merriam, 2009). Peer examination reduces possible influence of bias from the researcher. As someone with deep religious beliefs and with an interest in science, I may have brought certain biases to my reading of the data. However, participant validation and peer examination minimized the potential for bias. External validity was achieved by providing a rich thick description of the research setting and participants and selecting of typical samples (Merriam, 2009) of people with deep Christian believes who are also interested in science.

Finally, I ensured that internal validity was achieved through reflexivity-"the process of reflecting critically on the self as researcher, 'the human as instrument'" (Lincoln & Guba, 2000, p. 183, cited in Merriam, 2009). By making open my position as the researcher and clarifying the assumptions, experiences, worldview, and theoretical perspectives I bring into the study, readers will be able to judge how I arrived at certain conclusions from the evidences presented and form their own interpretations

Limitations of the study

Two sources of data (the participants self-reported position and approach, and the observed real-time managing of the tensions) are potentially limiting compared to multiple sources of data for triangulation purposes, that is, the conclusions drawn will not be as strong as those drawn from three or more sources. The reason why only two sources of data will be analyzed is because there are no potential documents to be analyzed. However, the use of multiple participants compensates for multiple sources of data.

Chapter Four

The Experiences and Resilience Strategies or Coping Mechanisms of People with Fundamental Christian Beliefs in the World of Science

Introduction

When students move from their home/real world culture into the culture of school science, they are most likely to experience cognitive tensions between the two worldviews if any meaningful learning is to take place (Aikenhead, 1999). However, such tensions are not confined only to the cognitive domain. The interaction between people's deep religious beliefs and scientific explanations can potentially produce effects beyond the cognitive conflicts that people experience, into the emotional, social, and even psychological (Lemke, 2000).

Students also encounter some form of hostility in their attempt to cross cultural borders into science. It is the hostility, and feeling of alienation that may deter some students from pursuing science studies (Celgie, 2013; Dodick, Dayan & Orion, 2010). I am certainly not taking the position that the interaction between science and religion will always lead to cognitive conflict, I wish to show where such conflicts arise, they are not merely cognitive, rather may produce other adverse effects.

It is interesting to note that although the interaction between people's deep religious beliefs and scientific explanations can potentially produce effects beyond the cognitive conflicts that people experience, the studies which have looked at how people manage the tensions that arise from these interactions have mostly focused on the cognitive domain, I elaborate on this later on in the chapter. The interconnected nature of students' academic life with other aspects makes it possible that what happens in the

classroom has potentials to reverberate in other domains of their life and vice versa. For example, religious beliefs of parents influence children's attitude towards evolution and the church culture in which children grow up exerts an influence on their view about evolution hence fundamentalist Christian students' acceptance of evolution could potentially create a rift in their family and other social relationships (Windslow, Shavar, and Scharmann, 2011). Hence the conflict between religious beliefs and scientific explanations extends beyond just the cognitive domain to the emotional, social, financial, and even psychological domains of people's lives.

Thus, it is important while examining the cognitive effects of these interactions to also, where possible, look at the emotional and social effects of these interaction for people with fundamental Christian beliefs. Such experiences can shed light on how to make our science classrooms a safe place for students with fundamental Christian beliefs by diminishing the non-cognitive adverse experiences they encounter in their border crossing endeavors. By so doing science educators may help increase the number of potential scientists from people of faith by reducing the number of those delineated from science because of their classroom experiences.

Another point of interest is to understand why students who may experience otherwise adverse effects in trying to cross the borders between their religious and scientific worldviews still succeed to maintain their pursuit of science related careers. In addition to collateral learning which students use to resolve the cognitive conflicts that arise between the religious beliefs and scientific explanations, it is imperative to know other techniques that students employ to help them maintain their pursuit of science related careers in spite of the potentially hazardous experiences they encounter when

crossing borders into the world of school science. Broadly speaking, I seek to answer the following questions: why do some students with fundamental Christian beliefs maintain their pursuit of science relate careers in spite of their negative experiences? What strategies, coping mechanisms, and support structures do they have in place that others may not? Answers to these questions can potentially inform science education practitioners on strategies that can help retain in the field of science, those students who, because of their beliefs, may withdraw from scientific pursuits.

This chapter seeks to answer the following overarching research question with the three subquestions to guide the research:

1. How do people with fundamental Christian beliefs manage to maintain their pursuit of science related careers in spite of the potential alienating experiences due to the conflicts that arise between their deep Christian beliefs and scientific explanations?

    - What are the emotional and identity-related experiences of people with fundamental Christian beliefs in the world of school science?

    - What coping mechanisms/resilience strategies do they employ to enable them traverse hazardous borders

    - What are the resources (social, cognitive, etc.) people appeal to, to help them manage the effects of such tensions and maintain their pursuit of science related careers?

Relevance of this chapter

Most of the studies that have looked at the conflict between science and religion have sought to examine how people resolved the tensions between their two worldviews, that is, they have all limited their attention to the cognitive domain. None so far has tried to examine the classroom or workplace experiences of people with fundamental Christian beliefs in the field of school science or the scientific enterprise. For example, Coll et al. (2013) investigated scientists' habits of mind in relation to the interaction between their science training and religious beliefs without looking at the work place experiences of the scientists.

Cordero (2007) examined the impact of scientific knowledge on worldviews just as Brickhouse et al. (2000) examined how students' view on the interaction between science and religion progressed in the duration of an astronomy course. Dagher and Boudjaoude (1997) explored how some university biology majors tried to accommodate the theory of biological evolution with their existing religious beliefs, without examining the classroom experiences of the students. Fish and Lucas (1998) investigated the beliefs about science and religion held by teachers and students.

Falcão (2008) looked at how religion played in the lives of two groups of life scientists, that is how their scientific training affected their views of religion and Falcão (2010) looked at the possibilities of settlement of the conflict between science and religion. Kose (2010) looked at how religious beliefs influenced students' attitude towards biological evolution. Taber and Billingsley (2011) looked at how secondary school students perceive the relationship between science and religion. Tang and Meitus (2003) presented a typology of how the conflicts between science and religion can be

resolved. Winslow et al. (2011) explored the perceptions of Christian biology-related majors' as relating to the conflicts between evolution and their religious beliefs.

Little or no attention has been given to the actual experiences, beyond the cognitive domain, and the strategies and resources used by the individuals in negotiating the borders between their religious and scientific worlds. The only literature that comes close to investigating students' border crossing experience, Costa (1995), comes from the broader border crossing literature, and even then, it doesn't describe the actual student experiences but instead categorized students according to the ease with which they crossed borders from their home culture into the culture of school science. This chapter fills a gap in the current knowledge of the science-religion interaction.

Chapter methodology

The data was examined, first, on an individual basis during which words or statements relating to classroom experiences, as reported by the participants, the strategies and resources they employed as identified by the researcher, were identified and labeled accordingly. Later, these labels were grouped into categories that encompassed the different labels while ensuring in some cases, to keep separate the cognitive and the emotional domains. The reason for this effort to maintain the emotional separate from the cognitive is because, since most of the previous studies had concentrated in the cognitive, blurring the lines between these two domains would have masked, to some extent, the very purpose of this chapter. For example in terms of the experiences I decided to keep emotional distress and mental distress/headache as separate categories instead of lumping both into one category of distress.

I will begin the report of this part of the study with four case studies of the experiences of different individuals and their coping mechanisms, and the resources they employed in the process of negotiating the borders between their religious and scientific worlds. These four cases were chosen because during data analysis, I realized these cases were typical of seven of the eight cases examined. After the individual case studies, I will provide a cross case analysis of the whole group including, where necessary, those cases which were not looked at on the individual level in this report.

George

George was a 23 year-old computer scientist who recently graduated from college and had been working full time for a few months at the time of the interview. He is an Immigrant from Cameroon but originally from Congo. He moved to the US as an adolescent with his two brothers and mother and completed his high school education in a suburban town in Maryland. George is very involved in his local church and doubles as both the leader of the church's media team and youth ministry. My interview with George took place at their home.

Classroom experiences

First, I notice that George experienced dissonance at the cognitive level which was expected due the conflicting schemata from the two worldviews as pointed out by the collateral learning theory. However these experiences go beyond mere cognitive to the different extents described below. George's experiences, although diverse could be grouped into two major categories: destabilization of faith and alienation.

Destabilization of faith

Georges classroom experiences caused a "shaking" or a destabilizing of his faith to a certain extent. Some science topics, according to George, generated more questions than he could provide answers, and even when he had answers from the Bible, in his own eyes these answers could not provide a sufficient counterweight in the face of the scientific arguments and evidences being put forth. To quote George, after certain science classes

> "at the end you go back with more questions and sometimes you don't, you think you don't have a solid foundation to your um [faith], and they have a scientific [evidence]; it sounds more robust than your um, Holy bible…so I was challenged in some um in some instances about my belief, Christianity, the existence of God, yeah"

Such experiences transcend the cognitive to the spiritual, where there is both a deconstruction and a reconstruction of one's faith. The robust nature of the scientific evidences George encountered in the classroom primarily caused George to question the foundation of his faith, and secondarily, in some instances, his faith and belief system. It is possible to infer that such a destabilizing of one's faith is sufficient in some instances to cause an abandonment of either one's faith or one's pursuit of science in favor of the other. When neither occurs, it is likely that the individual involved, like George, has confronted both schemata from the two worldviews and resolved in favor of one worldview. This is an example of what Jegede (1995) termed , secured collateral learning when the learner securely resolves the conflict between schemata from different

worldviews in favor of one, or is convinced of reasons to hold on to both. As George argued,

> You know it's like um, at one point you have to give a benefit of the doubt to either side. You are like okay, how did the two molecules come together? Who made those molecules? You know, at the end I rather, I have to believe God in the sense that I believe He has everything under control.

One possible interpretation here is that George views religion and science as providing different "layers" of explanation: God made the molecules and created the rules by which they bond (except when God creates a miracle), and science helps us understand those rules. However, I do not think he had this in mind because for other areas of potential reconciliation between science and religion, for example the explanations for moonlight and the rainbow where others sought to reconcile both worldviews; George still rejected the scientific explanations.

What George means by giving "the benefit of the doubt to both sides" is to be open-minded and ask important questions to oneself about the conflict in question. Although the questions George asks himself are themselves based on the assumption that there is a supernatural being who is working behind the scenes and has everything that takes place in the universe, known and unknown to mankind, under His control, they are nevertheless scientific and provide opportunities for deep learning. Such a belief about a superhuman agent is what some have termed belief about causation, which is a strong belief held by Pentecostals.

To conclude, this deconstruction and reconstruction of one's faith is not without further effects, in the case of George, it produced some form of alienation as we shall see. I do not mean to imply that the experience of alienation that students may feel in the science classroom is a direct result of a destabilization effect on their faith as result of the weightier scientific evidence as in the case of George. It is likely that one experiences one without the other, or experiences both irrespective of the other. However, in Georges case, it is very likely that the alienation felt is a direct consequence of the destabilization of his faith.

Alienation

By alienation I mean the perception of not feeling welcomed in the classroom due to the discomfort resulting from one's conflicting worldviews, in this case, the religious and the scientific. George reported feeling, in some cases, estranged during science lessons due to the contradictory nature of the schemata

> " there are topics that you even wished that you were not even in the classroom, in the sense that, because at the end you go back with more questions and sometimes you don't, you think you don't have a solid foundation to your um [faith], and they have a scientific [evidence]; it sounds more robust than your um, Holy Bible"

By describing his classroom experience from handling topics that were contradictory to his faith as a feeling of wishing he was not in the classroom, George gives us a picture of the "repellant" and alienating nature of the borders between his world of religious beliefs and the world of scientific knowledge making, it hazardous at least, and impossible at most. Such a hazardous border presents three possibilities for the student: abandon his religious beliefs and embrace science, abandon science and maintain

his religious beliefs, or maintain both. It is reasonable to ascertain that for a Christian with fundamental Christian beliefs, the first scenario is very unlikely since their religious beliefs determine what they accept and reject in life. This leaves us with the two last possibilities. Clearly for George, as expressed in the previous quote, "at the end I rather, I have to believe God in the sense that I believe He has everything under control".

To summarize, George experienced both a destabilization of his faith and an alienation from the science classroom. Destabilization of his faith was a result of the fact that he ask himself some hard questions, some for which he did not have any answers. Alienation was experienced during moments of controversy when he felt like "not being" in the classroom. While George was able to deconstruct and reconstruct his faith that was challenged, and maintain his pursuit of a science related career in spite of such feelings of alienation, it is reasonable to infer that others with a similar experience may have fallen on the wayside and abandoned the science classroom entirely. So what are the successful resilience strategies/coping mechanisms George used to maintain his pursuit of scientific career? The next section answers this question.

Resilience Strategies/ Coping Mechanisms

The hazardous nature of the conflicting schemata between people's religious and scientific worldviews forces them to develop certain coping mechanisms in order to maintain their pursuit of a science related career. In describing his classroom experiences and how he manages the tensions that arise between his two worldviews, George revealed several strategies, which could be grouped into two, that helped him navigate the borders. I discuss the two main strategies below:

Avoiding discussions/argument

George discussed using silence and avoidance of discussion or argument as a way of navigating the potentially hazardous experience of challenging the teacher's position on controversial topics. When asked how he reacted during controversial topics in the classroom, His response was,

> "it was totally a disbelief in the sense that okay I am just going to let the teacher talk because … I don't think with my argument I can challenge him to change his [mind], so I just like you know, fine, kind of like from avoiding discussion perspective."

His reaction of total disbelief and "just let the teacher talk" can be seen at the surface level as mere resignation. However, I see in it a strategy to avoid further exacerbating the hazardous border in order to maintain his already troubled sail across the tumultuous waters. By avoiding discussion, George also avoids the possibility of arguments from his teacher that may lead to further deconstruction of his faith and beliefs.

George's silence and avoiding discussion is clearly not because he agrees with the scientific perspective presented by the teacher but a way to avoid being convinced with the evidence the teacher presents but at the same time not ready to accept the scientific position. It is like a fighter avoiding a fight he knows he will lose, or refusing a fight because the reward is not worth the struggle. George intimates at the later by saying "I don't think with my argument I can challenge him to change his mind." By refusing to spend mental and emotional energy on what he thinks brings him no benefit, he reserves his energy to maintain his pursuit of a science related career.

Deferring understanding

Deferring of understanding is another subtle strategy George used to help him navigate the tumultuous science – religion interface. In some conflicting situations, George preferred to leave the schemata unresolved while giving the benefit of the doubt to his religious beliefs. Here, he doesn't reject scientific explanations in favor of His religious beliefs nor does he placed them side-by-side in unresolved conflict rather he temporarily "suspends" the need to fully understand the issues at stake albeit still leaning towards resolution in favor of his religious beliefs. In his own words,

> "I was not that disturbed like I um I have to find answers to all their questions else I am not sleeping, I was not... I was like okay, if I don't understand now, hopefully one day I will understand. I was not like, it did not really shake me to the point that I have to, some people can close themselves to find answers to those questions but I was not like that."

Deferring understanding to a later date enabled George, like in the case of silence and avoiding discussion, to diminish the experienced hazard resulting from the interactions of his two worldviews. However, unlike the previous strategy where he resolves this conflict in favor of his religious beliefs after giving the benefit of the doubt to both sides by asking the right questions, in this case he leans towards giving the benefit of the doubt to his religious beliefs but avoids, at the moment, the process of asking the right questions that leads to resolution. It is possible to infer two plausible reasons for this deferment; either because the extent of the conflict did not warrant urgent resolution as he intimates or because he did not think he had the resources whether cognitive or otherwise to help him resolve the conflict without further destabilizing his faith.

To summarize, George developed two main strategies to help him navigate the hazardous borders, namely, avoiding discussion and deferring understanding. George avoided arguments especially with his teachers on issues of conflict because to him it was going to be a waste of time and efforts. He also deferred understanding to a later date where he felt he did not have all it takes to fully understand the controversy at hand. Deferring understanding protected him from both mental and emotional stress.

Having looked at George's experiences and his resilience strategies/coping mechanisms, I will now turn my attention to the resources he used to help him navigate the borders between his fundamental Christian beliefs and scientific explanations.

Resources

By resources, I mean persons or groups of persons, materials, or activities which people employ consciously or unconsciously, in and out of the classroom, to help them navigate the borders between their world of fundamental Christian beliefs and the world of science. George employed two main resources to enable him navigate the religion/science border namely, extracurricular information sources and environmental support.

Extracurricular information sources

In explaining how he resolved the conflict between his religious beliefs and scientific explanations on the issue of the origin of species, George explained that,

> "It came to the point whether am I going to [ask myself], who is in control? Are the molecules controlling? Is science controlling? Because at the end we may have to trace back where, what's the origin of those molecules? There has to be a question answered. You raise one um, you can raise one thing and you still have

> questions so I better trust in God because I have experienced Him first through my[faith], He has never failed me, than trusting a molecule. I don't think I can give a benefit of doubt to molecules. So though there may be proofs, um and I think there was even one, one documentary, a Christian documentary that I watched about um I think they were able to give the date of, um through carbon dating they were able to give the date of the oldest dinosaur and the age of the earth. And they saw that the age of the earth, I forgot, they came to the conclusion that it could not be possible that man came from dinosaurs given the age of the earth and given the age of dinosaurs that there was such a contradiction, I think it is even online I can even give you the link so you can watch that."

George's response shows both the process he employs and resources which he uses to enable him resolve the conflict, in this case in favor of his religious beliefs. Our focus here, however, is the resource he employs, namely extracurricular materials, to help him resolve the conflict. His attempt to resolve this conflict on his own only led to the generation of further questions for which he could not provide any answers except to arrive at the conclusion of a "proof" from a documentary that the earth did not originate as science explains. It is reasonable to intimate that George's way of resolving this conflict, and the conclusion he arrives at doesn't stem from his knowledge of the Bible only but from what he learned from this video on the Christian Science perspectives on the origin of species. By citing and recommending this documentary, George betrays the influence it had not only on shaping his worldview but also in providing answers to the questions that arose in resolving the conflict between his worldviews. The conclusions he

couldn't arrive at on his own due to the endless questions arising when he tried to do so, were provided him by the documentary using scientific arguments.

