Science and Mathematics Education Centre

A Study on Christian Students Acceptance and Understanding of Biological Evolution in a West Australian Faith Based School

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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ABSTRACT

This study explored the relationship between acceptance of a Christian worldview and three other factors: understanding of biological evolution; acceptance of biological evolution; and science-related attitudes. In addition, the presence or absence of implications of this relationship for science education and learning were discussed.

Participants included 101 Year 8, 10, 11 and 12 students from a non-denominational Christian secondary school in metropolitan Perth, Australia. Their conceptions of the relationship between acceptance of a Christian worldview and the other three variables were assessed using a newly formed questionnaire consisting of four scales: Understanding and attitudes towards the Bible and Religious Faith (Pope, 2014); Test of Science-related Attitudes (TOSRA) (Fraser, 1981); Understanding of the theory of Evolution; and Measure of Acceptance of the Theory of Evolution (Rutledge & Warden, 1999). In conjunction with the questionnaire, follow-up interviews were conducted with eight Year 10, 11 and 12 participants who were either enrolled in the Western Australian Course of study, Human Biological Science or had completed a unit of study on biological evolution in their general science class.

The quantitative data was analysed using the SPSS software package, identifying associations between variables, and analysis of the qualitative data involved describing emergent themes. The relationship which produced the most significant results, both quantitative and qualitative, was that between acceptance of a Christian worldview and acceptance of biological evolution. The simple correlation and standardised regression coefficient, between the Acceptance of a Christian Worldview scale and the Acceptance of the Theory of Evolution scale were both statistically significant. Both tests reported a negative association.

Regarding acceptance of biological evolution, emergent themes in the interviewed data revealed three categories of participant perspective: complete rejection; complete acceptance; and partial acceptance. The majority of the participants were categorised as partially accepting and took this position with strong reference to their Christian worldview. In particular, to allow the co-existence of biological evolution and the participant's Christian worldview, many students created alternate explanations and interpreted the scientific evidence in a variety of ways. The findings demonstrated the

complex relationship between students' interpretations of their Christian worldview and acceptance of biological evolution. In conclusion, the study confirmed current research, demonstrating that adoption of a Christian worldview was negatively associated with acceptance of biological evolution. The study suggested the need for thoughtful and intentional teaching practice in the context of biological evolution in the science curriculum if acceptance is to improve.

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No evidence is powerful enough to force acceptance of a conclusion that is emotionally distasteful.

-Theodosius Dobzhansky, *Genetics and the origin of the species*

TABLE OF CONTENTS

List of Tables

List of Figures

List of Appendices

Chapter 1: Introduction

1.1 INTRODUCTION

The aim of this research was to explore the impact of a Christian worldview on science- related attitudes and acceptance and understanding of biological evolution of secondary level students within the context of a Western Australian faith-based school. This was achieved using the framework provided by the science-religion research community (Alters & Alters, 2001; Barbour, 1990; Ferguson & Kameniar, 2014; Lawson & Worsnop, 1992; Meadows, Doster, & Jackson, 2000; Miller, Scoot, & Okamoto, 2006; Shipman, Brickhouse, Dagher, & Letts, 2002; Wood & Scharmann, 2001), focusing on the interactions between a Christian worldview and various aspects of scientific thinking. Chapter 1 provides an introduction to the topic under investigation and an overview of any relevant background information. Section 1.2 aims to describe such background information, while Section 1.3 describes the research objectives followed by a presentation of the conceptual framework in Section 1.4. Section 1.5 and 1.6 detail the research questions and the context of the study and followed by, Section 1.7 includes a brief description of the researcher's background and personal views. To conclude, Section 1.8 summarises the chapter and describes an overview of the thesis.

1.2 BACKGROUND OF THE STUDY

Biological evolution has often been described as the single most important concept in biology as it acts as a unifying and coherent explanatory theme within the study of the natural living world (Cavallo & McCall, 2008; Rice & Kaya, 2010; Schilders, Sloep, Peled, & Boersma, 2010). It is also a key part of the Australian Curriculum: Science in Year 10 and then again in the Western Australian Year 12 Course of Study, Human Biological Science. According to the 2001 Australian Census, over 12 million Australian people claim to be Christians, which implies approximately 68% of the population claim to adopt a Christian worldview (Australian Bureau of Statistics, 2001). Along with the proportional enrolment of non-government schools in Australia being approximately 35% in 2014 (Australian Bureau of Statistics, 2014), these statistics provide a strong rationale for the benefit of a study looking specifically at students in a faith-based school. The literature consistently concludes that religious

beliefs can act as a predictor for rejection of biological evolution (Alters & Alters, 2001; Ferguson & Kameniar, 2014; Lawson & Worsnop, 1992; Meadows et al., 2000; Miller, Scoot, & Okamoto, 2006; Shipman et al., 2002; Wood & Scharmann, 2001) and it is therefore justified that further research be conducted in relation to students in Australian faith-based schools and their acceptance of biological evolution.

1.2.1 Christian worldview

According to Cobern (1997) a worldview can be described as a culturally dependant, generally subconscious fundamental organization of the mind. It sets the parameters for who and what an individual is, his or her relationship with the environment and even his or her perception of space and time. The development of worldview is one that happens over a long period of time but is already in its stage of infancy, setting the foundation for how new concepts are learned, at a young age. The term 'Christian worldview' is somewhat difficult to define as there are many diverse beliefs and interpretations of the Bible even within Christian tradition. It is important, however, to acknowledge the role of the Bible in forming a Christian worldview. Possibly one of the most essential core beliefs of an individual professing a Christian worldview would be the belief in the existence of a sovereign God as creator. Another would be the acknowledgement of Jesus Christ as a historical figure and source of salvation. These two major concepts are paramount and set the foundation for all other aspects of the Christian worldview (Dickson, 2007; Sire, 1988).

The notion that all of creation is the deliberate product of God's will and the object of His affection is the first and most distinctive feature of the Christian worldview. This theme establishes God as being the creator of the Universe and its preserver. The Christian worldview indicates that humans will only find their true purpose when they connect with their source, God (Dickson, 2004).

The second foundational theme is that at some point in human history, sin was introduced by mankind and this sin had to be atoned for in order for mankind to spend eternity with God the creator. It is believed the crucifixion and resurrection of Jesus Christ provided an adequate atonement for the sins of mankind, should the individual accept Christ as their personal saviour (Dickson, 2007; McGrath, 2011).

Additionally, there are several other core beliefs that are shared by all individuals who profess to have a Christian worldview. Dickson (2004) identifies these core beliefs as:

1. The Holy Trinity
2. The 'Kingdom of God'
3. The love ethic

1.2.2 Science-related attitudes

Gardner (1975) describes science-related attitudes as feelings, beliefs and values held about an object that may be the enterprise of science, school science, the impact of science on society or scientists themselves. An inquiry into various aspects of 'attitudes towards science' was made by Klopfer (1971), who categorized a set of affective behaviours in science education as the:

- manifestation of favourable attitudes towards science and scientists;
- acceptance of scientific enquiry as a way of thought;
- adoption of 'scientific attitudes';
- enjoyment of science learning experiences;
- development of interests in science and science-related activities; and
- development of an interest in pursuing a career in science or science-related work.