Spiritual environment support

Another resource which George credits for his successful navigation of the science-religion cultural border is his spiritual environment, in this case both the church family and his immediate family in which they all subscribe to fundamental Christian beliefs,

> "I would say that I was pretty firm in the Lord, and I was I think at that stage, I was kind of a little bit mature in the Lord that I could not be personally swerved in one side or the other… but I think I'll give credit to the maturity and the environment in which I lived in, I was able to fight that well."

George credits his ability to have fought well to his "firmness in the Lord" which prevented him from choosing either his religious beliefs or scientific pursuits at the expense of the other, that is, "being swerved to one side or the other". In a follow up discussion to ascertain what he meant by his environment being credited with the ability to have navigated this cultural border, George explained:

> The Spiritual environment, in which I lived in, was a big part of my life. I was heavily active at church, youth group, prayer group, house fellowship.... I was going to church pretty much 4 or sometimes 5 times a week. At home, our values revolved around God and the application of what we learned at church. More importantly, this environment shaped me to have a personal experience with God that really helped me to have a personal connection with God.

I think it may be reasonable to suggest that without such an environment George would have chosen one worldview over the other. One could argue that there is no way George's environment helped him not to abandon science seeing that it leaned heavily towards his religious worldview. However, in this particular case, George acknowledges the possibility, had he not attain a suitable degree of spiritual maturity, to have been swerved either to the abandoning of his faith or his pursuit of scientific knowledge. Thus someone without the level of maturity George had attained could have interpreted their experience as a reason to denounce science.

On the other hand with maturity, like George's, comes the ability to selectively accept scientific knowledge while maintaining one's religious faith. Also, for fundamental Christians, their academic, financial, and social worlds are intricately wound with the spiritual in such a way that one's pursuits in the other domains derive strength from the spiritual. As I stated earlier in the review,

Religiosity supports student engagement and achievement (Liou et al., 2009, cited in Celgie, 2013) and acts as a source of resilience (Javanmard, 2013). In one study, African-American and Hispanic students who have strong religious beliefs and engage in church activities outperform their counterparts (Jeynes, 1999, cited in Celgie, 2013). Woolnough (1996) remarks that belief in a rational, personal Christian God encourages people to seek to understand the order in the world and that many past and current scientists find their religious faith a motivation for studying and gaining an understanding of the world around them.

To summarize, George employed two main resources in his quest to abate the effects of the hazardous experiences and maintain his pursuit of a science related career. He used extracurricular materials to help him arrive at his own conclusions regarding certain natural phenomena and credits the spiritual and moral support from his church environment as a resource that helped him navigate the hazardous boundary between his religious and scientific worlds.

Richard

Richard was a 25 year-oil chemical engineering student in a renowned university in South-Western Germany at the time of this interview, working towards completing his Bachelors. He too is originally from Cameroon where he did his elementary and secondary education before moving to Germany for university studies. Usually students from Cameroon (probably all foreign students) lose about two academic years after high school to learn the German language to a level where they can pursue university studies in the German language. The first year after high school is spent to attain the language level B1 in order to secure admission into a university, after admissions and obtaining visa to study in Germany, they spend the second year to obtain the language level C2 before they are allowed to begin proper course work in their respective fields.

In the sections that follow, I am going to discuss Richard's experiences in the world of school science, the resilience strategies/coping mechanisms he developed, and the resources he employed to help him navigate the science/religious beliefs cultural borders.

Experiences

Of all the research participants, Richard experienced the most hazardous borders from his world of fundamental Christian beliefs into the world of science. I discuss below some of his experiences.

Emotional Stress/Distress

The stress Richard experienced in the classroom as a result of conflicting schemata was beyond cognitive dissonance. In my opinion, his experience can be described as emotional stress, including a declination of his self-esteem, as a result of what he learned in the classroom which was totally different from what he had learned at home and in church. When Richard was asked what his experience was, he provided this narrative relating to the origin of species:

> "I was really disturbed, I was really disturbed because, I uh, … it really disturbed me , I was like uh, every day at home I get up in the morning and am reading this in the bible, I come to school[and I am told otherwise and] am like huh? I even, I remember when I came back home I looked at myself in the mirror, I'm like huh, this face you come from a monkey? (Laughter) and I've been to the zoo in Limbe and I've seen monkeys, so I told my mom."

It is obvious from the above description that Richard's classroom experience did not end in the walls of the classroom and was not something he could easily shake off once he was out of the classroom. His misunderstanding of the theory of evolution made him to view himself as a "direct" descendant of monkeys, leading to emotional distress. The trifold emphasis of being "really disturbed" intimates at the depth of the stress he

underwent, forcing him to reevaluate his physical looks in the mirror and contrasting them with those of the moneys he had seen in the city zoo.

Mental stress/Headache

Apart from the emotional stress experienced by Richard as a result of conflicting schemata, he also reported experiencing mental stress each time he did or attempted to resolve the conflict or to grasp a deeper understanding of the phenomenon in question. Talking about how the universe came into existence, Richard reported that

> He[God] spoke, but how it actually came to be from nothing, how did it form, what really took place, the process itself, then one can actually go mad [trying to understand it]. I mean, from my own experience, there are certain things that I don't really try to go deep into, because at the end of the day I'll spend hours thinking then I'll get a headache, yeah.

The mental stress/strain that may be required to arrive at an intellectual resolution of conflicting schemata from his opposing worldviews was beyond what Richard could endure resulting in physical headache, hence the refusal to delve deep in trying to understand the origin of the universe we live in. His fear of "going mad" shows how severe the mental distress he felt was. Such an experience can potentially alienate some people from pursuing scientific knowledge.

While I do not think he would have actually gone mad, I believe, from personal experience and as explained by other participants, one can become actually very mentally confused at times in trying to reconcile the Biblical and scientific perspectives on the origins of the universe and species. The reason for considering emotional distress as a

separate experience from mental distress is because some who did succeed to isolate their emotions from what they studied, still experienced this mental distress in trying to reconcile both worldviews.

In summary, apart from cognitive dissonance, Richard experienced both mental and emotional stress/distress as a consequence of conflicting schemata from his religious and scientific worlds. It is important to know why Richard, in spite, of the emotional and mental stress/strain still maintained his pursuit of a science related career. What are his resilience strategies/coping mechanisms which helped him to navigate the borders successfully?

Resilience Strategies/Coping mechanisms

Deferring understanding

Deferring understanding of some scientific explanations for certain natural phenomena is a strategy Richard employed to help him abate the effects of the tensions between such and his religious beliefs and to maintain his pursuit of a science related career. It some cases, when the scientific evidence outweighed his religious beliefs, Richard did not let such evidences displace his religious beliefs rather he deferred understanding until such a time he could have additional "valid information" to counter the scientific arguments. When asked why he did not give room for certain thoughts his response was:

> "it might take me too far, I think um, by then I didn't have any, uh, any valid information I could really refer to (uhuh), I... that this situation I will not think about it, I know that when I am growing up I will come across it anyhow. (uhuh) but if, yeah, yeah, that's the conclusion I came to."

In deferring understanding, Richard temporarily suspends resolution of the conflict by shutting his "mental gate" to information that will stimulate any attempt to resolving the conflict for which he thinks he is not adequately armed. It's like avoiding a war for which one is not adequately prepared and shunning all provocations to do so while maintaining a disposition to engage when one thinks the resources are readily available.

"Mental shutting"

In deferring understanding, as described above, one consciously suspends thinking of a particular subject because of the lack of adequate resources to resolve the conflict that arises between conflicting worldviews, until at such a time when one thinks he or she is mature enough or has the resources to resolve the issue. In "mental shutting" one arrives at a point where for some reason, even in spite of the available resources, one refuses to engage in any thought concerning the phenomenon. Richard does not only defer understanding but in some cases, he decides to shut his mind from scientific explanations that contradict his religious beliefs. Talking about the age of the earth, he recounts that:

> From my own belief and where my faith stands, as I earlier said, man always tries to put his position as the master and we can never understand certain things God created or calculating the age, moreover (sighs, and laughs cynically) I'm really (sighs) it's something that I don't really like going deep into it, I usually have funny thoughts of which I'm scared of, I'm really scared of …I think it might even offend God (laughs), I mean that, I stop having such thoughts I think when I was still 10 or 11, 11 or 12 years old, yeah when I moved to secondary school, I

was in a boarding school and then yeah…all these funny thoughts, by the time I reached form1, form 2, (shaking the head in disagreement) I stopped thinking because from a point of view , and this period I started being, I started appreciating more, this side and building my faith on it. The more I turned to the Bible the more all this (making the hand as to push something aside) I think I stopped thinking of it and I didn't even think to lighten up the thoughts of it again, yeah.

Natural phenomena for which Richard thinks is beyond the purview of science, causes him to shun thinking about such, especially when the scientific explanations contradict his religious beliefs. To him entertaining the scientific explanations may cause him to offend God, something he is not ready to do for fear of the consequences which may just be imaginary. The thoughts Richard described as funny and scary made him "stopped thinking of it and didn't even think to lighten up the thoughts of it again".

This "mental shutting" is different from parallel collateral learning in which conflicting schemata are placed side-by-side with minimum or no interaction in the sense that in mental shutting, severe cognitive dissonance causes one to completely shut out thoughts about the scientific explanations for a natural phenomenon or about the natural phenomenon itself. Here also, Richard is neither engaging in simultaneous, dependent, or secured collateral learning since he does not engage the scientific schema or allow any interaction with the religious schema. A plausible reason is, he may think that science is going beyond its boundary and taking the place of God contrary to the Biblical injunction that "The secret things belong to the Lord our God, but the things revealed belong to us and to our children forever, that we may follow all the words of this law" (Deuteronomy

29:29) since he earlier asserted that "we can never understand certain things God created" therefore science should not attempt providing explanations for these things which cannot be understood.

Playing school

Because schools hold students accountable for what they learn in the classroom through tests and other evaluations, some students with fundamental Christian beliefs who study science have found a way to play by the rules without being affected by what is learned in the classroom, what I term "playing school". By playing school students try to understand without personalizing or accepting the scientific explanations for certain natural phenomena when such are contradictory to their religious beliefs. They consciously refuse to construct their own understanding but try to take at face value what they are taught without any deep learning.

Playing school is very similar to Fatima's rule described by Larson (1995) in which students engage in a game where they memorize important aspects of science lessons for the purpose of examination without engaging in any meaningful learning.

Richard described how he played school by saying,

> "Like I said I take things that I can take, I learn them for learning sake and just to be informed and also pass exams, naturally, yeah (laughs). Yeah, but there are certain things I don't [accept], I just learn, I don't take into my spirit, I just keep, leave it like that, I don't really take it in, yeah."

Richard selects what he accepts as valid scientific knowledge. What he deems not valid scientific knowledge is learned at surface value for the purpose of examinations. By

refusing to accept and personalize the knowledge he spares himself any stress/distress that may result from deep learning which may displace some schemata from his religious worldview to make room for the scientific knowledge.

Recasting

Richard re-presented to himself scientific explanations that coincided with his religious beliefs as a form of divine revelation and an avenue to understand God's greatness revealed in his creation. By recasting scientific knowledge both as an avenue to understand God's creation, and as a form of divine revelation Richard mentally positioned himself in one world- the world of his religious beliefs- without the need to negotiate boundaries from one world into the other. In this case both science and religion serve the same purpose namely avenues for the creature to relate with the creator. As he puts it,

> "There are certain things I've just learned to, I mean, I just learn it and say okay, the archeologists and the scientist or whatever, this is what they've found. I won't, I don't take it in, I just learn about it but I don't take it in. But there are certain things especially in biology when we learn about the human body it makes me marvel, I mean about how God created us, man in particular. Yeah, there are certain things we neglect that we don't even know about that we are very ignorant of but when you start studying the anatomy and physiology of man, wow! You are just like wow, it's just wow! And with physics I used to marvel , I'm like (laughs) God surely came down and revealed certain things to man because I cannot believe a man would sit down and start thinking of something like that, things like relativity, calculating angle of refraction, with these mirrors, images

and so on and so forth. The whole stuff I'm just marveled, I'm just really marveled, yeah."

Scientific knowledge, according to Richard, is a mystery that the ordinary mind on its own cannot construct, but can only discover through divine revelation. Also, scientific knowledge reveals the greatness of God and the wisdom with which he created the human body. Such a recast, helps Richard overcome the notion some hold that it is not possible to hold strong religious beliefs and be a scientist. When I pressed him on this he responded by saying,

> "As a Christian, there are fundamental things I have read about in the Bible and then as a science student also, I mean what the bible talks about man, God's creation and other things; while studying science it makes me marvel, I mean how awesome God is. I mean there are certain things, and the way He revealed it to us, because as a normal human being, it will take a revelation to get up and start explaining atoms, nuclear fission or fusion, um, human digestion, the reactions that happen in the body… from my on point of view, any scientist who is a believer, any scientist who is a believer, he just appreciates God's creation, I mean, he's learning the how, it's possible to learn the how while leaving yourself open for God to reveal the hidden secrets of the creation. I think it's very possible. For me I think it's very possible."

The pursuit of science, in Richard's view is putting oneself in a position to receiving revelation from God about the hidden things of creation, things not explained in the Bible. One may then ask why Richard refuses to accept certain scientific explanations

that contradict his religious beliefs? The answer lies in the fact that he regards the Bible as the final authority in validating knowledge and the purview of science he has personally defined; these are those explanations that coincide with what the Bible teaches or elucidates things the Bible is not clear about, but which however do not contradict the Bible.

To summarize this section, to safely navigate the hazardous borders between his religious beliefs and scientific explanations, Richard developed several strategies which include deferring understanding, mental shutting, playing school, and recasting. In deferring understanding, he temporarily suspends resolution of the conflict until he has enough resources to arrive at a lasting resolution. In mental shutting, he completely blocks his mind from entertaining any thoughts about natural phenomena, especially the scientific explanations of such for fear that he will offend God or to avoid stressful thinking that leads to headache. In playing school, he learns scientific explanations which are contrary to his religious beliefs without deep understanding, for the sole purpose of passing exams. Finally in recasting, Richard re-position science as a form of divine revelation and a means to be enlightened about God's creation. In doing so, he mentally places both science and his religious beliefs in the same world thereby removing the need to cross borders.

Having looked at the experiences of Richard's and the strategies he developed to navigate the hazardous borders, I now discuss the resources he employed to help him cope with the challenges stemming from the conflicting schemata and maintain his pursuit of a science related career.

Resources

Three main resources which Richard employed, emerged in the course of the analysis of the data, they are parental support, peer support, and extracurricular information sources.

Parental Support

When Richard encountered rigorous challenges in the classroom as a result of the conflicting schemata from his religious and scientific worldviews, Parental support was one of the resources he employed to help him manage the conflict. In the case of the origin of species, where Richard seems to have faced the most severe tension, it was parental support and guidance that helped Richard to safely negotiate the hazardous border he encountered. Describing the particular incident, Richard explained that,

> "I remember quite vividly I went home that day and I told my mom about it... So I asked my mom that "mommy is it really true that we came from the chimpanzee or what?" Because I knew at that time that she gave birth to me but then I am going to school and they are teaching me (laughs) that I came from a monkey... She told me that what I am learning in school is what I have to learn and pass but these, "we are Christians, we are believers, so this, what the Bible has written is a final say. So whatever you learn in school there if it doesn't agree with the Bible then it is wrong." So yeah, for me that is it… then to crown it all when my dad came back from work later in the evening I asked him too, and he said "no, Adam and Eve are the first, Adam is the first man on earth, and Eve is the first woman", so it just [settled it] (showing hands as if to say final), yeah."

Although the severity of Richard's border crossing experience in this particular instant stemmed from his misunderstanding of the theory of evolution which he

misunderstood as implying he was a direct descendant of an ape, he engaged his parents to help bring clarity to the cognitive dissonance and emotional stress he was experiencing. It is clear from his statement that the conclusion he arrived at, in favor of his religious beliefs, was a result of both of his parents intervening to reinforce his inclinations.

As noted in an earlier quote of Richard's, although on his own he still struggled to accept the scientific explanations that he encountered in the classroom because of what he had learned at home and at church, his previous knowledge of the Bible's position on the matter was not sufficient to help him overcome the conflict. It needed two separate sessions with each of his parent to bring him to the point where the resolution of the conflict was settled in favor of his religious belief.

Peer Support

There is some evidence that peer support was another resource Richard employed in his management of the tension between his religious worldview and scientific explanations. Peers, both those who shared his fundamental religious beliefs and those who did not, deliberated on the issue out of the classroom and ended by encouraging each other to seek for a help out of the classroom. According to Richard, "Even before coming home I talked, spoke with my classmates. Though some of them were not believers, many of them by then, yeah, but some were like men, they will also ask".

We see here that his first line of social support in negotiating the borders were his classmates, some of who also suffered the same dissonance. Although it is clear that their support did not immediately help him to resolve the conflict, they did encourage him to seek for a lasting solution. Most likely those who shared the same beliefs as himself

made him realize he was not facing the challenge all by himself hence gaining some mental and emotional energy in facing the conflict. This leads us to the final resource Richard employed to help him maintain his pursuit of science related career.

Extracurricular information sources

Peer and parental support did not act as isolated resources to Richard in negotiating the hazardous borders between his religious and scientific worlds. Extracurricular information sources were a form of resource Richard used, through the direction of his parents, to resolve the conflict between his religious worldview and scientific explanations. Referring to the conflict between his religious beliefs and the scientific explanations for the origin of species, Richard describes how he came to resolving the conflict:

> I had story books, my dad had bought story books about King David, how he was a young man, about Adam and Eve too, the beginning, everything. I also had these story books about the early man and about dinosaurs. So I asked my mom that "mommy, is it really true that we came from the chimpanzee or what?" Because I knew at that time that she gave birth to me but then I am going to school and they are teaching me (laughs) that I came from a monkey. And my mom told me that "go and take that story book and then read it", and I read the story book. She, then sent me to the Bible now, then when I read it, it was just clear.

Although his parents would have spoken to him directly about their view on the contradiction he was facing, they did send him primarily to extracurricular materials he had at home for him to read before giving him their own opinion about the conflict

between his religious beliefs and scientific explanations. With the help of this resource and others previously mentioned, Richard was able to draw his own conclusions.

To summarize, Richard experienced a hazardous border crossing for which he developed several strategies to help him navigate his religion-science borders. These strategies developed worked hand in glove with the resources he employed that enabled him to maintain his pursuit of a science related career without falling on the wayside. These resources include peer support, parental support and extracurricular information sources.