Osborne, Simon, and Collins (2010) have stated that there are a number of factors influencing attitudes towards science, including but not limited to gender, classroom/teacher factors and curriculum variables. Not mentioned in the literature were religious factors, which this study was designed to investigate.

1.2.3 Biological evolution in Science curriculum

The teaching of evolution in Australian schools has not met the same degree of controversy as in the United States, although resistance to acceptance of evolution is still clearly evident (Dawkins, 2009). According to Price (1992), Creationism was originally viewed as an insignificant and transient 'American Import', but it has since grown in popularity. Darwin has been credited with first presenting biological evolution to the public in its most credible form in his book, 'On the Origin of Species' (Darwin, 1859). Darwin made three key observations (Newton & Joyce, 2010):

1. Variation: There is variety within a species
2. Birth rate: More offspring of a species are produced than the environment can sustain
3. Natures Balance: Each species appeared to maintain their numbers at a constant level

According to Newton and Joyce (2010), as a result of these three observations, Darwin produced two important assertions which form the foundation of traditional Darwinian evolution. These include:

1. Struggle for existence: Due to excessive birth rate, and limited resources, there is a competition for survival
2. Survival of the fittest: The individuals with characteristics best suited to the environment have more chance of surviving and reproducing

In essence, the theory of evolution implies that through various mechanisms, natural selection being a major contributor, gene frequencies are able to change over time (Prothero, 2007). Coyne (2009) suggests that some of the key topic areas within biological evolution consist of random genetic mutation; natural selection; and speciation.

1.2.4 Acceptance of biological evolution

According to Sinatra, Southerland, McConaughy, and Demastes (2003, p. 512) acceptance 'refer[s] to a learner's personal assessment of the validity of a construct' based on a 'systematic evaluation of the evidence'. The rejection of biological evolution is an international controversy that exists in a variety of versions. Considering the incorporation of biological evolution in the science education curriculum, the current situation has been described as easily being the biggest failure of science education from top to bottom in recent times (Branch & Scott, 2008; Miller, Scott, & Okamoto, 2006). The Australian Institute of Biology conducted a national poll in 1992, including a sample of 4225 students across seventeen universities, revealing that 12.6% of first year biology students in Australian universities believed that, "God created man within the last 10,000 years" (Price, 1992). Although the major influence on students' acceptance of evolution is regularly cited as being based on

religious convictions, it is not the only factor being discussed in current research. Based on a review of current literature, Wiles and Alters (2011) compiled a list of factors which appear to be linked to students' rejection of biological evolution: religious factors; scientific factors; social and emotional factors; critical thinking and epistemological views; and demographic factors.

1.2.5 Relationships between Christian worldview and biological evolution

There is a large amount of literature available on the relationship between science and religion (Barbour, 2000; Brooke, 1991; Gould, 1990; Reiss, 2009). Among the most frequently cited concepts in the science/religion field is Barbour's (1990) four interactions of science and religion. These models could be summarised as Conflict, Independence, Dialogue, and Integration. The conflict model is commonly adopted by individuals who describe themselves as 'young-earth creationists' and a small group of infamous atheist scientists, and best described as a struggle between a religious worldview and science where they cannot both be correct. Barbour (1990, p.4) describes this visually stating, "In a fight between a boa constrictor and a wart-hog, the victor, whichever it is, swallows the vanquished. In scientific materialism, science swallows religion. In biblical literalism, religion swallows science".

The conflict between biological evolution and a Christian worldview has been greatly intensified by specific groups of evangelical Christians who identify themselves as 'Creationists' or 'young-earth creationists' (Ham, 1989; Sarfati, 1999). Sarfati (1999) suggests that the book of Genesis from the Christian Bible provides a literal account of the events leading to the origin of life on Earth taking place in a location known as Eden over six 24 hour days. Sarfati (1999) goes on to suggest that God instantaneously created different kinds of organism which reproduced and from them further biodiversity developed. According to several Creation Ministries publications (Batten, 1999; Ham, 1987; Sarfati, 1999; Weiland, 1997) some key reasons the authors encourage the rejection of biological evolution among the Christian community, in no particular order, are as follows:

1. Acceptance of evolution is the underlying foundation of immorality in society (Bergman, 2006; Cosner, 2010; Ham, 1987; Weiland, 1998; Zimmermann, 2008).

2. Acceptance of biological evolution is the rejection of the authority of the Bible (Batten, 1999; Doyle & Reed, 2013; Grigg, 1996; Sarfati, 1999).

3. Acceptance of biological evolution undermines the concept of original sin and therefore salvation through Christ (Batten, 1999; Cosner, 2008; Cosner, 2009; Ham, 1987; Sarfati, 1999; Smith Jr, 2007).

4. The evidence supporting the occurrence of biological evolution and the mechanisms driving it are unsatisfactory (Austin & Humphreys, 1990; Bergman, 2004; Doyle, 2014; Grigg Batten, 1999; Ham, 1987; Oard, 2014; Sarfati, 1999; Snelling, 1992; Swenson, 2001; Walker, 2010; Walker, 2014; Weiland, 1997; 1998; White, 2001; 2003; Williams, 1995).

An equally vocal cohort of atheist writers have over recent times been reinforcing the fundamental young-earth creationist dogma, evolution and religious faith are incompatible (Coyne, 2015; Dawkins, 2006). Within this body of literature there appear to be two major implications regarding the relationship between a Christian worldview and acceptance of biological evolution, the second being much broader in scope but equally significant. These are:

1. Biological evolution explains organic diversity without the need for the supernatural. Even more so it acts as evidence for the non-existence of god (Coyne, 2015; Dawkins, 1996, 2006).

2. Scientific practice is incompatible with a religious worldview (Coyne, 2015; Dawkins, 2006; Holliday, 2006).

Babour's (1999) second, third and fourth descriptions of the relationship between scientific thinking and a religious worldview all have one major theme in common, they are not in conflict. Several authors such as Meadows (2007), Jones, (2007) and Reiss (2007) have suggested adopting a non-conflict model regarding the teaching of biological evolution and the religious worldview of the students in the classroom. Within the literature there appears to be five major implications regarding the non-conflict model of a relationship between a Christian worldview and acceptance of biological evolution.

1. Acceptance of biological evolution is not significantly linked to immorality in society (Alexander, 2008; Miller, 1999).

2. Acceptance of biological evolution and an old earth does not undermine the authority of the Bible (Dickson, 2009; Giberson, 2008; Lennox, 2011; Miller, 1999; Osborn, 2014; Poole, 2007; Rana & Ross, 2005; Walton, 2009).

3. Acceptance of biological evolution does not undermine the concept of original sin (Alexander, 2005; Blocher, 1984; Collins, 2006; Lennox, 2011; Longman III, 2005; Osborn, 2014; Rana & Ross, 2005).

4. Biological evolution does not act as evidence for the non-existence of god (Alexander, 2005; Lennox, 2011; McGrath, 2007; Ruse, 2007; Walton, 2009).

5. Scientific practice is compatible with a religious worldview (Alexander, 2005; Collins, 2006; Lennox, 2011; McGrath, 2007; Walton, 2009).

1.3 RESEARCH OBJECTIVES

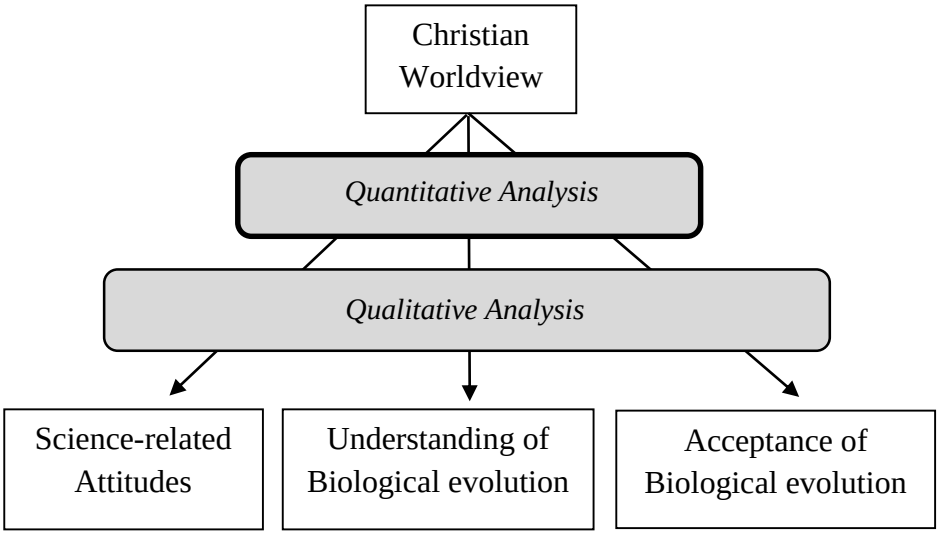
While a great number of studies pertain to the relationship between religious worldview and acceptance of biological evolution, the vast majority of these studies involve students from the United States or the United Kingdom. Very few studies have been conducted in an Australian context and none in a Western Australian context. These studies have revealed a negative trend towards acceptance of biological evolution in relation to religious beliefs and this study intends to add to this body of literature. To add greater context, this study aimed to investigate high school students from a Christian faith-based school of which many held a Christian worldview. Much of the literature focuses on students enrolled in tertiary institutions and therefore the perspectives of high school students are underrepresented. The research adds of the body of literature that explores the association between a Christian worldview and their acceptance and understanding of biological evolution. Another objective of this study was to describe the link between students who adopt a Christian worldview and their science related attitudes, if one exists. New information is presented in the form of students' discussions of their interpretations and perspectives regarding biological evolution and how this may be influenced by their Christian worldview. This information has the capacity to inform science educators so they are able to design engaging classroom experiences that allow a greater number of students to take part while minimising any conflict the students may be apprehensive about.

1.4 CONCEPTUAL FRAMEWORK

This study was designed to address four expansive areas of research and explore a possible link between them, in particular the influence of a Christian worldview on the remaining three areas of interest: Science-related attitudes; Understanding of biological evolution; and acceptance of biological evolution. The inter-relationship between these areas of study has been presented in Figure 1.1.

The methodological interaction between these fields, as utilised in this study has also been presented in Figure 1.1 where all three relationships were initially analysed by quantitative approaches and followed by qualitative methods. A justification for the methodologies used is described in Chapter 3.

Figure 1.1 *Methodological interactions of the key research areas examined in this study.*



1.5 RESEARCH QUESTIONS

There is a large body of literature discussing the link, if any, between understanding of biological evolution and acceptance of the theory. For the most part the findings do not necessarily indicate a general consensus as several studies have suggested a strong positive association (Rutledge & Warden, 1999, 2000; Trani, 2004) while others have described the relationship as non-significant (Bishop & Anderson, 1990; Demastes, Settlage, & Good, 1995; Lord & Marino, 1993; Sinatra et al., 2003). While this is an

interesting topic, this study was focused on the influence of a Christian worldview and has therefore led to the formation of the first research question.

1. What effect does attitude and acceptance of a Christian worldview have on students' understanding of the theory of biological evolution?

Several studies have explored this relationship (Kim & Nehm, 2011; Nehm, Kim, & Sheppard, 2009) and determined that any predictability is non-significant and this study aimed to add to this area of research.

An area of research which is abundant in literature is the association between religious beliefs and acceptance of biological evolution (Alters & Alters, 2001; Ferguson & Kameniar, 2014; Lawson & Worsnop, 1992; Meadows et al., 2000; Miller, Scoot, & Okamoto, 2006; Shipman et al., 2002; Wood & Scharmann, 2001). In each case a resounding negative association has been confirmed and this study aimed to add an Australian context to the current available scholarship. Consequently the second research question was designed.

2. What effect does attitude and acceptance of a Christian worldview have on students' acceptance of the theory of biological evolution?

A final area of interest are students' science-related attitudes and how these may be influenced by the adoption of a Christian worldview. A wealth of studies explore factors which may affect science-related attitudes (Cooper & McIntyre 1996; Myers & Fouts 1992; Osborne et al., 2010; Weinburgh, 1995) but none specifically address the influence of a Christian worldview. The final question therefore explored:

3. What effect does attitude and acceptance of a Christian worldview have on students' attitudes to science?

Through an examination of the three research questions above a deeper understanding of the relationship between a student's Christian worldview and their understanding and acceptance of biological evolution, as well as science-related attitudes has been developed.

1.6 CONTEXT OF THE STUDY

This study was conducted in a non-denominational Christian secondary school where the researcher was employed, located in metropolitan Perth, Australia. In Australia, faith-based schools are financially supported by a religious organisation in addition to receiving further financial support through the collection of tuition fees and state and federal funding. The complete secondary school (Year 7-12) consisted of approximately 321 students in 2011 and ran an almost identical curriculum to a Western Australian state school with some important differences. The key variances between a Western Australian state school and the Christian faith-based school from which the sample was obtained were heavily based on the Christian nature of the school. Regarding student enrollments, the school had an 'open policy' meaning that the students enrolled do not need to be a practicing Christian to attend but the parents must agree to support the Christian values and 'Statement of faith' professed by the school. The teaching staff, who must be practicing Christians, were also expected to integrate their Christian values into the context of their lessons on a regular basis. The school had no official statement regarding biological evolution except that it is part of the Australian Curriculum and must be taught. The Science staff had varying opinions regarding biological evolution, from complete acceptance to complete rejection, but would teach the topic according to the Western Australian curriculum.

The data was collected throughout the 2011 school year and the sample included Year 8, 10, 11 and 12 students. Students from Year 11 and 12 (aged 16, 17 and 18) were studying a Human Biological Science course while all students from Year 8 (aged 13) and 10 (aged 15) were invited to take part in the study. Only students from Year 10, 11 and 12 were invited to take part in the interview process as they were at an age where they were more likely to be mature enough to deal with the controversy of the topic.