Pauline

Pauline is a 28 year-old immigrant from Cameroon. She moved to the United States in 2010 with a post graduate diploma in microbiology. After working several part-time jobs she decided to enroll in a Bachelor in nursing program and was in her last but one semester at the time of the interview. She is a member of the worship team in her church where she plays the guitar and sometimes the keyboard or piano. Her father was one of the founding members of the ministry to which we both subscribe.

She was born into, and nurtured in the church environment which was very close knitted back home. It was not uncommon to find the children of the leaders oscillate between church, home and school, attending the numerous church meetings. Thus Pauline grew up in an intensely fundamentalist religious environment. She describes the effect of her upbringing on her attitude to life in the following words

> Oh it's that I was born in a Christian family , I was made this way since I was little. Sometime[ago], I was speaking with one of my friends and we were talking

about something completely[different], it was about marriage and you know compromises that people make, like they can get married to someone who is not really grounded in the word of God. I have trouble with that, like I can try (laughs), it's tough. And then he was telling me that it is because I was framed that way. I grew up in a family where my dad was a very deep man in the word of God and I cannot see any other serious believer that is not that way.

With such a radical outlook on life, one would have expected Pauline to have a very hazardous border crossing experience, however, as we shall see, she is one of those who had a comparatively smooth border crossing experience.

Experiences

Pauline is one of the research participants who had a relatively smooth border crossing experience into the world of school science. She succeeded to minimize the effects of the contradictions between her religious beliefs and scientific explanations. Her only hazardous experience beyond the normal cognitive dissonance was a feeling of alienation which I describe below.

Alienation

Pauline acknowledges that it is always a very difficult experience when she finds herself in situations that contradict her religious beliefs, and that she does everything to avoid such situations. However, in moments where she finds herself in such a situation unwittingly, her first reaction is to walk away or take a temporary break unless she is forced into a spot where she is asked to speak, in which case she will side with her religious beliefs. In her own words,

> it's very difficult. I always say, if I'm asked, I always say what I believe in. I always avoid, you know, finding myself involved with things that will be contradictory with what I learn from the bible…When I think about it, it scares me because I know that I would have to stand for my faith but I make everything to just [avoid discussion]…but usually if I'm not asked I just usually walk away or I just may be take a break from class.

It is possible to interpret her statement as a coping strategy rather than an alienating experience. However, I argue that it is both an alienating experience and a resilience strategy and will argue on the latter at a later time in this section. The fear of confrontation scares her away, to which her response is to walk away or take a break. Elsewhere she intimates to this alienating effect driving her towards what she terms practical science, where she doesn't have to deal with contradictory scientific explanations. Asked how it is possible for her to be a fundamental Christian believer and still be a scientist, she responded:

> One thing about being a scientist, I just think also that it depends because there is what I would refer to as practical science, like you are researching may be, something that you can see something that is, because all those theories are usually things, can say abstract ? Those things that you cannot really prove! Yeah, so I just think that I might not be able to be that kind of scientist but if it is something practical like studying an organism, um, you know, studying something that is real, I think that it's possible to be that kind of scientist without any problem and still not having any problem with your faith… now what I'm doing, we don't really deal with those kind of theories anymore, the only things

> which are may be contradicts my faith are other social issues. But about theories and all that, I have left it like almost since high school and my early years in college, some sciences just become so very practical.

It is reasonable to infer that, the alienation from science where she has to deal with explanations or theories that contradict her religious beliefs is part of the reason, if not the reason, she chose to pursue the "practical science" where she doesn't have to deal with such contradictions.

Like I mentioned earlier, although from Pauline's relatively stronger fundamental views one would have expected her to face a severely hazardous border crossing experience, she seems to have one of the smoothest of all the interviewees. Certainly this is not a result of mere chance but of well thought out strategies she implemented to ensure she did not have too much negative experiences. I now discuss some of the strategies she used to minimize the effects of the contradictions.

Resilience Strategies

Referencing/ attribution

One effective strategy used by Pauline to help abate the effects of the contradictions between her religious beliefs and scientific explanations was to consciously make sure she attributed the scientific explanations to the original author or source. By refusing to personalize or own scientific explanations that were contradictory to her belief, she avoided the mental stress which would have resulted. When asked how she succeeded to continue with Biology to the postgraduate level, her response was:

> They are asking me a question like "how did, you know, this specie happen?" I'll say that your book, this person, you know something about science that I like very

well? It's that you don't, I don't know the word to use exactly, you don't steal ideas without stating the people (laughs). **It just prevents you from making claims. You know that's one of the things that really helped me and,** because at a certain point, I remember when I was in high school I had that issue. I was like, I remember that question on evolution in biology actually asked and I was like, is it really right for me to answer this question? Then something just came to my mind that say that this, other questions in biology you can just write that this is what happens, this is what happens, but that specific question I remember writing that "this book says that this is what happened…". **It just gave me peace of mind,** that is what happened (emphasis mine).

Pauline explains the battle that was in her mind to respond to a question on evolution. To her, answering this question was equivalent to compromising her deeply held religious beliefs. To overcome this difficulty she developed her strategy to reference the book and its author while providing the correct scientific explanation. As such she refused to own or accept the contradictory explanation but rather attributed her explanation to others.

We see that while for some it may just be considered responding to a scientific question, for Pauline it was a question of the integrity of her faith and beliefs. It became an issue of right or wrong; owning the explanation and compromising one's faith in the process and have a troubled mind was the wrong thing to do hence her strategy of disowning the explanation which to her was the right thing, resulting to a "peace of mind". Therefore, attribution/referencing was a very successful strategy used by Pauline, to avoid the

hazards associated with cultural border crossing into the world of school science from her religious world.

Avoiding contradictory situations and arguments

To successfully navigate the cultural borders between her worlds of religious beliefs and scientific explanations, Pauline also developed a strategy of avoidance in which she consciously avoided being found in situations where she would have to reconcile the tensions between her religious beliefs and scientific explanations. In cases where she could not know beforehand whether there would be contradictions or not, when such occurred she preferred to walk away or take a temporary break, this time to avoid discussion or arguments. However, when she is put on the spot she doesn't hesitate to state her religious beliefs which she holds true unlike the scientific explanations which she already judged false if they do not coincide with her beliefs:

> I always avoid, you know, finding myself involved with things that will be contradictory with what I learn from the bible… but usually if I'm not asked I just usually walk away or I just may be take a break from class.

Disconnection

Another successful strategy used by Pauline to avoid the hazards of cultural border crossing is her emotional disconnection from what happens in class. Disconnection is different from mental shutting in that in mental shutting, one deliberately shuts out thoughts about a certain phenomenon while in disconnection, such thoughts may be given room but one succeeds to completely dissociate his or her emotions in dealing with the schema. By "isolating" her emotions from her classroom experiences, she creates for herself a safe space where others are allowed to hold their

opinions as she does hers. In her mind, scientific explanations that contradict her religious beliefs are just someone else's beliefs to which they have a right just like she does her religious beliefs. When asked about her emotional experiences as related to cultural border crossing in science she responded by saying,

> "Well everybody is allowed, I mean I personally believe, but I am sorry for those who don't believe what is right. But I just believe that everybody is permitted to believe whatever they want to believe so I don't get my emotions involved. I just state what is true and then "ma vie continue" as they say my life continues, yeah."

Having made up her mind that her religious beliefs are "what is true", she doesn't give room to entertain other "opinions" which she has already qualified as false. This attitude affords her to emotionally disconnect from whatever she learns. For example she describes an incident where she saw an article on the origin of species and became curious to know what it says but then succeeded to erect the mental/emotional barrier that helps her maintain her disconnect:

> At a certain point in time I remember I was really curious and I saw this article about, yeah, they have discovered new um, species from where human beings came from and I was really curious. I was like what kind of curiosity is this because, I know that is already false.

By entertaining and holding to the notion that scientific explanations on those contradictory topics are false, she creates a disconnection from any contradiction, therefore to any hazardous experience that may have ensued.

Self-talk

Self-talk is another strategy used by Pauline to enable her smooth border crossing experience and maintain her pursuit of scientific knowledge. In the classroom, when topics which are contradictory to her religious beliefs are being taught, Pauline resorts to self-talk as a way to prevent her mind from being affected by what the instructor is saying. In her own words, "I know it's not right. Sometimes I even say it, people around me can hear me, 'the Bible says no, God created us' and I just remind, repeat it to myself".

In addition to having made up her mind that the scientific explanations are wrong, she speaks to herself to remind herself of what she holds as truth. This self-coaching practice helped mitigate any negative effects that could have been created in situations where she could not avoid being there by walking away or taking a break from class, strategies she successfully used in other instances.

In summary, Pauline experienced a relatively smooth border crossing due to the fact that alienation was the only negative experience she reported to have had as a consequence of contradictory schemata. This experience, in spite of the fact that she holds very strong fundamental Christian views, might plausibly be attributed to the many effective strategies she developed to help her navigate the cultural borders. These strategies include referencing, avoidance, disconnection, and self-talk. In referencing, Pauline ensures that he doesn't own or personalize any scientific explanation she may have to give in areas where such explanations contradict her beliefs. By so doing, she is able to find "peace of mind".

In avoidance, Pauline does everything to avoid situations where scientific explanations contradict her religious beliefs; if she happens to find herself in such a situation, she rather walks away or takes a temporary break unless she is put on the spot to respond. In disconnection, Pauline disconnects her emotions from what she studies thereby creating a safe place where the reaction and comments of others cannot touch her. Finally in self-talk, in the course of contradictory lessons, Pauline talks to herself audibly, sometimes to the hearing of those around her, that what teacher or any other source of information is saying is wrong, that what the Bible says is the truth.

Ernest

Ernest was a 36 year-old man at the time of the interview. He was enrolled in a community College where he was taking the courses required to pursue a degree in aeronautics and space engineering. Before immigrating to the US from Cameroon, Ernest read physics at an English speaking university, after which he taught physics at the secondary school level. Although Ernest was brought up in a very religious environment, he did not become a fundamentalist Christian until he was an adult. At the time of the interview he was a leader in the church where he fellowshipped. A very detailed description of Ernest is given elsewhere in this report. I'll like us to look at his classroom experiences, strategies to minimize negative border crossing experience and the resources he employed in doing so.

Experiences

Alienation

Ernest hinted at experiencing alienation as a result of the conflict between his religious and scientific worldviews. When asked about his experiences in the science classroom, when what was taught ran contrary to his religious beliefs, his response was:

> I do not attach emotions to it because I have gotten to that point where I clearly make a fine line between science and the word of God. If you get to that point where you can make a fine line, you know nothing will disturb you; you know this is just for study purposes. With this I know I don't want to go further. Probably that's why I am not so inclined to the study of mankind or into the study of evolution because I don't want to get my mind messed up. So I better take something that is away from it, that keeps me grounded in my faith and helps me continue my course.

While Ernest did not attach emotions to what he encountered in the classroom, he hinted that the contradictions between his two worldviews is the reason he did not pursue further studies in areas like evolution which are contrary to his religious beliefs, why he kept away from such scientific knowledge that could "get [his] mind messed up". The fear of a "messed up mind" that is, having more questions than answers which could shake the foundations of his faith is the primary reason Ernest continued with physics where there are fewer possibilities of severe tension, and even then he chose to study applied or practical physics instead of theoretical physics or other branches of physics where he may have to deal with issues of the origins of the universe.

In the above statement of Ernest's, there are two potential experiences worth mentioning although the evidences for these are not as strong, it may be important to state here that potentially, Ernest could have experienced a destabilization of his faith, reason why he took "something that is away from [contradictions], that keeps me grounded in my faith and helps me continue my course". In addition to destabilization in his faith, his mention of avoiding "a messed up mind" hints at possible mental stress or confusion, which we saw earlier were some of George's and Richard's experiences.

It is also possible that emotional distress could be a potential negative experience for Ernest if he had not gotten to the point where he "draws a fine line between science and religion" in such a way as to not "attach emotions to it". By emphasizing "getting to the point" of separating his emotions from the contradictions between his worldviews Ernest suggests to us that at some earlier point the experience may have been emotional when he had not reached this point hence he had to expend some efforts to reach a point where he could avoid involving his emotions.

Resilience Strategies

Playing school

Playing school is one strategy used by Ernest to navigate the borders between his religious world and the scientific world. By playing school, he refuses to personalize or own scientific knowledge, but leans such without accepting the explanations. By differentiating what he learns for the purpose of passing exams and what he internalizes "deep in" him he reveals how he played school by writing "what the teacher wanted". In his own words,

> If I answer some science questions it might be that just to pass because that is what the teacher wanted. They cannot ask you about evolution in science, in biology in particular where they want you talk about how man evolved from an ape, you know all those stages, and you start talking about creation, you know. But you know deep in you that "this is my belief, this is what I belief but science is saying something else.

Clearly, playing school seems to be a strategy that enabled Ernest to successfully go through contradictory science courses without being affected, at least adversely, by the contradictory schemata presented.

Disconnection

By staying disconnected to what he learns, that is, a total emotional detachment from scientific explanations, Ernest was able to avoid the effects of cultural border crossing between his two worldviews. By staying detached, he creates a safe space for himself, both mentally and emotionally, within the science classroom where he is somehow insulated from the mental and emotional disturbance that others suffer from hazardous border crossing. He explained his disconnection strategy as follows:

> "I do not attach emotions to it because I have gotten to that point where I clearly make a fine line between science and the word of God. If you get to that point where you can make a fine line, you know, nothing will disturb you, you know this is just for study purposes."

Clearly, as Ernest describes it, disconnection does not just happen by chance; it takes some efforts on the part of the individual to get to such a point where one can

completely detach his or her emotions from what is studied in the classroom, especially when it stands contrary to one's religious beliefs. Building "a fine line between science and the word of God" makes it possible to avoid emotional and mental disturbance, however, it takes the expertise of being able to "know [what] is just for study purposes" and what has to extend to life out of the walls of the science classroom. In his opinion,

> I just wish that people should get to that place, especially Christians, where they can draw a fine line between science and their religion. So that so they don't get messed up, they don't get confused about what is going on, because if you can attain to that point, you know, I think that is the place you know that most Christians they just have to.

Once people get this to place of total disconnect, then they can study science without experiencing the negatives, for those who hold fundamental beliefs.

Avoidance

I mentioned earlier on in this report that sometimes it may be difficult to distinguish the experience of alienation and the strategy of avoidance as both usually seem mutually embedded. However, one is a direct cause of the other in that the feeling of alienation may lead to the strategy of avoidance. Nevertheless, avoidance is not an effect of alienation alone, other negative experiences like mental or emotional distress or confusion may produce avoidance as seen in the cases of George and Richard. Here, Ernest intimates that avoidance is a strategy to prevent both confusion, what he terms a messed-up mind, and destabilization of faith. As he explained,

> ... With this I know I don't want to go further. Probably that's why I am not so inclined to the study of mankind or into the study of evolution because I don't want to get my mind messed up. So I better take something that is away from it, that keeps me grounded in my faith and helps me continue my course.

Without this avoidance, there could be "a mind that is messed up" and a faith that is "ungrounded", that is, destabilized and therefore not being able to maintain the course of pursuing a career in the sciences.

In summary, Ernest developed strategies, not just to abate the negative experiences in border crossing, but to a large extent to completely avoid them. Ernest developed three main strategies to combat the hazardous border crossing experience. These strategies are playing school, disconnection, and avoidance. In playing school, Ernest refuses to accept, own, or personal scientific explanations but uses such for examination purposes only. By so doing, learning is done at the very surface or superficial level thereby avoiding hazardous border crossing.

In the strategy of disconnection, Ernest completely detached his emotions from what he studied so as to create a safe place where he is shielded from the effects of border crossing. And finally in the strategy of avoidance, he deliberately chose to pursue a course of study that has little or no contradictions between his religious beliefs and scientific explanations. I now look at the resources Ernest employed in negotiating the hazardous borders between his world of religious beliefs and the world of science.

Resources

Knowledge of Role Models

Knowledge of role models, that is, others with fundamental Christian beliefs who have, or are succeeding in the field of science can be a source of encouragement and stay power to those still navigating the tumultuous waters of the religion-science interface. When asked how Ernest succeeded to maintain his pursuit of science in spite of the contradictions to his religious beliefs, one of the explanations he gave is,

> I do not think, I do not believe that science, in anyway, should affect our belief in our religion or our belief in the word of God, because if you look for instance, there are many men of God [fundamental Christian preachers], mighty men of God that were science inclined. We know of papa Adeboye, he is a mathematician, an applied mathematician, he is doing well in the word of God. There is this, which other man of God again, Dr. Zacharias Fomum (DSc.), he was a chemist; he was still a man of God you know. Those things did not influence, you know, their belief in God. It never made them to rethink or to doubt what the bible tells them. So I believe that the word of God stands …you are a pastor, and you are doing science so when I look at all these things it encourages me a lot. Because in time past people just felt people who were pastors, you know, they were not really academically grounded. You see that a lot of the, many of the men of God that are preaching today they are doing vitally well. And even those in the past you know, they were mathematicians, physicists, chemists, it really encourages you.

Ernest's knowledge of these scientists, past and present, who held fundamental Christian beliefs but who were also preachers of the fundamentalist Gospel was a source of encouragement to him. Surely he derived some mental energy to maintain his pursuit by knowing that others in the past have trod the hazardous path he now treads, and that there are other contemporaries treading the same path he is treading. In a sense it's the positive attitude of saying to oneself, "if these people can do it, so can I. I need not give up" that prompted Ernest to cite these fundamentalist Christian scientists whom he was aware of.

Across the cases

In this section of across cases analysis, I will discuss both the cases looked at in-depth in the previous section as well as some of the cases that were not discussed. I will discuss both the similarities and the differences in the different cases that were investigated in the course of this study, highlighting both their particularities and the commonalities between them.

Ubiquitous Emotional distress

The very first thing that emerges is that most all the participants did experience or potentially experienced some form of emotional distress. As discussed, those for whom this emotional distress was diminished are those who developed very effective strategies prior to or as an immediate reaction to the interaction of the two worldviews. For example, only Richard experienced severe emotional and mental distress unlike the others who were able to significantly abate the level of emotional distress felt. It is possible that the difference in the spiritual and social maturity, and classroom environments and other unique factors I am not able to identify may account for the difference in their emotional experience in relation to conflicting schemata.