A mixed methods approach to the research problem was adopted and involved collecting data from 101 secondary school students from a Western Australian faith-based school. The data included responses to a newly formed questionnaire containing four distinct scales: Understanding and attitudes towards the Bible and Religious Faith (Pope, 2014); Test of Science-related Attitudes (TOSRA) (Fraser, 1981);

Understanding of the theory of Evolution; and Measure of Acceptance of the Theory of Evolution (Rutledge & Warden, 1999). In conjunction with the questionnaire, follow-up interviews were conducted with eight participants. The quantitative data was analysed using the SPSS 22 software package identifying associations between variables and analysis of the qualitative data involved describing emergent themes.

1.7 PERSONAL PERSPECTIVE

This research has been conducted from an Interpretivist paradigm as such includes the belief that each human will interpret stimuli slightly differently based on their personal experiences and beliefs. The role of the researcher in this study was significant and therefore commenting on his or her personal views and perspectives is essential.

I approach this research with my own personal worldview which has been shaped by my experiences and beliefs and could be described as predominantly Christian. My current employment was at a Christian faith-based co-educational school where I had been employed for more than a decade to teach general science and Human biology. My Christian faith influences all aspects of my life including my practice as a science educator, while my training in science is also deeply embedded into my worldview. In this sense I hold a personal epistemology and ontology which are strongly influenced by studies in Science and my Christian faith. I view the Bible as a credible source of truth in addition to the methods of Science. I also acknowledge the existence of the material and the immaterial, specifically God.

From a very young age I have attended religious events and have had regular opportunities to discuss my beliefs and their implications. One particular perspective which I had between childhood and late adolescence was that of a young-earth creationist. Up until the completion of my undergraduate bachelor degrees in Science and Education I experienced conflict between aspects of my Christian worldview and acceptance of biological evolution. If given an opportunity I would engage with peers or educators in debate regarding the reliability of the evidence for evolution and believed that biological evolution was incompatible with my Christian worldview. Over a period of time involving many lengthy discussions and extensive personal

research, I came to the conclusion that the scientific community can in fact be trusted and the evidence for biological evolution was overwhelming.

Two key principals guided my approach to this topic as a result of my personal worldview. Firstly, biological evolution is currently the most likely explanation for the diversity of life on Earth. Although the mechanisms of evolution are tentative and regularly debated, its occurrence is not. As a materialistic explanation for the process by which life has developed over time, I believe that biological evolution has stood up to criticism and scrutiny repeatedly. Secondly, I believe that this is not in contradiction with my Christian beliefs. I am completely satisfied with the materialistic methods of science and do not feel that my religious views are being threatened. In this way I strongly support the notion that Christian worldview and science can coexist and in this context need not conflict.

1.8 SUMMARY OF THESIS

Chapter 1 provides an introduction to the research project by describing the background to the research and outlining its objectives. Following this a conceptual framework is presented which demonstrates how this project can be placed within the literature. The research questions addressed in the project are articulated and the context of the study discussed, along with a brief overview of the methodology used to address the three research questions.

Chapter 2 presents an extensive review of the literature as it pertains to this study, including a review of the scholarship: Christian worldview; Science-related attitudes; biological evolution in science curriculum; acceptance of biological evolution; and the relationship between Christian worldview and acceptance of biological evolution. Throughout the review, studies that provide specific insight in these areas are synthesised and evaluated.

Chapter 3 reports on the methodology used in this study and includes a description of the techniques used to collect and analyse the data used in this investigation.

Chapter 4 reports the results obtained from the analysis of data where each of the three Research questions were addressed in succession. The results obtained from statistical analysis of the quantitative data are presented initially followed by analysis of the qualitative data. For each chapter the key findings are highlighted.

Chapter 5 provides a discussion of the results from the quantitative data analyses relevant to each of the three research questions. Following this, the results from the qualitative data are presented in an in depth discussion with specific attention to the interpretations and perspectives of the student participants. The research findings are placed within the context of the relevant literature and the chapter concludes with a general discussion and summary of the key findings.

Chapter 6 concludes the report on this investigation with a summary of the study and its findings. This is followed by a description of the distinct contributions made by the study, some comments on the limitations of the study and a discussion of the practical implications of the findings. Finally, recommendations for future research are presented followed by some concluding remarks.

This chapter is followed by Chapter 2, which provides a review of the literature associated with Christian worldview, Science-related attitudes, biological evolution in science curriculum, acceptance of biological evolution and the relationship between Christian worldview and acceptance of biological evolution.

Chapter 2: Literature Review

2.1 INTRODUCTION

Chapter 1 provided an overview of the purpose of this study, which was to examine the role of Christian worldviews on science-related attitudes and acceptance and understanding of biological evolution in secondary of students' from a Western Australian faith-based school. This second chapter will provide an overview of the literature that pertains to the achievement of that purpose. To achieve this purpose, three research questions were developed. The first question was designed to explore the effect that acceptance of a Christian worldview has on students' understanding of the theory of biological evolution. The second question sought to investigate the effect that acceptance of a Christian worldview may have on understanding of biological evolution while the final research question aimed to examine a possible link between acceptance of a Christian worldview and science-related attitudes.

This chapter reviews the relevant literature that pertains to the three fields of inquiry including the interaction of an acceptance of a Christian worldview, acceptance and understanding of biological evolution and science-related attitudes. After the introductory section, Section 2.2 explores the literature on Christian faith-based schools, core values of a Christian worldview, factors contributing to worldview formation and its measurement. Following this section, a review of the literature on science-related attitudes, factors affecting such attitudes and their measurement is also conducted in section 2.3. Section 2.4 consists of an analysis of the placement of biological evolution in science curriculum in addition to a brief summary of the key concepts of biological evolution according to the most recent scientific scholarship. Subsequently, section 2.5 synthesises the literature pertaining to acceptance of biological evolution, the factors affecting such acceptance and methods of measurement. Section 2.6 begins with a detailed review of the relevant literature available on the relationship between Christian worldview and acceptance of biological evolution. This section continues by contrasting the 'conflict' model of interaction with a model of 'non-conflict' and provides a synthesis of the literature expounding both models. The concluding section 2.7 provides a summary of the literature addressed in Chapter 2.

2.2 CHRISTIAN WORLDVIEW

This section provides a review of the literature on Christian worldviews. It begins by providing a rationale for faith-based schooling in Australia, followed by a general description of the concept of a worldview. The concept of a Christian worldview is then expounded identifying six core beliefs associated with such a worldview. These include: the Holy Trinity; the 'Kingdom of God'; salvation by grace; and the love ethic. Following this is a brief description of three major denominations within the Christian worldview. The final two parts of this section include a brief discussion on the factors contributing to worldview formation and finally a framework for the measurement of a Christian worldview.

2.2.1 Rationale: Christian Faith-based schools

According to the 2001 Australian Census, over 12 million Australians claim to be Christians, which implies approximately 68% of the population claim to adopt a Christian worldview (Australian Bureau of Statistics, 2001). Along with the popularity of non-government schools in Australia being approximately 35% in 2014 (Australian Bureau of Statistics, 2014), these statistics provide a strong rationale for the benefit of a study looking specifically at students in a faith-based school.