Varied experiences

The other classroom experiences of the participants were somehow different, both in the type and extent of the hazards encountered in their border crossing experiences. For example, in terms of similar experiences, we saw that George, Pauline, and Ernest all experienced alienation to one degree or another. Richard on the other hand did not experience any form of alienation. Alienation was also the only significant negative experience of Pauline and Ernest. In terms of the differences, only George experienced a significant destabilization in his faith although he was successful to regain his stability. However, the different strategies developed by each one may account for the disparity in their classroom experiences as I discuss in the following paragraph.

Intersection of strategies

Avoidance in its different shades seems to have been a very common and effective strategy intersecting most of the participants. George, Pauline, and Ernest all developed and employed the strategy of avoidance. George avoided discussions or arguments on contradictory topics while Pauline and Ernest both avoided contradictory situations all together. Richard did not develop any strategy of avoidance, a plausible reason why he had the most severe negative border crossing experience.

While George only avoided discussion, Pauline and Ernest did their best to avoid situations that were contradictory, a plausible reason why they did not experience the destabilization in their faith unlike George. In addition to avoidance, Pauline and Ernest developed and employed a strategy which George and Richard did not develop, namely disconnection. The strategy to detach one's emotions from the classroom contradictions to one's faith seems to have shielded both Ernest and Pauline from the additional negative experiences of both George and Richard.

Unlike Ernest and Pauline, George and Richard also had an additional strategy of deferring understanding. To defer understanding means they first of all gave room for a negative experience which when not solved, they decided to defer understanding without totally rejecting the scientific explanation. This deferring understanding may have put them in a situation of uncertainty, another plausible reason for their additional negative experiences.

Another strategy that was common among the participants including those not discussed here is the strategy of recasting where individuals recast science as a form of divine revelation and a means to better understand the creator through his creation. This strategy was employed by Richard, Victoria, Michael, Debby, and Eve. Playing school was another common strategy employed by many of the participants. Richard, Ernest, Michael, Debby, Victoria, and Yves all employed this strategy to help them navigate the cultural borders.

Some unique strategies

In terms of strategies that were unique to individuals, mental shutting was a strategy unique to Richard. This may be due to the severity of his border crossing experience which led him to develop this strategy to protect himself. On the other hand, one may argue that it is the ineffectiveness of this strategy that led to severity of his border crossing experience. I argue that it is likely the former since the resources he employed after his experience led to the development of this strategy to avoid further damage. The strategy of referencing every scientific explanation which she provided in response to examination questions was also unique to Pauline.

Other strategies like switching off and filtering were also noticed as used by other participants. In switching off, an individual deliberately switches off attention so as to intentionally ignore what is being said. Filtering is selective acceptance of scientific knowledge based on one's religious conviction. Here, the individual immediately rejects what does not align with his or her religious faith without consideration for any evidence or weight of argument.

Two classes of strategies

The strategies used by all the participants can be classified into two broad groups, namely strategies of prevention and strategies of counteraction. Strategies of prevention are those developed by individuals in advance to experiencing any tension, that is, these strategies were put in place to prevent or minimize negative experiences before they were felt by the individuals. These strategies of prevention include, disconnection, avoidance, recasting, and playing school. On the other hand, the strategies of counteraction are those developed as a result of negative experiences the individuals had. These strategies of counteraction include "mental shutting", deferring understanding, self-talk, and referencing. Those who had more of strategies of prevention had a less hazardous border crossing unlike those who had more of strategies of counteraction who experienced a more severe border crossing.

Variability in resources

Finally in terms of resources employed, only Pauline did not acknowledge using any resource nor could I find any while examining her data. The primary reason for this absence of resources in her data, I suppose, is because the family and environmental

support was so nested into her everyday life that she may not have taken conscious note. For example, a good number of the leaders of the Church she grew up in were University professors in the sciences, who may have acted as role models to her without her acknowledging it. A second probable reason for Pauline not making mention of any resources is because the strategies she put it place were so effective to prevent any significant hazard, hence there was no need to employ any other resources.

George and Richard used extracurricular information sources to enable them resolve the contradictions faced. George, Richard, and Ernest all employed environmental support to help then navigate the borders. George's environmental support came in the form of spiritual support from his family and church environment. Richard's environmental support came in the form of parental support and peer support. Ernest's environmental support came in the form of knowledge of role models, those with fundamental Christian beliefs who are also scientists. This form of environmental support as a resource was also used by Victoria and Michael who both reported that knowledge of, and contact with others with fundamental Christian beliefs who were in the field of science were a source of encouragement to stay the course in the pursuit of a science related career.

I summarize the different experiences, coping mechanisms/resilience strategies, and the different resources in the table that follows.

Table 2: Summary of participants' experiences, strategies and resources

Participant	Experiences	Strategies	Resources
George	Alienation Destabilization of faith	Avoidance Deferring understanding	Extracurricular materials Social support-spiritual environment
Richard	Emotional stress Mental stress/headache	Deferring - understanding Mental shutting Playing school recasting	Social support-parent Social support-peers Extracurricular activities
Pauline	Alienation	Referencing Avoidance Disconnection Self-talk	None
Ernest	Alienation	Playing school Disconnection Avoidance	Knowledge of role models
Others	Feeling disrespected Feeling insulted	Switching off Filtering	Contact with role models Prayer

Discussion

In this section, I synthesize the findings of the experiences, strategies, and resources of people with fundamental Christian beliefs in the science classroom specifically, during controversial topics. I discuss what experiences stood out among the research participants, which strategies seemed to have been very effective in mitigating the hazardous border crossing experience, and what conclusions we can draw from this study respecting the relationship between science and religion. Finally, I discuss the findings in relation with previous literature on cultural border crossing.

A need for escape

As we see, students with religious beliefs all seek some form of escape from the emotional and mental distress that results from conflicting schemata and therefore developed various escape routes as described above. Irrespective of the degree of effectiveness of the different routes, teachers may need to be aware that their students will sometimes seek for escape in other to avoid emotional or mental stress, and therefore assist them where possible to ride their escape routes or redirect them to use more effective or beneficial routes. For example, a student whose escape route is to avoid discussions and arguments on these sensitive topics or avoid the lesson entirely, may be redirected to and encouraged to disconnect their emotions from the lesson while trying to understand what is being thought without feeling compelled to accept the scientific explanations since understanding does not necessitate acceptance (Southerland et al, 2001).

Most effective strategy

Though there were a variety of strategies, those who developed and implemented the strategies of disconnection were able to neutralize, or at least minimize, any emotional or mental distress they could have felt. Pauline, Ernest, Yves, and Victoria are all examples of those who implemented disconnection and reported none or very minimal emotional and mental distress. Teachers can play a role in helping their students establish this disconnection by discussing with their students beforehand, the possible effect of the conflicting schemata and the need to try to separate their emotions from what is being learnt at the moment.

Effects of negative stereotypes

A recent "stereotype threat" study showed that negative stereotyping of Christian believers causes them to underperform in and disidentify with science (Rios et al., 2015). According to the authors, "Christians' awareness of the negative societal stereotypes about their group's scientific competence may be partially responsible for the underperformance and underrepresentation of Christians in scientific fields" (Rios et al, 2015; p. 959). We speculate that the strong negative emotions experienced by fundamentalist Christians in the science classroom may arise in part because of their consciousness of these negative stereotypes; the stressful emotions may mediate between the stereotype threat and the impaired performance. In trying to avoid such negative experiences, fundamental Christian believers may be less likely to "master" those controversial topics which may lead to underperformance. The strategy of avoidance that many employed may be a result of their consciousness of these stereotypes.

Traces of inseparableness

As argued earlier in the review of the literature in chapter two, the separation between science and religion seems to be an artificial one. In this study, we saw how some participants recast science as a form of divine revelation, and a means to understand the creator through the creation, in the same way Woolnough (1996) remarked that belief in a rational, personal Christian God encourages people to seek to understand the order in the world and that many past and current scientists find their religious faith a motivation for studying and gaining an understanding of the world around them, as we saw was the case with Micheal, Victoria, Richard, and Yves.

In a similar vein, it has been argued that religion contributes to acquisition of social capital and academic motivation (Antrop-Gonzalez et al., 2007; Barrett, 2010, cited in Celgie, 2013), and religious beliefs are a form of cultural capital for some students (Celgie, 2013). We saw this cultural capital in the form of environmental support, and role models who were a source of motivation to some of the participants in maintaining their pursuit of academic careers. Some of them attributed their resilience to the fact that they could pray during seasons of hazardous border crossing to find relief from the stress they felt.

I also showed that people gave very valid scientific reasons for which they rejected scientific knowledge in favor of their religious beliefs. Also, several of them put forth scientific arguments to validate their religious beliefs. This is in line with Cobern's (2000) argument that separation of knowledge and belief does not stand within a constructivist framework of learning. There are rational reasons behind people's knowledge and people's beliefs. The focus should shift from separation of knowledge

and belief to reasons behind both people's knowledge and people's beliefs, therefore students should be encouraged to explain their choices of either acceptance or rejection of scientific explanation without fear of being penalized.

Implications

In this section I discuss the potential implications of the experiences, strategies, and resources of people with fundamental Christian beliefs on science teaching and learning, curriculum, and policy.

Implications for instruction

Reinforcing support

One thing that is eminent in terms of resources is that every one of the participants seems to have benefitted from some form of support, whether they were conscious of it or not, in their efforts to negotiate the borders between their worldviews. We saw the influence that role models played in helping some navigate the borders. Teachers could bolster this avenue of support by getting their students in contact with devout fundamental Christian believers who are also successful scientists. This could be in the form of visiting experts on these topics for the entire classroom or some form of after school programs for the group of students with fundamental Christian beliefs.

Students can also be encouraged to form support groups where they share their experiences, with classmates or younger school mates, and how they negotiated the borders. Such peer support groups will be a way for these students to share not just their experience but also their valuable strategies and resources with each other. This will help bolster the support students have in helping them navigate cultural borders.

Implications for curriculum

Science teaching has been largely devoid of the history of science and of those who have made valuable contributions to the field. Knowledge of role models was a source of motivation for some students with fundamental Christian beliefs pursuing careers in science, therefore, a brief history of scientists who have made valuable contributions to the field of science who also held fundamental Christian beliefs, if included in the science curriculum, at least as additional materials which students can readily consult, can go a long way to act as a source of motivation for students with fundamental Christian beliefs.

Several participants mentioned that having read about scientists who were also Christians acted as a source of encouragement to them even though they had not personally met one. Personally, having read about the role of religion in the lives of science's greats like Newton, Faraday, Boyle, Pascal and others was a strong motivating factor for me even before becoming part of a Christian community where many of our pastors doubled as University professors in various fields of science.

Implications for policy

Just as there is dropout prevention for at risk students in general, there could be a science dropout prevention tailored specifically for students who are interested in science but whose religious beliefs places them at risk of dropout due to hazardous border crossing. Teachers can be trained to specifically assist students early on by equipping them with strategies and resources they need before they encounter scientific materials which may turn them away from science. Contrary to the notion that religious beliefs held by people curtails the supply of scientists, and therefore a detriment to national productivity (Granger & Price, 2007), I think with adequate attention given to this

specific group, we can retain some who would otherwise drop out from science. It is not enough to advocate for science literacy for all if we cannot put in place policies that can help prevent people from dropping out of science and consequently augmenting the supply of scientists.

Further Research

There were glimpses of evidences throughout this study that people's classroom experiences may have had an influence on their choices of scientific career. A follow-up investigation into the relationship between people's classroom experience and their eventual choice of scientific career will contribute to the body of knowledge that can be useful to helping guide individuals in the world of school science.

It will also be interesting to conduct a similar study as the one reported in this chapter in an actual classroom setting where students with fundamental Christian beliefs are observed in a science classroom on both topics which are controversial and those which are not to draw a comparison between the two situations. A third line of study will be an experimental study in which the effects of role models on people's attitude to the science-religion conflict can be gauged.

Chapter Five

The Shifting, Contextual Nature of the Interaction between Fundamental Christian Beliefs and Scientific Explanations

The current literature on the interaction of people's religious beliefs and scientific explanations has mostly placed people into categories as to how they manage the tensions that arise between their religious beliefs and scientific explanations. Only one of the few available studies has intimated to the contextual nature of the way people manage the tensions between their religious and scientific worldviews, although they too ended up categorizing the respondents. This chapter presents findings that show the contrary, that is, people do not squarely fit into any one category as to the way they manage the interactions between their fundamental Christian beliefs and scientific explanations.

Understanding this shifting contextual nature of the scientific explanations/religious beliefs interaction is important both to science education practitioners and researchers. First this result is important to teachers in that, those who hold very strong religious beliefs are not necessarily hostile towards scientific explanations but need to be engaged in intellectually challenging debates and discussions where they can be led to see the inadequacy of some of the arguments. More importantly, teachers may need to pay more attention to the arguments and reasons these individuals put forth instead to just the way they manage the tension. Second, researchers need to start paying more attention to the reasons and arguments individuals put forth in their approach to negotiating the differences between their religious and scientific worldviews instead of trying to categorize individuals. When we understand the reasons for this shifting contextual nature of the interaction between scientific explanations and religious

beliefs we can ask important questions regarding how both the curriculum and instruction can be modified to engage these students in the science classroom.

The research question I seek to answer in this chapter is:

How do people with fundamental Christian beliefs and with an inclination for science view the roles of both science and the Bible in their lives? How do they manage the tensions that arise between their religious and scientific worldviews?

- What justifications do people provide pertaining to their approach to managing the tensions between their fundamental Christian beliefs and scientific explanations?

- Can people be squarely placed in different categories as to how they manage the tensions that arise between their deep Christian beliefs and scientific explanations?

I examine the data through the categories that have been commonly used in the literature and through the lens of Jegede's collateral learning theory as described in chapter three on methodology. Earlier in chapter two on the review of the literature, I offered a synthesis on how the current categorization in the literature fits with Jegede's collateral learning theory by examining those categories through the lens of the theory.

The rest of this chapter will present the findings firstly on an individual case study basis, then on a cross-case basis. I will present how the individual manages the tensions between his/her scientific and religious worldviews then present the reasons/ justifications they put forth regarding their approach. After presenting the findings on the

individual case level, I will then present a cross-case analysis of the results to bring out possible general approaches on how this group of people manages the tensions, their common justifications, and the nuances between them. I will end the chapter by discussing the implications of the findings on science education classroom instruction and research.

Individual Case Results

I will begin by giving a description of each research participant, what their view of science and religion is, and the roles each of these plays in their lives. I will then present the findings by describing how they manage the tensions. After I have presented each individual case, I will then present a cross-case analysis of the individuals.

Ernest

Ernest moved to the Unites States in 2010 as an adult in his early 30's and has been living here since then. At the time of the interview, Ernest was enrolled in a community college, taking engineering course to pursue a degree in aeronautics engineering. He is a member of the honors society of his school despite the fact that he currently works as a geriatric nursing assistant alongside his studies. Ernest is a member of a Pentecostal church that emphasizes personal holiness and the pursuit of academic excellence. The president of the church whose headquarters is in Africa was himself an Organic chemist who held a DSc.

A committed member of the small congregation of about 45 members, Ernest involves himself in many of the church's departments like picking up church members on Sunday mornings who do not have a ride to church, sometimes using the church Van and

other times using his own private car. I had the opportunity of observing Ernest lead a Bible study class on a Sunday morning in his church during which he emphasized on living according to the Word of God, and making the greatest commitment to service in His house. My interview with Ernest lasted for about an hour and short follow-up interviews were also conducted where I needed clarification on certain things he said during the first interview. The first interview was videotaped and transcribed verbatim for analysis.

Ernest and the Bible

How does Ernest perceive the role of the Bible in His life? It is possible that religious beliefs are an integral part of the family culture for some people and the Bible provides the guide for their cultural values. In Ernest's case, his religious beliefs are a part of his family culture as he explained,

> "I believe that the Bible for me is like a book of reference, because I grew up in a Christian faith, my parents, from childhood, were Christians, though they were not Pentecostal Christians at first. But when my mother believed, she gave her life to Jesus, she was always there guiding me, and sending me back to the Bible to read from the Bible because it is a book of life, so I believe that there is a lot in the Bible, all about life and godliness is all in the Bible, the Bible is just like em, gives us directions, you know, on the right path to take, so it plays a very important role in my life"

His personal relationships are a part of his religious beliefs' support structure. This means when such a student as Ernest comes into the classroom, he comes with his religious beliefs as part of the lens through which he will view whatever new

explanations he encounters in the classroom. To Ernest the Bible doesn't just provide a lens through which he sees and interprets other things, it provides a standard by which the relevance and usefulness of new knowledge is measured. The Bible provides the skeleton of the cognitive structure into which new knowledge and explanations fit, and new explanations are rejected when they do not conform to this skeletal structure of biblical precepts and explanations. As he puts it,

> "when I go there [to the bible] and I see those things that I understand how they are, then I come [to the science classroom] and get another explanation about it, you know, I don't bother much about the other explanation, because I know already that from my reference book [the Bible] I already had what I had, I have already learned what I have to know, you know"

One important criterion I established for the participants in this study is that individuals should have deep Christian beliefs and embrace the Bible as the inerrant word of God. This criterion was fulfilled in Ernest's case due to personal knowledge of him, the observation I did at his place of worship, and now the interview. When asked what role the Bible plays in his life Ernest discussed the importance of the Bible to him as an individual in guiding his decisions and giving him directions in life, and the choices he makes. As he puts it, "…I believe that there is a lot in the Bible, all about life and godliness is all in the Bible, the Bible is just like em, gives us directions, you know, on the right path to take, so it plays a very important role in my life…"

He also believes the Bible to be not just an ordinary book written by men, but a book written under inspiration from God. He even goes further to refer to the Bible as

what God has written: “God gave men inspiration and they wrote the Bible… so the Bible is a very good book and plays a very important part in my life… what God has written in the Bible…”

Furthermore, Ernest doesn’t just see the Bible as an important book to guide him and enable him to make good choices in life. He believes the Bible is perfect and what is written therein as an everlasting statute. In his own words, “…But the word of God is perfect. Those are the differences you know,(laughs), the word of God is perfect, it stands forever you know…”. With such a perspective of, and attachment to the Bible, it warrants an inference that whatever comes as contrary to what Ernest believes is a Biblical position will be met with doubt and possible resistance. Ernest is a perfect example of a student with deep Christian beliefs.

Ernest and science

How does Ernest perceive the role of science in his life? Ernest believes that science is good, important, and relevant to his daily living, but situates relevance mostly to understanding the natural environment. To him, his religion is very personal; science, he embraces at a distance. Science helps him relate with his natural and social environment but does not influence his personal decisions and choices as seen in this series of statements made at different points in the interview:

> “…well science is good. Physics in particular because physics relates directly to the environment… So science, I in particular, I appreciate it very much especially physics…I embrace science you know, just the way it is, I do not give room for science to conflict with my religion. You know, I study science you know to understand more about how things happen around us but that doesn't

affect the ground work I had had on my religion… apart from that I embrace science, I love science, I love the discoveries that are being, the new stuffs you know"

Ernest views science as a useful tool to explaining some apparently supernatural phenomenon. Talking with excitement about how science may sometimes explain happenings that Ernest had been made to think needed supernatural powers for their occurrence, Ernest explained how using the concept of atmospheric pressure he had demonstrated in a lesson the same phenomenon which had been described to him during his childhood days as pure magic. He acknowledged that his lack of scientific knowledge had caused him to believe that the magicians had powers to command water to start flowing or stop flowing from a pierced can. Science demystified a heretofore supernatural phenomenon. While Ernest uses his knowledge of physics to explain the apparently supernatural demonstration he witnessed in his elementary classroom, he still believes there is a supernatural to which science has no access and for which it cannot provide any explanations as seen in the following argument, in this case instant supernatural healing which he seems to have witnessed:

"How can science explain, okay, how can science explain that somebody can just see you and tell you everything about your life? How can science explain, I know we also have you know, the other side (referring to psychics) but science cannot explain that. How can science explain that somebody that has been blind for forty years, thirty years, a man of God preaches over his life and he gets his sight. Science will want to take him through an operation and they are not even sure if

you are going to regain your sight. So there are lots of things that science cannot explain, that the scientists themselves cannot explain."

Thus, to Ernest science is useful, relevant and provides explanations of some natural phenomena that we could get through no other means. However, he also views science as having boundaries, with certain domains of supernatural phenomena science has no access to.

Having provided a detailed portrait of Ernest, his relationship with the Bible and with science, in the section that follows, I look at how he manages the tensions that arise between his fundamental Christian beliefs and scientific explanations.

How Ernest Manages the Tensions between his Beliefs and Science.

Ernest used different approaches to resolve the tensions that arose between his religious and scientific worldviews depending on the conflicting schemata at any particular instance as we shall see below.

Compartmentalization of Science and Religion

One approach Ernest uses to manage the possible tension between his fundamental Christian beliefs and scientific explanations is that he compartmentalizes science and religion, especially in areas that he finds contradictory. For example when asked as to how he manages the conflict between his religious beliefs and scientific explanations he responded by saying, "…I embrace science, you know, just the way it is, I do not give room for science to conflict with my religion." Here, Ernest appears to see the world of science and the world of religion as two separate worlds which do not interact with each other. He sees a clear dichotomy between his science and religious worlds, which if allowed to come in contact, may result in conflict. Therefore, he puts

them apart to avoid "giving room for science to conflict with my religion". Hence the conflict between science and religion occurs only when an individual allows the conflict, or makes it possible for there to be such a conflict. Ernest appears to create a safe space where he only interacts with schemata from one worldview at a time without interference from the other worldview. He continued,

> "I make the distinction between studying science and studying the word of God. There is a clear cut distinction. I don't mix both. So when I am with my studies and am studying something related to science I know this is science. When I am with my Bible, I know yes this is my belief, this is my religion."

It is evident in his response that science is something he embraces but deals with at arm's length. When he talks of science he doesn't own it and just says "science" but he talks of "my bible…my belief…my religion". This affect and personalization of his religion may show different levels of attachment and likeness, affect and value he gives to the worldviews. Not only does he compartmentalize them, but they are placed at different depths. His beliefs are deep, while scientific explanations are surface, used when appropriate for examination purposes as seen in the following statements:

> "When you are in class make sure you pass your exams. That's what the teacher wants…If they ask you about evolution and you start telling about God (laughs) they'll give you a zero. So pass your exam and go ahead. You won't have those courses or subjects throughout your course. Just work then after that you won't have them again"

> "…in biology in particular where they want you to talk about how man evolved from an ape from emm you know all those stages, and you start talking about creation, you know. But you know deep in you that this is my belief, this is what I belief but science is saying something else. So you just have to..., it doesn't really affect my religion… so those, the aspects that are contradictory to what we have in the Bible, yeah… it doesn't influence how I think… in the area that are contradictory to the Bible, that's what I mean, not every area"

If one was to rely only on his perception of the interaction between his religious beliefs and scientific explanations, it would be possible as others have done to categorize Ernest as one who compartmentalizes his religious beliefs and scientific explanations. However, as we shall see later, when handling real time tensions, he doesn't always resort to compartmentalization. Ernest acknowledges that science and religion are not always in unresolved conflict as will be evident in other parts of this analysis. However, he believes there are domains in which the conflict cannot be resolved and as such he compartmentalizes his beliefs and the conflicting scientific explanation as a way to manage this conflict. In such an instance, Ernest is employing parallel collateral learning (Jegede & Aikenhead, 1999) by placing the cognitive schemata side by side unresolved.

Integration of science and religion

Another strategy Ernest uses to manage the conflict between science and religion is integration. In some cases he sought to reconcile the conflict between science and religious beliefs by integrating the two worldviews. To him, he didn't see any contradiction in these situations even when such a contradiction was apparent. In some cases he reasoned that science was providing explanations which the Bible did not

provide, but that those explanations do not contradict the Bible. For example, in the case of moonlight (see Appendix), though the Bible talks about God creating two lights, the sun and the moon while science describes the moon as not a source of light but a reflection of sunlight, Ernest resolved this conflict by some form of integration. He reasoned that the Bible doesn't tell us how the two lights are formed or how they function but science does. He sees the scientific explanations as God's design:

> "Okay the Bible tells us that God created two lights, you know. One to govern the day and one to govern the night, you know, but the bible didn't tell us how the light from the moon or how, I don't know how to put it. so you know, it doesn't give us an insight of what science has given us so I think the two can mean one and the same thing, you know. Because it doesn't really give us that, it doesn't tell us that the moon at night, how can I say it? It produces its own light. Maybe God designed it that way, that during the night while the sun is shining on the other part of the world, you know, in this other area it will be the light of the sun that will be reflected on this particular moon to bring light to this other part of the world"

Another instance where Ernest integrates science and religion is when I asked him about the rainbow. He believes as written in the Bible that the rainbow is a sign of God's covenant to never destroy the earth with water. Each time he sees the rainbow he thinks it is a sign of God's remembrance of that covenant. Reasoning that since the rainbow doesn't appear each time water droplets are in the sky and there are light rays, it means the rainbow is not just a coincidence but it is God's design. Science explains how the rainbow happens and not why it happens. Here Ernest is employing simultaneous

collateral learning (Jegede & Aikenhead, 1999) because he uses concepts from both sides of the apparent conflict to produce an integrated explanation to the why and how of rainbows. He argues that,

> "Let science accept the fact that God makes it to happen at that particular time because He wants to remind His children of that covenant. They may have found the way that, okay maybe it is refraction or, they tell us that light is made up of seven colors, and in the rainbow you find all those seven colors. That's true. I do not dispute science, that it's a refraction of light, and dispersion that makes the rainbow to appear but I also want science to accept the fact that God allows it to be that way because He wants to remind His people of His covenant."

In both of the cases of integration of science and religion above, Ernest is employing simultaneous collateral learning. Exploiting the gaps in both domains, he draws from both scientific and religious explanations to explain the why and how of rainbows.

Religious belief dominates

While in some instances Ernest seems to compartmentalize his religious beliefs from scientific explanations, and in others he seems to integrate both worldviews, there are instances where he rejects the scientific explanation in favor of his religious beliefs, that is, his religious beliefs dominate over scientific explanations. For example when it comes to the theory of evolution, Ernest rejects the theory in favor of his religious beliefs about creation. He argues that

> "Evolution tells us that man started from the primitive stage and started growing and changing forms you know. And if you look at evolution, well it talks about

> man that we all originated from, I will just say, like from monkeys before getting to what we are. But our Bible tells us something different. That God created the universe and everything. That He created man according to His own image and likeness…He created us, He just created us."

Ernest states his version of the theory of evolution side by side the biblical teaching on creation and states his own position when he says, "He created us, He just created us", thus giving his religious beliefs precedence over the scientific explanation of the origin of species.

As we have seen in the three instances above, it would be difficult to put Ernest in any one category as to how he manages the tensions that arise between his religious beliefs and scientific explanations. To continue the analysis, it is necessary that I look at the justifications he gives for the different views, why does his religious worldview seem to take precedence over his scientific worldview in case of strong contradictions? I explore this in the next section.

Reasons for choosing religion over science in cases of contradiction

It is not enough for us to know that Ernest's approach to managing the interaction of his scientific and religious worldviews is shifting and contextual. We need to understand why it is shifting and contextual. Understanding the reasons or justification behind each of his approach gives us insight as how science education practitioners can help individuals like Ernest to negotiate the cultural borders from their religious life-world to the world of school science.

Ernest gives several reasons he believes warrant his favoring his deep Christian beliefs over scientific explanations. Such reasons include:

1. ***Permanent, immutable nature of God's word versus temporary, fallible nature of science***

Ernest uses the nature of science and the nature of his religious beliefs as a justification for his different perceptions of the two worldviews. He believes that in situations of contradictions, because of the temporary nature of scientific explanations which sometimes might be laden with human error compared to what he considers the immutable, unchanging, and inerrant nature of God's word, he chooses to believe in God's word rather than in scientific explanations which may one day change. As he puts it,

> "The Bible tells us "forever oh God..." (laughs) the word of God stands forever. There is nothing that can change it you know. But from time to time, science itself has some defect from time to time. Some people postulate some theories, then after a while they discover that they had errors in that theory. They have to revise it, they come up with new suggestions you know. You see that science itself is not perfect. But the word of God is perfect. Those are the differences you know,(laughs), the word of God is perfect, it stands forever you know. When you follow the word of God, follow whatever is there, if they give you instructions, you follow those instructions, believe me you get your results. Yes."

2. ***The bounded (limited) nature of science versus God's unlimited, unbounded nature***

Bringing up the story of the virgin birth as one of the things science cannot provide explanations for, Ernest discusses the limited nature of science in interpreting certain occurrences in life. The bounded nature of science places it at a disadvantage compared to the unbounded nature of the word of God and the God of the word. Using the virgin birth and miraculous healings as examples, he points to how science cannot provide any logical explanations for some things that his Christian beliefs can explain. Because God's word provides explanations for some things science cannot explain, he gives the Bible precedence over scientific explanations in situations where there are contradictions:

> "…the virgin birth is supernatural (laughs) because um, that one contradicts science in every [way], you know, but that is how God works… Because I have seen things happen you know, in a congregation of God's people where they assemble together, prayers you know. How do you explain that a man that was lame, lame for years comes into a prayer ground and a man of God prays over him and instantly he is healed? How would science explain that? A blind man that has not been seeing for several years comes into a place of prayer and they lay hands on him, and they pray. With his faith he believes and his eyes are opened."

Ernest seems to confront a contradiction between science and religion using arguments from personal experiences and others he has witnessed to resolve the conflict in favor of religion. He uses both religious arguments and the bounded nature of science to resolve the conflict. Ernest is employing Secure Collateral learning (Jegede & Aikenhead, 1999) in this instance. Even though the conflict is resolved in favor of his religion, he provides reasoning from both perspectives to resolve the conflict as opposed

to just choosing religion over science or vice versa in which case he would have been employing dependent collateral learning (Jegede & Aikenhead, 1999).

Reasons for reconciliation of both worldviews

Silence of the Bible on certain details

The principal reason Ernest advanced for reconciling, in some cases, the tension between his religious and scientific worldviews is that fact that, science sometimes fills in the details which are missing in the Bible. Although at a casual look the schemata might appear contradictory, Ernest believes that a detailed look will reveal that science is just filling in the missing gaps in the Bible. According to Ernest,

> "The bible tells us that God created two lights, you know. One to govern the day and one to govern the night, you know, **but the bible didn't tell us how the light from the moon or how, I don't know how to put it. so you know, it doesn't give us an insight of what science has given us** so I think the two can mean one and the same thing, you know. Because it doesn't really give us that, it doesn't tell us that the moon at night, how can I say it, it produces its own light. may be God designed it that way, that during the night while the sun is shining on the other part of the world, you know, in this other area it will be the light of the sun that will be reflected on this particular moon to bring light to this other part of the world (emphasis mine)."

Can Ernest be squarely placed into a category?

As has been shown, it is difficult to squarely place Ernest in any one category as to his approach in dealing with the interactions between his fundamental Christian beliefs

and scientific explanations. He seems to employ different strategies as the context warrants and provides both scientific and religious arguments to justify his actions in compartmentalizing, integrating the two perspectives, or giving his religious beliefs precedence over scientific explanations. Next I will like to present another participant, Michael, and how he manages this science-religion interaction.

Michael

Michael is a student in a prestigious technological institute in the south of Germany, currently working towards his master's degree in Geodetics. Originally from West Africa, Michael worships in a multicultural church of about 200 members. He is a committed church member involved in the choir and also does special dance presentations in church. At the time of this interview, he was also in charge of the sound and IT system of the church as a volunteer, making sure everything is functioning in the course of meetings. This church is the same church I worship in when I am in Germany and have had several opportunities to observe Michael involved in his different duties in Church. The senior pastor of this church holds a master's degree in computer programming but gave it up to be involved in fulltime ministry.

Michael and the Bible

Michael views the Bible as the inspired word of God where God has laid out his thoughts, ideas, and instructions for mankind in His efforts to communicate with us. To him, the Bible is central in his communication with divinity, acts as a manual for life, and as a source of guidance in his daily choices. The Bible, according to Michael is a reference about anything and everything you see in the world, with three-quarters of the message hidden from the natural mind, and in need of revelation by the Holy Spirit:

> The Bible is actually the inspired word of God… God, in communicating with us has laid out His instructions, his ideas, His thoughts, in a book called the Bible… so the bible is sort of a manual, um, sort of a guidance that when you want to know what God has for you …the Bible has a lot to say about the world around us. I think the Bible has, um says everything about anything in this world that you can think of…it is a condensed book, it's dynamic and for whatever reason you are reading it when the Holy Spirit reveals it to you then you can be able to know what it has to say about this or that, that by normal reading you don't see

Michael views the Bible and his Christian faith as the source of his life's foundational principles, the center of his world around which every other thing revolves. To him, whatever does not fit well into this centerpiece of his life flies away from the "solar system" of his life. As he puts it,

> " from my experience, the thing is um, there is this popular saying that goes like this, if you don't stand for anything, or if you don't stand for something then anything goes for you, so if you personally have a belief and you belief in one thing and you're a scientist, the thing is um when you begin um hold your belief up very strongly you will notice that everything else begins to revolve around that belief that you have and that belief is in God and Christ Jesus so it is difficult being a scientist and also being um, a believing Christian, a strong believing Christian because you notice that there are so many things that would not add up that you see in science, that are explained by science and that um, you believe because it's said in the bible it's this way but science says it is that way so it is a lot of conflict for most people who um, are in this direction or area, but the thing

is knowing what you believe, and believing in the God that you believe in you notice that when you hold strong your belief everything else in science will revolve around what you believe, yeah"

To Michael, being a Christian with fundamental beliefs makes it difficult for him to be a scientist. He is conscious of the conflicts that he experiences in the world of science due to his deeply held religious beliefs. To him the only way to stay sane in the midst of such cognitive conflict is to make the Bible the center around which every other thing must revolve.

Michael and science

Michael views himself as a lover of science. He says, "generally I love science a lot because um, my, um, my area of expertise is also about science, geographical science and geodetic um, yeah so science, I love science a lot". His likeness for science is evident in his science related profession. In addition to saying that he loves science, he also sees science as both useful and practical on the one hand, and controversial and theoretical on the other. One the one hand he views a science that is based on practical things and evidences which he accepts, and on the other hand a science that is based on assumptions and people's ideas and untestable theories, which he rejects. In his own words,

"Where science is practical and there is evidence of things that, that we see and apply and use, that is the limit to which my science goes. Most of the science that goes outside these boundaries where theories are propounded and so on and so forth, they are theories, they are things that people are trying to put together, as in scientists are trying to make sense of something so they make assumptions, they make deductions and presume this and that and they classify it into a box called a

theory which isn't proven so at that level of theorems and theories that have to do with the higher science of evolution and um, um and other things that science tries to explain but evidently the explanation is found in the things of God and the bible, I do not go in that direction to believe it."

To Michael, science has boundaries and therefore there are domains where scientific explanations are not admissible. To him when science gets beyond these boundaries he thinks should be respected, he doesn't want to have anything to do with it, "there are certain outliers that when science tries to make sense out of it just complicates the matter and it makes further 'no sense' because there are certain things that are out of the boundaries of science… where science tries to play God is where I put my stop".

Having painted a portrait of Michael and his relationship with the Bible and science, I now take a look at how he manages the tensions that arise between his fundamental Christian beliefs and scientific explanations.

How Michael Manages the Interactions between his Religious Beliefs and Scientific Explanations

Like Ernest, Michael too adopts different approaches for the resolution of the conflict between his religious beliefs and scientific explanations depending on the context of the conflicting schemata. Below, I examine the different approaches he employed in managing the tensions.

Rejection of scientific explanation from a scientific standpoint

There are several instances where Michael chose his religious beliefs over scientific explanations, albeit for different reasons. For example, one instance where he rejected scientific explanation in favor of his religious beliefs is the case of the origin of the universe, namely the Big Bang theory. While Michael rejects this scientific explanation in favor of his religious beliefs, he does so putting forth a scientific argument. According to Michael, the explanations of the big bang theory do not "hold water":

> "the theory behind the earth being created out of nothing, and um, science says there was a vacuum and a void and there was a big bang and things started forming- little cells and this and that and then we are where we are now today, which doesn't make sense cause when I did physics some time ago but when you take a look at the theories and the laws of science, um, something cannot be created out of nothing, it has to have an origin point or something. um, um, energy is transferred, it doesn't just create itself out of nothing so, um, most of this um, scientific theories, they don't hold water for me… scientific evidence shows that there was once a flooding of the whole earth at a point in time in history and its found in the bible."