The current research looking at students in private Christian schools is abundant in North America (Crawford & Freeman, 1996; Williams, Rancher & Hunter, 1983) and Britain (Patrikios & Curtice, 2014) while research in Australia is more limited. A relevant study in North America conducted by Crawford and Freeman (1996) sampling 384 families, aimed to research the factors influencing parent choice of a Christian private school compared with a local public school. An interesting result from the surveys demonstrated that two major contributing factors for parent choice of a private Christian school were that religious aspects of the students' education were believed to be missing from the public school experience and the notion of discipline was not a focus.

Another study by Williams, Rancher, and Hunter (1983) revealed similar results, suggesting that religion and the educational program were cited as the major reasons for switching to private schools, while discipline, child-related factors, and school staff were identified as secondary reasons for transfers from public to private schools.

Both sources of research highlight the idea that many parents were sending their children to a Christian faith-based school as they were specifically interested in the incorporation of religious studies and the exposure of a Christian worldview to their children.

2.2.2 Definition of Worldview

According to Cobern (1997) a worldview can be described as a culturally dependant, generally subconscious fundamental organization of the mind. This organisation has a direct effect on how an individual may feel, act and think according to predictable patterns. Much of Cobern's (1997) research is based on the work of Kearney who described a worldview as a, "culturally organized macrothought: those dynamically inter-related basic assumptions of a people that determine much of their behaviour and decision making, as well as organizing much of their body of symbolic creations" (Kearney, 1997, p. 1) Similarly, in 'World Views: From Fragmentation of Integration', Aerts et al. (1994, p. 17) describes worldview as, "a coherent collection of concepts and theorems that must allow us to construct a global image of the world, and in this way to understand as many elements of our experience as possible".

Cobern (1997) states that a worldview essentially defines the self. It sets the parameters for who and what an individual is, his or her relationship with the environment and even his or her perception of space and time. The development of worldview is one that happens over a long period of time but is already in its stage of infancy, setting the foundation for how new concepts are learned, at a young age. Cobern (1997) suggests that it is in these early years of schooling and formal education that worldview is heavily influenced and developed. Kearney's (1984) research discussed seven cognitive categories forming the foundation for a logico-structural model of a worldview: Self; Other; Relationship; Classification; Causality; Space; and Time.

Several authors have allocated more contextual criteria for classifying a worldview such as Sire (2004) and Geisler and Watkins (1989). Sire analyses eight worldviews: Christian Theism, Deism, Naturalism, Nihilism, Existentialism, Eastern Pantheistic Monism, New Age and Postmodernism although also acknowledging several others. Geisler and Watkins (1989) identifies a similar list including; Theism, Atheism, Pantheism, Panentheism, Deism, Finite Godism, and Polytheism. Although these

representative worldviews are far more limiting and prescriptive compared with Kearney's (1984) logico-structual categories, they are particularly relevant in this study as the students in the sample group all attended a Christian school where a core value was to provide a curriculum that teaches students to think as a Christian and develop a Biblical world-view against which life's issues can be measured. Although this study refers to the Christian worldview, worldview is culturally dependent and therefore influenced by many cultural factors (Cobern, 1997). A religious framework would be a significant contributing factor but it would not be the sole contributing factor (Bandura, 2006).

It is important to note that even though the very definition of a worldview is a description of the presuppositions which underlie virtually every aspect of an individual's life, many people would not necessarily have a coherent worldview or be able to articulate it clearly (Barna, 2004). Moreland (1997) suggested that many people have no understanding of how a Christian is to view the world, highlighting the fact that regardless of an individual's willingness to adopt a particular worldview, many people may hold specific views on the world around them but may be unable or unwilling to act on such convictions.

2.2.3 Christian Worldview

The term 'Christian worldview' is somewhat difficult to define as there are many diverse beliefs and interpretations of the Bible even within Christian tradition, all of which may contribute to the formation of a worldview in various ways. It is important, however, to acknowledge the role of the Bible in forming a Christian worldview.

> If we truly believe that the Bible is God's Word to us, the true story of the world, it is clear that our worldview must be rooted and grounded there (Goheen & Bartholomew, 2008, p. 31).

The role of the Bible in the formation of a Christian worldview is directly linked with a Christian epistemology. This establishes the notion that truth can not only be acquired through the scientific method but also through the revelation of scripture. Therefore an individual who possesses a Christian epistemology, and consequently a Christian worldview, identifies the Bible as a credible source of truth. The idea that individuals who hold a Christian worldview are convinced that the Bible is an equally

trustworthy source of knowledge and truth as the scientific method, reveals a unique and noteworthy epistemology.

Possibly one of the most essential core beliefs of an individual professing a distinctly Christian worldview would be the belief in the existence of a sovereign God as creator. Another would be the acknowledgement of Jesus Christ as a historical figure and source of salvation. These two major concepts are paramount and set the foundation for all other aspects of the Christian worldview (Dickson, 2007; Sire, 1988).

The notion that all of creation, including mankind, are the deliberate product of God's creativity and the object of His love and affection is the first and most distinctive feature of the Christian worldview. This theme establishes God as being behind the Universe as its originator and also above it, as its preserver. For Christians, the physical cosmos and humans within it are deliberate rather than accidental. For this reason it is believed that humans will only find their true purpose when they connect with their source, God (Dickson, 2004). This belief directly influences a Christian ontology where the acknowledgement of God, being immaterial, immediately rejects the materialist ontology which professes that only the material exists (Cohen, Manion, & Morrison, 2013).

The second foundational theme is based on the idea that at some point in human history, sin was introduced by mankind and this sin had to be atoned for in order for mankind to spend eternity with God the creator. This introduction of sin is sometimes described as the 'Original sin' and it is believed the crucifixion and resurrection of Jesus Christ provided an adequate atonement for the sins of mankind, should the individual accept Christ as their personal saviour (Dickson, 2007; McGrath, 2011). Salvation is a foundational doctrine in the Christian worldview where 'grace' refers to the unmerited gift of God's pardon. This pardon was made available by the actions of Jesus Christ who was crucified and shortly after resurrected (Dickson, 2004). As a direct consequence of this action, God's mercy can be experienced and this is directly related to God's final judgement where everything leading up to salvation is the free and unmerited gift of God, given out of love for sinners. God withheld condemnation for humanity by instead providing salvation through the sacrifice of his son, Jesus Christ (McGrath, 2011).

Additionally, there are several other core beliefs that are shared by all individuals who profess to have a Christian worldview. Dickson (2004) identifies these core beliefs as:

1. The Holy Trinity
2. The 'Kingdom of God'
3. The love ethic

2.2.3.1 The doctrine of the Holy Trinity

The concept of the Holy Trinity is consistent across all Christian denominations and refers to one God existing as three separate persons. These persons are described as God the Father, Jesus the Son and The Holy Spirit. Dickson elaborates on the relationship between God and Jesus by stating, "Jesus implied to his contemporaries that he personified the presence of God on earth. The one true God of Jewish history had entered into first century history in the person of the Messiah" (2004, p. 156). The third member of the Holy Trinity is the Holy Spirit whose purpose has been summarised by McGrath (2011, p. 231) 'The Christian tradition has generally understood the work of the Holy Spirit to focus on three broad areas: revelation, salvation, and the Christian life'. McGrath suggests the active role of the Holy Spirit in a Christian's life is to reveal God, aid in salvation, and enable the individual to live a life according to Christian tradition.

2.2.3.2 The doctrine of the 'Kingdom of God'

According to Dickson (2004) the concept of a 'Kingdom of God' is a direct reference to God's dominion over all things including the Earth and its inhabitants. His kingdom is also not confined by time in the sense that it includes past, present and future. Regarding the notion of a future 'Kingdom of God', Christians believe that there are three major aspects of which will be briefly summarised.

Dickson (2004) succinctly describes these three aspects as:

1. The belief in a so called 'Second coming' of Jesus. The return of Jesus to human history.

2. The belief in a 'Day of Judgement' where God will assess the conduct of all people and separated those who are deemed as 'right' and 'wrong'. Christians believe that

they would be deemed ‘wrong’ if not for the sacrifice and resurrection of Jesus Christ on their behalf.

3. The belief in a ‘new creation’ or afterlife where Christians and creation itself will be renewed and restored and void of sin.

2.2.3.3 The love ethic

The ethic of love found in a Christian worldview is agreed to be a direct consequence of the grace of God where, “Christianity taught that mercy is one of the primary virtues - that a merciful God requires humans to be merciful” (Stark, 1997, p. 209).

According to Dickson (2004) Jesus’ command to ‘love thy neighbour’ was not necessarily a new concept as it was essentially derived from the Jewish *Tanak* but what was unusual about Jesus interpretation of this statement was his definition of ‘neighbour’. Jesus described a ‘neighbour’ as all people, including one’s own enemies. Dickson (2004) goes on to state that it is commonly believed by historians that the Jews were the first to implement a welfare system for the poor while it was Christians who took this practice and extended it to include believers and non-believers alike. Although the commitment of followers of Christ to this ethic of love may not necessarily be consistent among all believers, it is a foundational concept of a Christian worldview.

2.2.3.5 Key Denominations of the Christian worldview

Although the core values of the Christian worldview as described previously are consistent across all subgroups of Christians, Dickson (2004) succinctly identifies three main denominations which an individual who commits to a Christian worldview may broadly prescribe to. These include:

1. The Roman Catholic Church: This sub-category of a Christian worldview could, in summary, be distinguished from the others as it reinforces the moral and doctrinal authority of the Pope (Bishop of Rome); venerates Mary the mother of Christ; comprises the transubstantiation of elements in the Lord’s supper; and implements the inclusion of several additional books in the Old Testament (Dickson, 2004).

2. The Protestant Church: This sub-category of a Christian worldview could, in summary, be distinguished from the others as it rejects the absolute authority of the

Pope and instead professes that only the Bible is infallible; sets an emphasis on salvation by grace; and rejects transubstantiation of the elements in the Lord's supper, insisting the Lord's supper is an act of remembrance rather than an actual miraculous change from bread to the physical body of Christ (Dickson, 2004).

3. The Orthodox Church: This Eastern Roman sub-category of a Christian worldview could, in summary, be distinguished from the others as it rejects aspects of the absolute authority of the Pope without breaking apart from the Roman Catholic Church and additionally acknowledges the Archbishop of Constantinople as the honorary head of Orthodoxy; the notion of salvation as a process of sharing in the nature of God; and the use of icons or images of God in worship (Dickson, 2004).

With particular reference to this study, an important variance within the denominations is the flexibility to support the compatibility of biological evolution and the Christian worldview. This is demonstrated by acceptance of biological evolution among Clergymen, such as the Bishops of Oxford, St Albans, Hereford, Birmingham, Southwark, Portsmouth, Archbishop of Canterbury and even the Pope (Dawkins, 2009).

2.2.4 Construction of worldviews

Factors influencing worldview formation can come from many places (Bandura, 2006) and in the same way a student's Christian worldview would likely influence their acceptance of various concepts in Science, such as biological evolution, their worldview has also been shaped by external sources. In an educational context, some of these sources could be identified as: parents (Bao, Whitbeck, Hoyt, & Conger, 1999; Grusec, Goodnow, & Kuczynski, 2000); community (Stassen & Gushee, 2003); teachers (Riesen, 2002); and the school sector (McDowell, 2006). Each factor has the potential to influence a student's worldview and in the context of this research, a student attending a Christian school, with Christian teachers, as a member of a predominantly Christian community with parents who are either Christians themselves or encourage Christian values, would likely develop if not wholly, in part, a Christian worldview. In an educational context, the studying of evolutionary biology provides an opportunity for these students to examine presuppositions and cultural norms that are inherent in their worldview and perhaps challenge their own preconceptions.

2.2.5 Measuring Christian worldview

The degree by which a student adopts a Christian worldview must take into account several key components. These components include personal importance of religion, understanding of core religious beliefs and acceptance of core religious beliefs. Personal importance of religious belief indicates religious activity and the dedication of the individual. The aspect of a Christian worldview which describes understanding of core beliefs, such as those about God and his action in the world, can be measured through a Christian Orthodoxy scale (Pope, 2014), while belief and acceptance of those same core ideas can be measured using a similar scale with slight modifications.

2.3 SCIENCE-RELATED ATTITUDES

This section provides a review of the literature on science-related attitudes. It begins (section 2.3.1) by providing a rationale for the study of science-related attitudes followed by a general description of the definition of science-related attitudes. The factors affecting science-related attitudes are then expounded identifying thee relevant factors affecting science-related attitudes. These include: gender, classroom/teacher and curriculum variables. The final part of this section includes a brief discussion on the methods used to measure science-related attitudes.

2.3.1 Rationale for the study of 'Science-related attitudes'

According to Osborn et al. (2010), the investigation of students' attitudes towards studying science has held great significance in the science education community for over forty years. It has recently grown in importance as there has been mounting evidence of a decline in the interest of young people in pursuing scientific careers (Department for Education, 1994). This decline in interest combined with widespread scientific ignorance in the general populace (Durant & Bauer 1997; Miller, Pardo, & Niwa, 1997), and an increasing recognition of the importance and economic utility of scientific knowledge and its cultural significance (Dearing, 1996) has driven researchers to engage in the study of attitudes towards science with renewed interest.

Osborne et al. (2010) describe a 'swing away from science' making specific reference to a study conducted by the Department for Education (1994) in England and Wales. The study presented results indicating only 16% of the sample collected in 1991 enrolled exclusively in science and mathematics A-level subjects while a staggering

43% enrolled in subjects other than science and mathematics. The same figures in 1980 included 37% enrolled exclusively in science and mathematics A-level subjects while 36% enrolled in subjects other than science and mathematics (Department for Education, 1994).

A number of Australian studies have shown a general decline in students' interest in science across the compulsory secondary school years (Adams, Doig, & Rosier, 1991; Goodrum, Hackling, & Rennie, 2001). This decline in interest in science in the early years of secondary school is particularly of concern, as it is in these years that attitudes to the pursuit of science careers tend to be formed (Speering & Rennie, 1996).