To Michael, the laws of physics, as he understands it, do not support the big bang theory. While his understanding of the theory may just be superficial, he uses his scientific understanding to reject the scientific explanations for the origin of the universe, in favor of His religious belief of creationism. To Michael, not only do the laws of physics not in support of the big bang theory, scientific evidence about the history of the

planet, particularly about a global flood, supports the bible's position about the origin of the universe. Michael thinks, and maintains that, "if you back track things that you find in the Bible through analysis, the system of analysis will be historical evidence, and historical evidences would show you everything that you find in the Bible, that has been told in the Bible". To him one can use tested scientific methods to validate the records of the Bible, hence he gives precedence to his religious beliefs partly because scientific evidence supports it.

Another instant where Michael tried to use scientific arguments to favor his religious beliefs over scientific explanations is when he talked about outer space scientific probes. To him, the fact that no other earthlike planet has been found is partly a proof that the big bang theory cannot explain the origin of the universe. Michael yet again demonstrates his naïve understanding of certain scientific explanations by arguing that probes have explored and are exploring "millions of light years" away . Although his argument is faulty, he does demonstrate his use of scientific arguments to validate his religious beliefs. He argues,

> "If there is something called the big bang and if there is an earth where you find life on out of the whole universe, it is too exact too, particular, too precise to not have been purposefully created by a higher being, a bigger being. Science or skeptics will say higher being, but I would call Him God. Because if there was a big bang, one way or the other there should be an earth somewhere else in the universe that also is a replication of the um, of the conditions we have here on earth to support life but we haven't found anything up till this day. And millions

of light years all around us probes have been searching, satellites have been snapping pictures but it doesn't add up…"

It is plausible to argue that although Michael gives scientific reasons for the rejection of scientific explanations, these are only pretexts to mask his underlying religious reasons for rejecting scientific explanations. The sometimes faulty scientific arguments can be viewed as just a rationale for his religious arguments as I discuss in the next section.

Rejection of scientific explanation from a religious standpoint

Michael also seems to reject scientific explanations from a religious perspective, that is, to give religious belief priority from a religious standpoint. To him, any scientific explanation that is not supported by what the Bible says is fit for rejection. From his argument that the big bang theory should be rejected because no other earthlike planet has been found so far, I pressed him if he would accept the big bang theory if one such planet was discovered today. His reply was, " if the Bible doesn't talk of another earth somewhere or any other solar system of any sort, then, if today we find a solar system I don't think I would believe it". By putting forth such an argument, Michael rejects scientific knowledge from a religious standpoint thereby allowing his religious beliefs to dominate this science-religion interaction.

Another instant where Michael rejects scientific knowledge from a Biblical standpoint is on the origin of species. After having rejected the scientific explanation for the origin of species, I asked Michael if his position would change if there were a compromise that species originated through evolution but by the design and agency of God. His reply was,

> "But God didn't say that in the Bible. God specifically said He created man in His own image and He created man out of the dust of the earth. He didn't say 'I was sitting somewhere in the heavens and then I created man to come out of a cell which further developed in this and that'. It is not found in the Bible. So if science is trying to say that it just doesn't add up, yes"

What is not found in the Bible is rejected by Michael, even if it makes logical or scientific sense, to him the Bible is the standard by which he evaluates even scientific explanations.

Integration of Science and Religious Beliefs

From the analysis of Michael so far, we might think that he would be quite consistent in privileging religion over science whether from a scientific or a religious standpoint. But as we will see, in some situations of contradiction between scientific explanations and Bible beliefs, Michael resorted to integrating the two viewpoints. For example, when asked about the nature of "moon light", where science explains that it is merely a reflection of the sun's light by the moon while the Bible, at least from a literal interpretation, claims that the moon is a light source just like the sun, albeit to a far lesser intensity, Michael sought to integrate both perspectives:

> "He created the sun to govern the day and the moon to govern the night. and um, um, God said this is what is, through science we've seen how it happens so science will tell you that there is revolution of the earth and um when the earth turns you have day and then you have night, so to me in certain situations or in most situations science goes to explain what God has set as law or what God has set or decreed… science says the moon is not a light, but at the end of the day um,

> we see a light in the sky. It is a light. That's why I say that science goes to show us how what God has decreed is actually taking place. So science telling us that the moon is not a light, if it is not a light um… but at the end of the day it achieves the purpose of lighting. Because if I am on a bicycle or am taking a run in the middle of the night and am wearing reflectors, and there is a vehicle coming and the light shines and the reflectors I am wearing reflects the light, the driver driving the vehicle see a light and he sees a light moving. So he sees that there is someone there and then drives carefully. So at the end of the day the purpose for which I am wearing that reflector is to create light enough for whoever is driving to see me. So I think the purpose for, it is, science explains how God has done it yeah, yeah, that's it for me."

One might have expected that here, Michael would accept the scientific explanation over the religious explanation because it doesn't appear to be a tenet of the fundamental beliefs of the Christian faith. However he downplays the contradiction by emphasizing the fact that science simply shows us the "how" of what the Bible says, filling up the gaps that have been left out by the Bible. To Michael, both science and the Bible address the same thing- God's creation, with one-religious beliefs focusing on the "what and why" and the other - science focusing on the how, the mechanisms and operations of intelligent design. To Michael, both science and religion are facets of the same gem, revealing but just a part of the whole.

Another instance where Michael sought to integrate scientific explanations with his religious beliefs is the situation of the rainbow. To Michael, the scientific explanations of the rainbow phenomenon tells us the "how" and not the "what and why".

He maintains that each time he sees the rainbow it reminds him of God's covenant and simultaneously acts as evidence of the global flood mentioned in the Bible:

> "When I see the rainbow I remember the sign of His covenant that he wouldn't destroy the earth with water again yes, and it goes to prove that after that great flood which has, um, which through science and through history, um which field of science? I think it's ethno botany, yeah, I studied that sometime in secondary school, and I read extensively on it where some explanation is given to how plants have evolved but then all of them seem to have evolved from a particular point in time or they all evolved at the same time. So when you take a look at that and you try to add one and two you notice that it was after a time of a great flood. It goes to explain the same analogy of day and night. This is what God said, okay, so we see it and we notice that it's something that we can't explain so in trying to explain it we find out how it works and I think it is the same thing for the rainbow. Not the purpose of the rainbow. The purpose of the rainbow is set by God but then science goes to explain how it is, how it is created, how it is done."

Compartmentalization of Science and Religion

Another way by which Michael manages the tension between his religious beliefs and scientific explanations is by compartmentalization. That is, separating his religious beliefs from scientific explanations. It is as though he creates two artificial worlds, one consisting of his religious beliefs and the other consisting of scientific explanations. By separating what he considers knowledge for academic purposes, and knowledge for real life, Michael creates an artificial dichotomy that enables him to avoid tension between

certain schemata from the two worlds. When asked about the origin of species, Michael responded in the following manner:

> "I took what I needed to learn from that class because at the end of the day there is going to be an examination and you are going to need to produce what was given to you. I can't definitely tell the professor or teacher that "okay this is what you taught but this is what I believe so this is what I would give to you in the exam. I take what is for academic purposes academic and I leave it within those confines but personally my belief system will tell me that the earth was not created out of evolution. If I find a situation where someone asks me, "how was the world created?" I would definitely tell them what I believe, not what I was taught in school… certainly I understand for a fact that it is for academic purpose that we are being taught that and it remains in those confines just as a said."

By creating confines for scientific knowledge learned in school from what he considers his real beliefs, Michael makes it easy for himself to simultaneously be a science student and a fundamentalist Christian believer. He places his religious beliefs at a deeper intuitive level where it determines his response to questions about the origin of species in real life, while scientific explanations are given a reflective status. He has to be conscious that he is within the walls of the school and that the information is needed for examination purposes for his response to be scientific.

Reasons for choosing religious beliefs over science

1. *The deductive and assumptive nature of science*

One of the reasons why Michael rejects certain scientific explanations in favor of his religious beliefs is that fact that, it is in the nature of science for assumptions to be made and certain conclusions deduced without absolute certainty. To Michael, theories which are based on such assumptions or deductions cannot be trusted, and therefore he tends to reject such. In his own words,

> "Most of the science that goes outside these boundaries where theories are propounded and so on and so forth, they are theories, they are things that people are trying to put together, as in scientists are trying to make sense of something so they make assumptions, they make deductions and presume this and that and they classify it into a box called a theory which isn't proven. So at that level of theorems and theories that have to do with the higher science of evolution and um, um and other things that science tries to explain but evidently the explanation is found in the things of God and the bible, I do not go in that direction to believe it."

In his view, theoretical sciences do not have the same weight as practical science, things which can be observed or experienced in the physical. Theories, he argues, can't be verified since they are based on assumptions and deductions.

2. *The bounded nature of science*

Another reason why Michael rejects some scientific explanations in favor of his religious beliefs is because he does believe that science has boundaries which it tries to violate to

explain what is in the domain of the Bible. When scientific explanations are beyond the boundary he has assigned to science or which he believes are reserved for the metaphysical, his tendency is to reject such explanations. He argued that,

> "Science is put on the same pedestal or is seemed to be used to replace the unexplainable that is only attributed to God, but then, just as I was saying that, the practicality of things that we see and that we experience is how far with which I'll go with science. If it goes to attempt to explain something that is unknown that can only be attributed to God then I stop there … there are certain outliers that when science tries to make sense out of, it just complicates the matter and it makes further "no sense" because there are certain things that are out of the boundaries of science."

Reasons for reconciliation

The Bible is silent on certain details

Like Ernest, Michael chose reconciliation between his scientific and religious worldviews in situations where he felt the Bible was not very clear with respect to the details of the "how" of the phenomenon. To him certain scientific explanations, while they do not explain the purpose of the phenomenon, bring clarity to the way it happens and therefore are seen as complementary to his religious beliefs. As he explained in the cases of the moonlight and the rainbow,

> "This is what God said, okay, so we see it and we notice that it's something that we can't explain so in trying to explain it we find out how it works and I think it is the same thing for the rainbow… not the purpose of the rainbow. The purpose of

the rainbow is set by God but then science goes to explain how it is, how it is created, how it is done."

Can Michael be squarely placed into a category?

As I showed previously, Michael used a variety of strategies depending on the context to resolve the tension between schemata from his religious worldview on the one hand and his scientific worldview on the other hand. So it will be impossible to fit Michael into any one of these categories of how he approached the resolution of this conflict.

Victoria

Victoria is a fifth year medical student in a prestigious medical school in the South West of Germany. Like many of the participants in this study, she moved to Germany mainly to pursue her studies while she was already a Christian fundamentalist. Because her university is somehow far from the church were the others attend, she comes to church on average twice a month. The other Sundays, she attends a church in the city she lives. This city is about 90 minutes from our church by public rail transportation which many people use in Germany. Victoria grew up reading the Bible in a largely Christian home with French as her first language. She was a part of the church service interpretation team and also the worship team when the church hosted a separate French/German service. However, when the French/German service was suspended, she has not taken up any other responsibility in the church probably because of the increased demands of medical school life.

Victoria and the Bible

Victoria sees the Bible at the center of her life. The Bible is where she discovers herself and draws her identity from. Thus the Bible is an integral part of who she considers herself to be, and where she draws her life purpose. It is her source of guidance, the hand book of her responsibilities in life and one of her means of communication with God. In her own words,

> The Bible has an essential role, the main role in my life because it really gives me guidance, like tells me who I am first of all, and what God wants me to be, what God wants me to do and it really guides me in some decisions. When I want to take some decisions, sometimes, I take the Bible and I read, I really see how God talks with me, and yes, you can see the Bible has a main place in my life.

This means that, for Victoria, every other book plays at best a peripheral role in her life since the Bible is at the center of her world. Anything that contradicts the "self" she has discovered in the Bible and which she has embraced will likely be met with a strong resistance and ultimately rejection because she views the Bible as "the will of God".

Victoria and science

Victoria's view of science is largely shaped by the fact that she is a medical student. To Victoria, science is practical and physical. It is something she can see and touch and relate with. To her this practical and concrete nature of science makes science interesting. She shows a proclivity for that which is evidence based or verifiable. In her own words

> "About my science classes I really liked the truth of what I am seeing. When a professor sometimes comes and gives a lecture on anatomy, for example, and says

> that for humans, you have, for example, that the heart is here and you go to an operation and you see it that the heart is really there like they said, or it's really um , like, how can I say it? It's not abstract, it's practical and concrete, I can see it, I can touch it; it's not like mathematics. Mathematics is like more abstract and for me I like things that I can practice, I can see when they say for example this medicine is working like this, you try it and it really works…"

It is possible to infer that Victoria's view of science is partly authoritative and transmitted, and also based on personal observations. That is, scientific knowledge is handed down by authorities, in this case her professors, and her experiences at best validate what she learns in the classroom, that is, told her by authorities.

She also considers science as tedious and demanding requiring long hours of study making it impossible for one to be available to socialize and fulfill ones religious responsibilities. In other words it takes a lot of sacrifice to study science. As she puts it,

> "You have to work hard, not that I don't like it but sometimes it's so annoying that you work hard and there are still so many things to read. You read every day but it's never ending. You always have something to learn, yes, that's a little bit, it's interesting but it's annoying sometimes when you are tired because, for now, for example I don't have the motivation even to read or but you have to because you have many things to read and that's what can, science studies are really hard and you have to give your time for that. Sometimes you can't go out with friends or do some things, or be readily available for the church because you have to, you really

have to read. People may not understand but if you want to become a good doctor you really have to do that work. Yes!"

In her view, the demands and sacrifices required to study science are enormous but ones she is ready to fulfilled, at the risk of being misunderstood by the people surrounding her. I think this willingness to pay the price of being a scientist, and to endure the "annoyance" from science is inspired by the prestige that comes with being a scientist, and the reward of upward mobility.

Another viewpoint of Victoria's is that science reveals God's Greatness. Her interest in science seems to be buttressed by the view that science, from her experience, is a great avenue to discover God's wisdom and greatness through His creation. It is interesting to see that as she studies the human body her first reaction is not inclined to scientific explanations for the origins of species but that from the Bible:

> "Medical science studies are really interesting because I can see how God is great. There are so many things we see at school for example how the heart pumps blood or it's pumping this amount of blood per hour, you cannot believe it when you see it you are just like God created it, it's so amazing. You see for example when you see some other functions of the body, yes you are so like God is really wonderful… yes, the greatness of God; when the Bible says God created man, when I see what He created in just one day, humans can take years to understand exactly how the body functions, and still now we don't understand everything, but God did it in just one day, like He did it now and He did it with His word like "I want to make man now" and He did it. So it helps me sometimes even when I...

> sometimes when I see somebody walking, when I see somebody smiling, you cannot imagine how many nerves he uses to do that, it's so amazing"

Victoria views the piecemeal, accumulative nature of scientific knowledge as a limitation compared to the biblical account of a seven-day process of the creation of the heavens and the earth. Each additional human discovery or invention to her is a revelation of not how far humanity through science has come, but how far it still needs to go in understanding God's creation. In the same vein, as victoria views science as a means to discovering the greatness and wisdom of God, she also views scientific knowledge as another form of divine revelation. Victoria believes that science is only able to construct knowledge and bring about inventions contingent on divine revelations to individuals. As she puts it,

> "To be a scientist you have, the best way to be a scientist is to be a believer because God will reveal so many things to you because for me all the things that men are discovering every day are what God reveals to them. The way He makes the heart pumps, the way He makes that I can um breathe, He is the one that creates it and He is the one to make me discover what He created because He knows it better than me. So for me the best way even to be a scientist is to be a believer"

Such a viewpoint gives the impression that Victoria does not differentiate between her religious beliefs and scientific knowledge which seems to contradict, as will be shown later, her position that she differentiates between science and her religious beliefs. This shows that, sometimes, peoples "theoretical" position in terms of the science/religion

debate may be different from their actual approach to resolving the tensions that arise between schemata from the two worldviews.

How victoria manages the interaction between her religious and scientific worldviews

Like the others, Victoria seems to have no set way she approaches the interaction between her religious beliefs and scientific explanations. Her resolutions of the tensions were found to depend on the context of the conflict as I show in the following paragraphs.

Compartmentalization of science and religion

Victoria believes that she is someone who compartmentalizes her religious beliefs from scientific knowledge. She posits that she consciously separates her religious convictions from humanly generated knowledge. In her own words: “for me I have my conviction, I have my assurance and I have to separate what men say, what men believe from what God tells me. I don't have to mix it”. It would have been easier to label Victoria as one who compartmentalizes her religious beliefs from scientific knowledge had this study elicited only respondents perception or self- report of how they manage the tensions between these two worldviews. However, providing contradictory situations from the two worldviews shows the contextual nature of the resolutions of the conflicts.

Integration of science and religion

Two situations in which Victoria, like many of the other participants, applied a reconciliatory approach to resolve the conflict between her two worldviews is the case of the moonlight and the rainbow. For each case Victoria was asked what she knew from the scientific and Biblical perspectives about the phenomenon after which she was asked to resolve the difference. Below is her response for both situations:

"I can assume that in the night I have a light and in the day I have light too, so what God says is true, there is light in the night and light in the day so um, how the light comes, may be science is right that the sun is lighting the moon so that it will light the earth at night, it is not that contradictory if that is the way God used to light the night... When you go in detail you don't see any contradiction because you can explain it that God used that way to create the light in the night."

No, I don't see a contradiction because um, that rainbow is just like a light reflection doesn't mean that it is a not a sign of covenant between me and God. so I can believe, may be it is like the bible like science says it's a reflection of water but God has many ways of doing something, and for me it is still, because when I was seeing rainbow from my room, I think it's yesterday or something like that and I remember about the covenant of God, and anytime that I see a rainbow I always tell the person next to me that God said He will never destroy the world. For me it's that, um it does matter how science says it is, but for me it's the definition of this rainbow, yes."

In the first situation, Victoria admits that the scientific explanation for moon light is valid but sought to integrate it with her religious explanation. By saying "that is the way God used to light the night", she embraces the scientific explanation without getting rid of, or modifying her religious believes, and attributes the former to a divine way of working. While she doesn't expressly states it, I believe like the others, she thinks science

explains the "how" of God's creation without contradicting the "why" and "who" of creation.