The Australian Department of Education, Science and Training reported that between 1997 and 2002 there has been an overall decline in commencing enrolments in undergraduate courses in the physical and natural sciences (Australian Department of Education, Science and Training, 2003). There is also increasing concern at the declining number of students electing to undertake science courses at the tertiary level, for example, the Royal Australian Chemical Institute released a report on the supply and demand for chemists (RACI, 2005), which expressed concern at the decline in the number of students taking chemistry at university.

Considering that only students who select science subjects are able to qualify for scientific careers, the decline in the number of science-based students has raised concern about the international economic future (Dearing, 1996; National Commission on Mathematics and Science Teaching for the 21st Century, 2000).

This research aimed to explore a possible link between students' attitudes towards science and their acceptance and adoption of a Christian worldview.

2.3.2 Definition of 'Science-related attitudes'

The term 'Science-related attitudes' has been used in Science education research on many occasions (Durant, Evans & Thomas, 1989; Durant & Bauer, 1997; Miller et al., 1997) but requires a certain degree of clarity regarding the intended meaning. Gardner (1975) distinguished between 'attitudes towards science' and 'scientific attitudes' where the former refers to feelings, beliefs and values held about an object that may be the enterprise of science, school science, the impact of science on society or

scientists themselves. The latter is a description of the complex mixture of longing to know and understand, a questioning approach to statements, a search for data and its meaning, a demand for verification, a respect for logic, and a consideration of premises and consequences (Education Policies Commission, 1962). This research is solely focused on 'attitudes towards science' rather than 'science attitudes.

An elaboration into the various aspects of 'attitudes towards science' was made by Klopfer (1971), who categorized a set of affective behaviours in science education as:

1. the manifestation of favourable attitudes towards science and scientists;
2. the acceptance of scientific enquiry as a way of thought;
3. the adoption of 'scientific attitudes';
4. the enjoyment of science learning experiences;
5. the development of interests in science and science-related activities; and
6. the development of an interest in pursuing a career in science or science-related work.

Klopfer's (1971) list describes six specific and measurable aspects of a student's attitude towards science and in doing so provides the needed clarity to determine what constitutes an individual's attitude and ultimately what factors may affect such attitudes. The Test of Science-Related Attitudes (TOSRA), designed to measure these categories separately, was subsequently developed for use with secondary school students (Fraser, 1978; 1981).

2.3.3 Factors affecting science-related attitudes

Osborne et al. (2003) have stated that there are a number of factors influencing attitudes towards science, including but not limited to gender, classroom/teacher factors and curriculum variables.

2.3.3.1 Gender

Gardner (1975) comments that, 'sex is probably the most significant variable related towards pupils' attitude to science'. A meta-study by Weinburgh (1995) reviews the literature revealing that boys have a significantly more positive attitude to science than girls although the effect is stronger in the physical sciences rather than the biological sciences. The most common thesis regarding this effect suggests that

current cultural socialisation offers girls considerably less opportunity to apply scientific methodology to technological devices and commonly used measuring instruments compared with boys at a young age. Jones, Howe, and Rua (2000) have suggested that boys tend to be encouraged to dismantle and build, to modify and explore while young girls are provided less opportunities and less frequently rewarded for such behaviour.

2.3.3.2 Classroom/teacher factors

The influence of classroom environment on students' attitude towards science has been the focus of many studies (Cooper & McIntyre 1996; Hattie, 2008; Myers & Fouts 1992). Using 699 students from 27 high schools in America, Myers and Fouts (1992) found that the most positive attitudes were associated with a high level of involvement, very high level of personal support, strong positive relationships with classmates, and the use of a variety of teaching strategies and unusual learning activities. Cooper and McIntyre (1996) demonstrated in their study in History and English that there were common aspects of teaching perceived by both student and teacher to be effective in promoting positive attitudes to science. These included:

- clear goals for pupil learning;
- clarity of communication of lesson goals and agenda to pupils;
- use of preview and review of lesson content;
- helping students to contextualize content in terms of their own experience and knowledge, as well as in terms of other teaching goals and learning experiences;
- some willingness to allow pupils to have input into goal and agenda setting;
- a supportive social context designed by the teacher to help pupils feel accepted, cared for and valued;
- an ability and willingness to allow for different cognitive styles and ways of engaging with the learning process among pupils, through multiple exemplification, and the use of different types of illustration and mode of presentation, and offering pupils a choice from a menu of possible ways of engaging; and

- a willingness to take into account pupil circumstances and to modify/pace/ structure learning tasks accordingly.

In addition to high quality teaching, Woolnough (1994) identified the supply of well-qualified, enthusiastic graduate science staff as being heavily influential on students continuing with science education post-high school. In his study involving 1180 A-level students he suggested that staff who not only have a good spread of expertise across science but who also have individual subject loyalty were particularly effective teachers.

In his book, 'Visible Learning for Teachers: Maximizing Impact on Learning' which summarises his study of over 800 meta-analyses, Hattie (2012) discussed the role of effective teachers in student learning and specifically the impact of expert teachers compared with experienced teachers. Several traits mentioned were the way classrooms are represented, the degree of challenges that are presented to students, and the depth of processing that their students attain. Students who were taught by expert teachers tended to exhibit a more integrated and coherent understanding of the concepts targeted in instruction and at a higher level of perception than the understanding achieved by other students. In another study conducted by Fraser, Aldridge, and Adolphe (2009) involving a sample of 567 Australian students, positive associations between the classroom environment and student attitudes to science were revealed using simple correlation and multiple regression analyses.

2.3.3.3 Curriculum variables

According to Osborne et al. (2003) studies conducted focusing on curriculum variables influencing students attitudes towards science have been numerous but fairly inconclusive. Simpson, Koballa, Oliver, and Crawley (1994) elaborated on this view stating,

> The science education literature contains hundreds if not thousands of reports of interventions designed to change attitudes. Development of programs to influence the likelihood of certain science-related attitudes is important because it is assumed that changes in attitude will result in changes in behaviour. Unfortunately, few simple and straightforward generalisations can be made about how and why science-related attitudes change (1994, p. 223).

Some recent studies have indicated that a science curriculum that relates to students' interests and life-world experiences encourages a more positive attitude to school science. Munro and Elsom (2000) found that science teachers tended to market their subject based on its instrumental value rather than any cultural significance. This attitude fosters the underlying notion that knowledge of science has no intrinsic cultural value. In the context of gender, according to Lightbody and Durdell (1996), only a change in content to show a greater interest in people will lead to a significant increase in the choice of sciences, specifically the physical sciences.

This emphasis on relevance can also be observed in the varying attitudes towards school science between the science content areas (Havard, 1996; Osborne & Collins, 2000; Whitfield, 1980). Osborne and Collins (2000) state that biology, particularly human biology, tends to be viewed as relevant and pertinent, addressing pupils' self-interest in their own bodies and concerns about health and disease, while the relevance of the physical sciences was difficult for students to identify. Without the essential feature of relevance, sustaining interest in science appears to be difficult, directly affecting students' attitudes towards science.