Similarly, in response to the case of the rainbow, she still admits the validity of the scientific explanation but places it in the context of explaining the how of the rainbow. It is interesting that here, as in order places, her religious beliefs seems to be predominant. Her first reaction on seeing a rainbow is not the beauty of a random physical phenomenon but an activation of her religious belief of a divine covenant. This can be explained by the fact that teleological beliefs are very strong amongst Pentecostals, that everything is created for a purpose; nothing is random, rather it is orchestrated or permitted to happen by divinity for a reason. In this case the rainbow is a divine design, as stated in the Bible, to remind humanity of His covenant to never again destroy the world through a flood.

Choosing religious beliefs over science on religious grounds

Another way Victoria manages the tension between her two worldviews is by rejecting scientific explanations on the grounds of her religious beliefs and convictions. In the case of the origin of species, Victoria completely rejects the scientific explanations put forth by the theory of evolution in favor of her religious beliefs on creation:

> "For evolution for example God explains in details in Genesis how He did it. He said I'll first make the animals then I'll make man in my image", So how can I believe evolution when God tells me that He made me in His image. And the Bible is so clear on it. For me, no I cannot believe it."

Her reasons, stated above, for rejection of evolution are based entirely on religious grounds. This means Victoria rejects scientific knowledge which does not fit into her religious beliefs or which she cannot modify to fit her religious schemata.

Choosing religious beliefs over scientific explanations on scientific grounds

It is interesting to note that Victoria also rejects scientific knowledge from a scientific perspective, that is, although the principal reason behind rejecting scientific knowledge is her religious beliefs, she puts forth plausible scientific arguments to justify the reason for her viewpoint. For example, on the subject of the origin of species, she argues that

> "The Bible says that He made man to dominate the animals and His creation. For me I just understand it, like I said, may be we have the same genes because we are from the same God, we are from the same origin. He used those genes in many ways, but that does not man I come from the fish. I come from God but He is the one that used the same material to make me."

Science has used the argument of the genetic similarity between humans and other species, especially those from the ape family, and between other species, as possible evidence for evolution. Victoria presents a counter argument from a scientific perspective that the gene similarity is possibly due to the fact that the same Creator made all the species using the same basic materials as there could be links in the different car makes and models manufactured by VW.

Reasons for choosing religious beliefs over scientific explanation

There are two main reasons Victoria gave for choosing to reject certain scientific explanations in favor of her religious beliefs:

1. *The theoretical nature of certain scientific explanations versus the experiential nature of her religious beliefs*

Victoria seems to lack an understanding of how scientific theories are arrived at. To her, it is something someone just gets up to imagine and states as a theory which cannot be tested. Because of this, scientific explanations which are theoretical in nature are met with rejection because she views them as untestable. As she put it,

> "I don't believe in those theories **because to me it's something that someone just seats and thinks like that**. It's true because there are some genes you see in the animals that are alike with us. but for me that is not telling me that I am from those animals… for me I have the Holy Spirit that tells me that I am from God, I am not from an animal or from a fish . **So I have more than a proof, for me the Holy Spirit is the proof in me"** (emphasis mine)**.**

By contrasting untestable scientific theories to her "provable" religious beliefs, she tells us why she rejects certain scientific explanations in favor of her religious beliefs.

2. *The clarity and details of the bible on certain issues*

The second reason why Victoria chose her religious beliefs over scientific explanations is that the Bible is very clear and detailed on such aspects as the origin of species, providing detailed explanations for both the "how" and the "why" of the different species. Explaining why she rejects the theory of evolution, she stated that,

"I don't believe because even, for the evolution for example God explains in details in Genesis how he did it. He said "I first made the animals then I made man in my image" so how can I believe evolution when God tells me that He made me in His image? And the Bible is so clear on it. For me, no I cannot believe it."

Once the Bible is clear and detailed on any subject, Victoria doesn't give any room for either reconciliation or dominance of the scientific explanation. For her, it is clear and simple, the Bible says it, she believes it, and it is settled.

Reasons for reconciliation or integration

The Bible is silent on certain details

When Victoria believes the Bible is silent on certain details and the scientific explanations make logical sense to her, she opts for the integration or reconciliation option, especially when the scientific explanations seems to provide the "how" of the phenomenon which is absent from the Bible. In the cases of the moonlight and the rainbow, she explained that,

"What God says is true, there is light in the night and light in the day so um, how the light comes, may be science is right that the sun is lighting the moon so that it will light the earth at night, it is not that contradictory if that is the way God used to light the night… yes when you go detailly [sic] you don't see any contradiction because you can explain it that God used that way to create the light in the night.

"No, I don't see a contradiction because um, that rainbow is just like a light reflection doesn't mean that it is a not a sign of covenant between me and God.

> So I can believe, may be it is like the Bible like science says it's a reflection of whatever, but God has many ways of doing something, and for me it is still [true], because when I was seeing rainbow from my room, I think it's yesterday or something like that and I remember about the covenant of God, and anytime that I see a rainbow I always tell the person next to me that God said He will never destroy the world. For me it's that, um it doesn't matter how science says it is, but for me it's the definition of this rainbow, yes."

Because the Bible doesn't explain the details of the how of the moonlight and the rainbow phenomena, Victoria chose to reconcile the religious perspective with the scientific.

As I have shown, Victoria, like the previous cases does not fit into any one category as to how she reconciles the tension between her two worldviews. I now present the final case study of this chapter.

Yves

Yves was a 26 year-old man at the time of this interview studying mechanical engineering in a renowned southwestern German university. He was in his final year in the Masters of mechanical engineering program. Yves is one of the worship leaders of his church and also doubles as a co-leader of the youth and young adult ministry. He grew up in a home where both of his parents were fundamental Christian believers and involved in the ministry. This is how he described his upbringing:

> "My parents, they are Christians since 30 years, and for the past ten years they have also be working in the um, how do they call it, in the missionary ministry, and my mom she has been in Africa in many countries for evangelism or

> seminars. My father, he's been working but like um, besides working has also been involved in the ministry, and in some ways, teaching in the weekends in the bible training school. So that's the way we were raised up. So like every morning by 4 or 5 O'clock we had to wake up for prayers. Yeah, it's like at that time I was just doing it because I had to, it's not like I decided I'd do it free willingly, it was like an obligation. I just had to wake up and, I went through that and then to school. I did that and it's actually here in Germany that I decided for myself that I will not go that way because I actually saw the importance of it for myself not because my parents wanted me to do it."

Yves home culture was steeped in fundamentalist Christian practice, especially amongst the African communities where family morning devotion is compulsory for everyone in the home. During this time family prayers are done accompanied by a short exhortation from the word of God-the Bible.

Yves and the Bible

Although he was steeped in this environment, Yves did not actually make a personal commitment to follow Jesus and to personalize the fundamentalist Christian beliefs. Nevertheless at the time of the interview he had personalized his faith, viewed the Bible as his guideline in life. To Yves,

> "The Bible um, it's like for me it's a guideline , everything I do I try to um, look out for the point of view of the Bible, what God says about the thing and try to act accordingly. I've been raised in a Christian home, so we started very early to reading the Bible and try to ask God what is His will about everything. So it's

actually like, I don't know, whenever I have something I try to look out what the Bible is saying about it before I take a decision or before I do anything."

This implies Yves viewed the Bible not only as a guideline but also as the final authority since everything he did while growing up had to be validated by the Bible. Such a view of the Bible means whatever Yves encounters in school will likely be evaluated in the backdrop of the Bible which is his guideline.

Yves and science

Yves grew up with a likeness for the practical aspects of science, with a curiosity to understand how things work. He regards science as an interesting practical field. He got to find physics in particular very interesting as he studied planetary and satellite motion. Yves views the developments and inventions of the scientific enterprise as very fascinating. To him Science fits his personality since he doesn't like talking he could not pursue arts related careers. He explained his relationship with science as follows,

"Literature, um, I don't like to talk much, I don't talk much (Laughter) and I mean sometimes I write but for me it wasn't something suitable let's say it like that. I got into mechanical engineering I got into mechanical engineering; I wanted to study actually physics because in the last two classes in high school I was really into physics because it was something really interesting for me because we studied the movements like the satellites turning around the earth and some stuff like that. Then I came to Germany through my uncle and he also studied mechanical engineering, so that's how I kind of, how I got into that direction. I was actually, it was for me either physics or aeronautics."

Apart from the positive aspects of viewing science as interesting and as fitting to his personality, Yves also views science with skepticism and a dose of suspicion. In his view, science is out to discredit the Bible which he considers his life manual. His views about scientists and the science enterprise are,

> "I think sometimes it's just to contradict the Bible because they don't believe in what is said in the Bible so they try to find ways to put is so that people would say "yeah the Bible is not true and what they are saying is true"… it's like the human being is really curios and he will try and explain things his own way so, they will be trying to find, I mean my own point of view is that the people, when they don't understand it they don't want to go the way of the bible so they try to find another way. I mean they have evidence or they try to find evidence or I don't know if they even fabricate the evidence who knows? It's like people will find any other way to explain it instead of explaining it the way of the Bible."

To him, scientific explanations sometimes contradict the Bible because people are looking at alternative ways to explain the world and by so doing they do everything possible to discredit the Bible even to the extent of falsifying evidence. Therefore Yves views science and the Bible as antithetical to each other. It is important to note that Yves' views seem contradictory – on the one hand, he really expresses his likeness for science and physics in particular, but on the other hand, he thinks science sometimes has an anti-biblical purpose. In the following sections I will examine how Yves manages the tension between his religious and scientific worldviews and show how these different aspects of his thinking come out in different situations.

How Yves manages the tension between his religious and scientific worldviews

Reconciliation of scientific explanation and religious beliefs

Integration of religious beliefs with scientific explanations is one of the ways Yves resolves the tensions between his worldviews. On the issue of the rainbow, here is what he had to say about the scientific explanation in relation to the Biblical position on the rainbow:

> "When you are into physics yes it makes sense because when a source of white light gets refracted, then it produces like all of those colors; blue, indigo, green and it has also been proven like they broke white light through a prism and then it happened. But my question is why does it occur in nature only when there is rain? So, it's not like it is only the raindrops that can refract the light, it could also be like the mirror or just another substance, exactly, so it is not actually false what they say that it is white light being refracted, but it doesn't also say that what God says about the rainbow in the Bible is wrong from my point of view, …I mean it might be true what they say that the white light is being refracted when it happens but it is also a promise from God that He gave us. I am accepting both because God gave us the rainbow, but it's like He didn't show us or tell us how the rainbow is formed. So that's the, it's like, I don't know, He gave us for example like a mind or the intelligence to create laptops and all those things, it's like, I don't know how to put it (laughs). I believe it is from God, but um, I don't know how to put it let me think, um (long pause). Let me say it like this, they don't necessarily go hand in hand but I think they don't contradict themselves because on the one hand the science is talking about how the rainbow is created, on the other hand God has given us the rainbow."

Yves acknowledges the correctness of the scientific explanations for the rainbow while also admitting the veracity of the biblical explanation for the rainbow. To him the fact that science explains the "how" of the rainbow while the Bible explains the "why" of the rainbow makes it possible for the two explanations, though from opposing worldviews, to be reconcilable.

Rejection of scientific explanation from a religious standpoint

Another approach Yves employed in resolving the conflict between schemata from his religious and scientific worldviews is the rejection of scientific explanations from a religious standpoint. When asked about areas of contradicting schemata he may have encountered in the science classroom, this was his response:

> "Yeah, I mean, when I hear that I think directly about the big bang theory for example, because it's like out of nowhere something just pops up and the universe was created. I was like it makes no sense for me. There must have been someone there who did that, who created all things so that's one thing. And also the theory of evolution, I don't really get it right? How is it possible that we come from monkey or from an animal although it is written that God created us and gave us actually to rule over the animals? Those are, I think the two things I, I don't really agree with."

Yves stated the Big bang theory and the theory of evolution as areas of contradiction for which he rejects the scientific explanations for religious reasons. First, he cites his belief in causation as grounds for which he rejects the scientific explanations since science doesn't give credit to any causative agent for both the origin of the universe and origins

of species. Second, he cites the biblical explanation of divine creation as grounds to reject the scientific explanations.

Rejection of scientific explanations from a scientific standpoint

Apart from rejecting scientific explanations from a religious standpoint, Yves also rejected scientific explanations from a scientific standpoint. As he explained,

> "First of all the fact that I grew up with the Bible and I knew what the Bible was saying about all those things, that the first reason I didn't believe in it. And second, when I think about it, it doesn't make much of sense to me because like I said before, something just popped up and the universe was created. It just doesn't make any sense."

Here Yves` second reason for rejecting the scientific explanation for the origin of the universe is based on a logical reasoning as opposed to just a religious ground like the first reason. Hence from a scientific standpoint, Yves gives his religious belief dominance over a scientific explanation.

Reasons for rejection of scientific explanations

There are two reasons given by Yves why he chose to reject scientific explanations in favor of his religious believes in certain situations.

Human dignity

In the case of evolution, in addition to the obvious which is the Bible's stated position on the issue, another apparent reason for which Yves was unwilling to compromise his position was the fact that he couldn't associate himself evolving through a monkey. Such a position has to do with human dignity. To him, evolving through a monkey is the same as being a descendant of a monkey. Unlike science, his religious

explanation dignifies mankind to the status of being made in the image of God and given dominion over the rest of earthly creation. He reasoning against evolution was:

> "No, that one I don't believe it because I cannot believe that I come from an animal because in the Bible it is written that God gave the man rulership [sic] over the animals. So that one I don't think it is plausible, yeah."

Fallibility of humans and their inventions

The second reason for which Yves rejected certain scientific explanations was the fallibility of humans and human inventions. Talking specifically about scientific conclusions drawn from calculations made using data collected by machines like telescopes and robots sent into space by humans, his reasoning for rejecting such conclusions was,

> "I don't have to believe someone who tells me that there is water on Mars because I've never seen it so it's like, why should I trust that your calculations are right?...I mean on what do you base your calculations? There is always a hypothesis somewhere, like I go from the fact that it might have been this or this way and then I do my calculations. It's not like you are sure that it has been this way."

To Yves, the fact that scientists are likely to make assumptions means they are likely to make wrong calculations, the reason he cannot trust such, and therefore must reject the conclusions drawn from such. When pressed with the fact that there are computers which make accurate measurements and calculations, his counter argument was,

> "Even so I won't believe in it because where is the, I cannot trust a machine. I have just said it that I believe that a car can drive from A to B alone (C: and it is a machine) yeah it's a machine and it's happening but you cannot put 100% of your trust in a machine because a machine can fail. I mean the safety in the cars nowadays are at a high level but still there are accidents because those machines in the system they fail."

Hence faulty human assumptions are not the only reason for rejecting such calculations, in addition error prone human inventions is an additional reason for rejection of scientific explanations made from such data collected remotely.

Again, like the others discussed earlier, Yves does not squarely fit into any one category. Having looked at some of the individual cases as described in the previous sections, I will now do an across the cases analysis. What is common among, and what is different between, the individual cases?

Across the cases

In this section I discuss some of the common trends and nuances among the different participants in this study.

Differences in Religious background

While all of the participants hold fundamental Christian beliefs, there seems to be both similarities and some subtle differences on the influence of the home environment on their belief. As expected, all the participants consider the Bible as the word of God and their life manual. They all alluded to the Bible as the final authority by which they determine what is acceptable or unacceptable. In terms of family influence on their beliefs, Ernest, Richard, and Yves seem to come from homes that exerted more influence

on their beliefs than does Michael and Victoria. In the course of the interviews only Ernest, Richard, and Yves unlike Michael and Victoria mentioned the influence of their parents helping them develop their Christian beliefs and resolving the tensions between their worldviews. Nevertheless these nuanced differences in their religious upbringing did not seem to affect the way they individually resolved the tensions. On the contrary, they exhibited very similar approaches to managing the tension between schemata from the two worldviews.

Contextual nature of resolution of cognitive tension

In looking across the cases described so far, which are representative of how most of the research participants in this study managed the tensions that arose from the interaction of schemata from the two world views, it is easy to notice that all four cases resolved the contradictory schemata in different ways depending on the context of the conflict. That is, they all had multiple approaches to resolving the tensions. In all the cases, there was none who resolved the tensions in favor of scientific explanations.

Six of the eight cases in total had a contextualized approach while two resolved everything in favor of their religious beliefs, rejecting every scientific explanations presented. Although both of them were from the same home, there is no indication that this had any influence on the way they approached the tensions. One of these two, George, rejected scientific explanations from both a scientific and a religious standpoint while his brother rejected scientific explanations only from a religious standpoint. Whatever did not align with what he believes to be the biblical position was rejected on grounds of what the bible says only by Lawrence while George attempted to put forth logical scientific arguments for the rejection of scientific explanations.

Nuances in their approaches

For the others who had multiple approaches, Ernest mostly rejected scientific explanations from a religious standpoint, while Michael, Richard, and Victoria in some cases attempted to put forth scientific arguments as to why they reject certain scientific explanations and also sought to use scientific arguments to defend their religious beliefs, sometimes referring to "historical evidences".

A common reason for reconciliation and for rejection of scientific explanation

However, there is a common thread, among the participants, of reconciling the two worldviews on matters that are only related to aspects of the physical world around us, that is, inanimate things like questions relating to the sun and moon and the rainbow, but rejecting the scientific explanations that had to do with the origin of species and the universe. I discuss this trend and the possible reasons for it in detail below.

Discussion

In this section I discuss the findings of this study in relation to the current literature on cultural border crossing. I will also explain the findings in light of the literature on religious representations and how they might have influenced people's choices or approaches to resolving the science-religion interaction.

Cognitive explanations for people's approaches

When it concerned matters that pertained to the human being, especially on the topic of evolution, there was a common thread of rejection of scientific explanations in favor of religious beliefs. I think the reason being this is the very strong teleological beliefs that many fundamental Christian believers hold when it comes to the humankind. Man was purposely created by God in His image to accomplish a purpose on the earth,

and that man is superior to the rest of terrestrial creation over which man was given dominion. To accept the theory of evolution will mean denying the purpose for their lives. Also, teleology seems to be a strong reason why they sought to reconcile the two worldviews when it came to matter relating to inanimate things like the sun and moon or the rainbow. They based their arguments on the purpose of the moon and the rainbow, that is, on the "why" rather than on the "how".

Since the scientific explanations for the moon and the rainbow do not violate these strong teleological beliefs, but tended instead to reinforce those beliefs, it was easier for the participants to reconcile both explanations. By contrast, an area where participants tended to reject scientific explanations was the domain of the origin of the universe, of humans, and of the inanimate world around us. The Big Bang Theory attributes the origin of the universe to a random, accidental event which strongly violates participants' teleological belief that things were designed and exist for a particular purpose. This strong violation of teleological beliefs results in the rejection of the scientific explanations of origins of both species and the universe.

Essentialist beliefs may have been another strong reason for participants' approaches concerning the origin of species. Recall that we defined Essentialism as "the belief that members of certain categories have inherent and stable properties, which are causally responsible for more superficial properties, and which make members of one category fundamentally distinct from members of other categories" (Diesendruck and Haber, 2009; p. 100). Clearly, the theory of evolution violates the stability and inherency the different categories in the animate world around us, making it difficult, and maybe impossible, for fundamentalist Christians to accept the theory without violating their

beliefs that God, the creator-causal agent, made the world and created the different species in their current state, different from members of other species. This is a very strong belief amongst fundamentalist Christians because the Bible is clear that God created separate categories of beings, both terrestrial and celestial on separate occasions, and that these categories stand separate and distinct from each other. Because the theory of evolution, at least part of it, strongly violates this essentialist belief, people tended to reject the theory of evolution.

Through the lens of collateral leaning theory

In terms of the collateral learning theory, there is evidence of the different types of collateral learning in the continuum of the theory. By compartmentalizing the schemata from the two worldviews, the participants were employing parallel collateral learning, where the schemata from the different worldviews are placed side-by-said with very minimal interactions. However, it seems in this case that the "worlds", that is, the religious world, and the academic world, are placed side-by-side instead of the schemata from the two worlds. This is because the participants seem to have resolved the conflict in favor of their religious beliefs. However for the purpose of school examinations, they hold the scientific explanation temporarily, without any influence on their religious beliefs. Thus, while Jegede's parallel collateral learning holds that the schemata are placed side-by-side in an unresolved conflict, in this case it is the worlds that are placed apart with minimal interaction, with the tension between the schemata being "resolved".

When participants integrated their religious beliefs with scientific explanations, they were employing simultaneous collateral learning where schemata from one worldview help the understanding of similar schemata from another world view. In this

case, the "how" of the scientific explanations for the moon and rainbow helps their understanding of the religious beliefs of the "what and why" of the moon and the rainbow. When they allowed their religious beliefs to dominate, they mostly chose their religious beliefs over scientific explanation, hence employing dependent collateral learning. Secured collateral learning was exhibited by Michael, Victoria, and Pauline when they used scientific arguments to justify their rejection of scientific explanations for the origin of the universe and species.

Unlike in the current literature which has placed people into categories, we clearly see that in cases of Ernest, Richard, Yves, Victoria, Pauline and Michael, depending on the conflicting schemata, they either resolve the conflict by integration, or they compartmentalize the schemata, or they resolve the conflict in favor of one schema. These diverse ways of dealing with the conflicts mean we cannot place people into any particular category because their position seems dependent on the conflicting situation. Hence categories are not people dependent, they are context or conflict dependent; they are not stable and permanent but are dynamic and fluid.

The reason for this disparity of the results from those in the current literature may be due to the fact that, researchers have mostly looked at the creation-evolution argument. However, creation and evolution argument is not the only area people may find conflict between science and religion. By bringing in other potential conflict areas, we can see that people cannot always be placed in any singular category of how they manage the conflict between their religious beliefs and scientific explanations.

Religious explanations versus religious beliefs

Biblical explanations, when personalized, become religious beliefs. For example the biblical explanation of the origin of species, when personalized (internalized and accepted) by a fundamentalist Christian believer, becomes a *belief* in a God who created the heavens and the earth and everything that inhabits these realms both physically and metaphysically. To a nonbeliever, a religious explanation found in the bible may just be someone's idea, while to a believer the same religious explanation is a central tenet of faith which must be adhered to. Hence religious beliefs can be used interchangeably with religious explanations in the context of fundamental Christian believers.

On the other hand, they can be viewed as different from each other. It is possible that religious explanations may be people's personal ideas, that is, they are extra-biblical explanations unlike beliefs which are usually shared by a religious community and central to faith confession. Religious explanations can be peoples' way of using aspects of their beliefs to explain natural phenomena, and such explanations may vary across individuals because they may depend on the individual's understanding or extent to which the belief is held. For example, a young girl can explain rainfall as God crying, but this doesn't make it a religious belief although she uses her belief in a God to explain rainfall. However, it is a religious belief that rainfall is under the control of God and He can decide to cause rain to cease or cause it to flood or cause just the right quantity to fall to water the earth. It is not uncommon to find Christians praying for rain in times of drought. I have witnessed personally during outdoor evangelistic crusades on the eminent threat of rain where the saints lift their voices in prayer and the clouds are dispersed. These differences between religious beliefs and religious explanations may have had an influence on people's approach to managing the conflict between the two worldviews;

however, the data did not speak directly to this issue, and therefore I did not rely on this distinction in my analyses.

Implications for Instruction

The arguments some participants gave in favor of their religious believes over scientific explanations were grounded on solid scientific reasoning. Therefore, classroom discourses on such controversial topics will give people like Ernest and Michael opportunities to express their logical and evidence-based reasoning behind their decision to choose religious beliefs over science explanations in some instances. Dagher and BouJaoude (1997) argued that avoiding classroom discussion on the religious and science worldviews does not help ease the tensions that students encounter when they are exposed to conflicting schemata. Other authors have concurred. By arguing that a distinction between knowledge and beliefs is wrong, Cobern (2000) calls for educators to focus on classroom discourse that addresses reasons behind people's knowledge and beliefs instead of categorizing knowledge and belief.

In relation to their classroom experiences

I discussed in chapter four that participants avoided discussing issues that were controversial to their religious beliefs due to the emotional discomfort it brings. This seems to be contradictory to the recommendation of classroom discussions on the tensions between religious beliefs and scientific explanations. However, just like the treatment for those with acrophobia is to gradually expose them to heights, those who avoid discussions because of its emotional effects can be gradually expose to classroom discussions in line with the recommendations from previous studies.

Teaching the nature of science

Several reasons participants gave for choosing their religious beliefs over scientific claims fall within the nature of science argument; the bounded and temporary nature of science. Although they used this nature of science argument as cause to discredit scientific explanations when they conflict with their religious beliefs, teaching that science is empirical, tentative, and bounded, and that it's only one way, but not the only way, of understanding the world can help ease tensions experienced by students. Southerland and Scharmann (2013) argued that explicitly teaching the bounded nature of science (i.e., the way of thinking, way of working, and way of knowing employed by scientists), can help students navigate the contradictions between their beliefs and science explanations. Southerland and Scharmann (2013) also argued that teaching the epistemological foundations of science and encouraging students to apply that epistemology when they see appropriate can also help.

On my teaching practice

Before this research, I had shied away from discussing religion-science tensions in the classroom with my students. This research has made me to see the need to explain beforehand to students, where I anticipate that the topic under discussion will be controversial, that there may be things that contradict what they believe. In this case, I will encourage them not to take it very personally as opposing their beliefs but as alternate ways of explaining the same phenomenon. I will also encourage students to openly discuss their viewpoints on controversial issues in the classroom and that they are free to choose whichever explanation makes more sense to them. However, they are required to learn the scientific explanation for the purpose of assessments. I will also

offer additional assistance to students who need help in navigating the cultural border, sharing strategies that others have used.

Conclusions

I conclude that people may not always be placed in categories as was portrayed in the existing literature, but will manage the tension as per the issue at stake. The divide that has been placed between science and religion is at best artificial in nature and may not always determine how people relate with the two worldviews.

Chapter six: Conclusions and further research

In this chapter, I will summarize the main points of this study and discuss the conclusions drawn from chapters four and five. I will also discuss the directions for further research which were partly discussed in chapters four and five.

As shown in chapter four, when schemata from people's religious and scientific worldviews interact, people experience far beyond cognitive dissonance. These experiences were shown to affect some emotionally, others "spiritually" in the sense that they had to deconstruct and reconstruct their faith, and others even experienced physical headache as a result of the stress they had to handle when dealing with conflicting schemata from the two worldviews. Irrespective of the degree of influence of people's environment, each participant was shown to have at least one form of negative experiences due to the conflicting nature of the religious beliefs and scientific explanations. These negative experiences include feelings of alienation, destabilization of faith, emotional distress, mental distress, and feeling disrespected or insulted. We showed that some of these experiences were unique to individuals while others were common across individuals.

To mitigate the effects of these negative experiences, people developed resilience strategies in anticipation of, or in response to, the experiences. Those who were able to anticipate such negative experiences and develop strategies to overcome them showed less hazardous border crossing experiences unlike their counterparts who only developed such strategies in response to the negative experiences. I also showed that those who experienced the least hazardous border crossing had invested some efforts to "get to a point" where they could disconnect themselves emotionally from what they studied.

Also, those who endeavored to avoid situations of argumentation were able to significantly reduce the hazardous nature of their border crossing experience. The resilience strategies developed include deferring understanding, disconnection, recasting, avoidance, playing school, mental shutting, referencing, and self-talk. We showed that there were resilience strategies that were unique to some individuals and others that were common across individuals.

In addition to developing strategies to overcome their negative border crossing experiences, participants engaged certain resilience resources to help them navigate the borders between their religious and scientific life-worlds. The resources employed were extracurricular information sources, spiritual environment support, peer support, parental support, knowledge of role models, and contact with role models. Again, like with experiences and resilience strategies, resilience resources had elements that were both common across individuals and some that were unique to individuals.

In chapter five, I looked at how people manage the tensions between their religious and scientific worldviews and what justifications or reasons they provide for their different approaches to resolving the tensions. Unlike the current literature which categorized people with respect to their approaches to resolving the tension between conflicting schemata, I showed that people's approaches are fluid in nature and could not fit into any one category because the approach used at any one time depended on the particular conflicting situation at hand.

Three approaches were common among most of the participants namely rejection of scientific explanations in favor of religious beliefs, compartmentalization of religious

beliefs and scientific explanations, and reconciliation of both worldviews. There were two cases were every scientific explanation was rejected in favor of their religious beliefs even when the conflict was just an apparent one. Even for those who applied different approaches depending on the context, they did so from different positions or using different arguments. For example those who rejected scientific explanations in favor of religious beliefs did so from a scientific perspective or from a religious perspective. That is, some provided scientific reasons, sometimes faulty, for rejecting scientific explanation while others provided religious reasons for rejecting scientific explanations while some did so from both perspectives.

Justifications people provided for their approaches to resolve the tensions between their worldviews centered on the nature of science and the "nature" of God and His word arguments. Such justifications include the bounded nature of science versus the unbounded nature of God, the temporary nature of science versus the eternal nature of God's word, gaps in the Bible's position on certain aspects, the theoretical nature of certain scientific arguments versus their personal experience of their beliefs, and the fallible nature of human arguments and inventions.

The separation that some have tried to establish between science and religion was shown to be artificial due to the fact that people's life-worlds have been shown to be very interconnected in nature. Many of the participants did not see any separation between their religious beliefs and scientific explanations as some viewed science as just another form of divine revelation or an avenue to understanding God's creation. Even those who held a theoretical position of separation of their religion and science, in some cases sought to reconcile the two worldviews when it came to actual approaches to resolving

the tension. Hence, people's theoretical position did not always match their practical positions.

Implications

In this section, I will give a recap of the implications drawn in chapters four and five, and discuss further implications from the findings. I showed that students with fundamental Christian beliefs all experience some form of border crossing hazard and are in need for some form of escape. Teachers can reinforce whatever support these students have by encouraging them to form peer support groups, facilitating their contacts with scientists who hold fundamental Christian beliefs, and act as tour guides for these students in the world of school science.

Science curriculum should include readings on the history of science and scientists who made contribution to the body of scientific knowledge we have today and the different worldviews they espoused in addition to their scientific worldview. Doing this will provide students with knowledge of role models like Newton, Pascal, Faraday, and a host of others who held fundamental Christian views yet were scientists who made significant contributions to the world of science.

Just as there is dropout prevention for at risk students in general, there could be a science dropout prevention tailored specifically for students who are interested in science but whose religious beliefs places them at risk of dropout due to hazardous border crossing.

Church school partnerships

Schools and local churches can also collaborate in helping students with fundamental Christian beliefs maintain their pursuit of scientific careers by working with pastors to identify church members of churches with fundamental Christian beliefs to act as role models for their fellow parishioners and act as support group mentors, visiting experts, and coaches and tour guides for students in local schools who may be experiencing hazardous border crossing. Churches can provide their venues to host discussions on the relationship between science and religion.

For example, Church dining rooms or other unused rooms can be used as a third space between mentors or role models and students who are having a hazardous border crossing experience into the world of school science from the religious life-world. In such a third space, these mentors or role models—that is, practicing scientist who also hold fundamental Christian beliefs—can share their own personal struggles in crossing the science-religion border both as students and as practitioners. Such a sharing of their experiences, and the strategies and resources that helped them navigate those borders, can go a long way to ease the border crossing experience of these individuals in several ways. First, just being upfront with their personal struggles will be a form of encouragement and motivation for these struggling students. Second, sharing their strategies and resources will equip these struggling students on how to navigate this cultural border. Third, these experts can help facilitate access to extracurricular information sources that will enable students to arrive at their own conclusions without feeling obliged to accept scientific explanations.

Similarly, this third space should provide opportunities for struggling students to freely discuss their own struggles and tensions and ways by which they have personally handled it. Sometimes students learn best from peers rather than from experts. In such a case the experts will act as group facilitators of the exchanges between students. In this third space, students can also be given the opportunity to discuss these controversial topics using funds of knowledge from their religious worldview, and asked to defend their positions on these controversies between their worldviews. The roles of the experts during such discussions can also be to help students construct bridges where possible between their religious worldviews and the world of school science.

Local schools and local churches can also create some form of curriculum that looks into detail the life history of scientists like Newton, Pascal, Faraday, and others to help students develop the mindset that science and religion are not always at odds.

Future research

There are several directions the dissertation research can take in the future. First, I will like to broaden the research pool to include participants from other ethnic groups and races. Such a broader participant pool will make it possible for generalization of the research beyond those from West African nations. The insights gained from this study will be of utmost importance when conducting a similar study with a broader research pool.

A second direction for future research is to conduct a similar research for people with fundamentalist leanings from other religious groups and draw a cross religion analysis. A similar research was conducted in Lebanon in 2007 by Dagher and Boudjaoude but with nominal members of the different religions of the nation. Like I

argued before, those who subscribe to a religion only nominally may not be inclined to hold dear some fundamental tenets of their religion and therefore may not be disturbed cognitively or otherwise by schemata that challenge the beliefs. Limiting the pool to those with fundamental beliefs can give a true picture of the differences and similarities across religions.

A third possible direction for future research is to conduct a separate research with elementary school children and another with secondary school children. Since all of the participants in current research were all college students or graduates, it may be informative when one looks into each of the aforementioned groups and a possible comparative analysis between groups for age specific experiences, strategies, and resources or age-specific approaches to resolving the tension between people's religious and scientific worldviews.

Finally, a fourth possible direction for future research is to carry out a longitudinal study across at least one school level, of individual's experiences, strategies, resources, and approaches to resolving the tension between their worldviews to look for evidence of whether people change or not along these dimensions as they move across academic grades.

Appendix A

Interview Protocol Part 1

- Tell me about the role of the Bible in your life
- How does the Bible influence what you accept or reject in life?
- Tell me about some of the things you liked about your science classes and why?
- What topics didn't you like in your science classes and why?
- In what ways do your religious beliefs affect your attitude to science and scientific explanations?
- Has there ever been a situation in class where some science explanations contradicted your religious beliefs? Tell me about one or two specific situations.
- What was going through your mind when you encountered such contradictions?
- How did you feel about such contradictions?
- In what ways have scientific explanations influenced what you believe?
- How have you succeeded to keep the pursuit of science related career in spite of these contradictions and negative emotions?
- Are there things or people who may acted as supports or role models in your pursuit of science related career?
- Is there an advice you may want to give to others who may face such conflicts, on how to keep their pursuit?

Sample Interview Questions part 2

1. Have you ever thought about the creation story? How do you explain these verses "Then God said, "Let us make mankind in our image, in our likeness, so that they may rule over the fish in the sea and the birds in the sky, over the livestock and all the wild animals,[a] and over all the creatures that move along the ground." 27 So God created mankind in his own image, in the image of God he created them; male and female he created them." (Ge 1:26-27)
2. What do these verses mean to you?

   "And God said, "Let there be lights in the vault of the sky to separate the day from the night, and let them serve as signs to mark sacred times, and days and years, 15 and let them be lights in the vault of the sky to give light on the earth." And it was so. 16 God made two great lights—the greater light to govern the day and the lesser light to govern the night. He also made the stars. 17 God set them in the vault of the sky to give light on the earth, 18 to govern the day and the night, and to separate light from darkness. And God saw that it was good." (Ge 1:14-18)
3. I am interested in knowing what these verses mean to you,

   "And God said, "This is the sign of the covenant I am making between me and you and every living creature with you, a covenant for all generations to come: 13 I have set my rainbow in the clouds, and it will be the sign of the covenant between me and the earth. 14 Whenever I bring clouds over the earth and the rainbow appears in the clouds, 15 I will

remember my covenant between me and you and all living creatures of every kind. Never again will the waters become a flood to destroy all life. 16 Whenever the rainbow appears in the clouds, I will see it and remember the everlasting covenant between God and all living creatures of every kind on the earth." (Ge 9: 12-16)

4. Explain, what does "moon light" mean?

   How does the light come about?

5. Tell me what you know about the rainbow:

   - How does the rainbow occur?

   - Can you explain to me why there are rainbows?

6. Have you heard/learnt of the theory of evolution? Tell me what you know about it. What is your opinion about this theory?

Appendix B

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DATE:	October 14, 2013
TO:	Celestine Nakeli, MS
FROM:	University of Maryland College Park (UMCP) IRB
PROJECT TITLE:	[507010-1] Cultural Border Crossings in Science: Religious beliefs and their interference with, or enhancement of Scientific Phenomena among African Immigrants
REFERENCE #:	
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	October 14, 2013
EXPIRATION DATE:	October 13, 2014
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # *6 & 7*

Thank you for your submission of New Project materials for this project. The University of Maryland College Park (UMCP) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the appropriate revision forms for this procedure which are found on the IRBNet Forms and Templates Page.

All UNANTICIPATED PROBLEMS involving risks to subjects or others (UPIRSOs) and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

This project has been determined to be a Minimal Risk project. Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of October 13, 2014.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

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