There is an apparent lack of literature addressing a possible link between a Christian worldview and science-related attitudes indicating that it has not yet been identified as a significant factor.

2.3.4 Measuring Science-related attitudes

Osborne et al. (2010) describe attitudinal questionnaires as being one of the most common methods of collecting data to measure students' attitudes towards science. Such questionnaires tend to be composed of Likert-scale items and are fairly abundant in the literature. Scales which are possibly more well-known include the Scientific Attitude inventory (Moore & Sutman, 1970), Simpson and Troost's inventory (1982), the Attitudes toward Science Inventory (Gogolin & Swartz, 1992), the Views on Science–Technology–Society instrument (Aikenhead, Ryan, & Fleming, 1989) and the Test of Science-related Attitudes (TOSRA) instrument (Fraser, 1981).

The Test of Science-related Attitudes (TOSRA) instrument developed by Fraser (1981) has been used fairly extensively as it can be easily administered during a

normal class lesson as well as its ability to yield a separate score for a number of distinct attitudinal aims rather than one single overall score (Fraser, 1981). This makes the TOSRA particularly useful in the context of this study and for this reason it will be the focus of any further discussion regarding measuring Science-related attitude.

Validity studies using the TOSRA in Australia (McRobbie & Fraser, 1993), Taiwan and Australia (Aldridge, Fraser, & Huang, 1999), Indonesia and Australia (Fraser et al., 2010), Brunei (Scott & Fisher 2004), Singapore (Wong & Fraser, 1996; Wong, Young, & Fraser, 1997) and the USA (Martin-Dunlop & Fraser 2008) have all produced strong reliability results.

2.4 BIOLOGICAL EVOLUTION IN SCIENCE CURRICULUM

This section provides a review of the literature pertaining to biological evolution in secondary science curriculum. It begins with an account of the historical development of biological evolution in secondary science education followed by a description of the placement of biological evolution in the Western Australian Curriculum (2009). Within this description some of the educational benefits of including Biological evolution in Science Curriculum are highlighted. The key conceptual ideas of the theory itself are then clarified as random genetic mutation, natural selection, speciation and evidence for evolution.

2.4.1 Historical development of Biological evolution in Secondary Science Education

Regarding development of science curriculum in Western Australia, the School Curriculum and Standards Authority, formerly the Western Australian Curriculum Council, developed the science curriculum independently but also collaborated internationally, including British and American education institutions. The teaching of evolution in Australian schools has not met the same degree of controversy as in the United States, although resistance to acceptance of evolution is still clearly evident (Dawkins, 2009). According to Price (1992), Creationism was originally viewed as an insignificant and transient ‘American Import’, but it has since grown in popularity.

The most pivotal events regarding the teaching of evolution in science classes have generally come from the United States and therefore would logically be the focal point for this discussion. Clearly the starting point for the topic of evolution as part of science education would be the publishing of Darwin's (1859) book 'On the Origin of Species'. According to Moore (2007), by the 1890s there was little controversy associated with Darwin's theory and it wasn't until the early 1900s that several individuals, specifically in the US, began to publicly oppose the teaching of evolution in public schools and by the 1920s antievolution opinion had grown significantly in support. Throughout the 1920s in the US several states had passed laws banning the teaching of evolution leading to the infamous 'Scopes trial' of 1925. Moore (2007) states that the final outcome of the trial accomplished nothing legally but it had a major impact on society resulting in the word 'evolution' disappearing from most US biology textbooks and the majority of biology teachers no longer teaching the subject.

It wasn't until the late 1960s that National Science Foundation published a new series of biology books which not only included evolution but were based on it. In the following years the teaching of evolution in American public schools across various states became more and more common until eventually evolution was to be taught as a foundational concept in biology in all US public schools. It is also important to note that this period of change was not met without resistance where periodic case law appeared throughout the United States involving the various movements of Christian fundamentalist groups. Moore (2007) concludes that creationists have lost every legal challenge involving the teaching of evolution and creationism in public schools over the past thirty years but highlights the fact that there is still a large proportion of the population holding strong creationist views and opposing the teaching of evolution in the science classroom.

2.4.2 Biological evolution in Science curriculum

According to Jones (2007, p. 180) biological evolution is, 'the single most important concept developed in the human quest to understand the living world, and biology teachers should be expected to teach evolution'. This is a common sentiment among scientists and has been stated repeatedly throughout current research (Cavallo & McCall, 2008; Rice & Kaya, 2010; Schilders et al., 2010). Schilders et al. (2010) in their research on worldviews and evolution in the biology classroom state that as the

majority of scientists consider evolution to be one of the few foundational concepts underlying biology then it would be expected that it should also be one of the leading threads within the biology curriculum. When describing the importance of evolution in the study of biology, Cavallo and McCall (2008) make reference to scientific organisations such as the American Association for the Advancement of Science (AAAS) and the National Academies of Sciences (NAS), which repeatedly stress the significance of evolution in biology and strongly advocate teaching evolution in American schools. According to the NAS (2008), evolution epitomises what science is, being supported by empirical, data-driven evidence and explanations. Blackwell, Powell and Dukes (2003) state that in the absence of evolutionary theory, biology is void of a unifying theme, coherence, understanding, and interpretation of relationships.

Furthermore, Cavallo and McCall (2008, p. 552) mentions another benefit of the presence of evolution in science curriculum referring to the notion that 'evolution makes clear the case that many new theories in science challenge current views and ways of thinking and, in so doing, exemplify the very nature of science as a discipline'

According to the Australian Curriculum: Science content descriptors it is a curriculum requirement that biological evolution be taught at the Year 10 level in Science. Specifically, the Year 10 content descriptor for biological science states, "The theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence (ACSSU185)" (Australian Curriculum, Assessment and Reporting Authority, 2011). It is worth noting that this content descriptor clearly mandates the teaching of biological evolution through natural selection including the evidence for evolution. The descriptor does not require that human evolution be specifically mentioned and is therefore not likely to be emphasised in a typical Year 10 biology lesson.

The Human Biological Science 3A/3B document (Curriculum Council, 2009) gives a clear outline of the content which is required to be covered in Western Australian Secondary Schools offering the Human Biological Science 3A/B Course of Study. This Course of study is unique to Western Australia and would be delivered in a slightly different form in other Australian states. This course is typically offered to Year 12 students. The document includes 'Variation and Evolution' as a compulsory

component of the course. Specifically the 3A Unit description states, "Gene pools are affected by evolutionary mechanisms including natural selection and chance occurrences. The main evidence for evolution comes from comparative studies in anatomy and biochemistry, and the fossil record." (Curriculum Council, 2009) The Unit 3A description goes on to elaborate by detailing concepts such as changes in allele frequencies being due to mutation; natural selection; random genetic drift including Founder effect; and migration. The evidences for evolution which are directly referenced include comparative studies of DNA, protein sequences, anatomy including embryology, homologous structures and vestigial organs and the fossil record (Curriculum Council, 2009).

2.4.3 Major concepts in Biological Evolution

At this point it may be beneficial to clarify that biological evolution is an essential area of study within the biological sciences but it is not considered a worldview (Schilders et al., 2010). It is a well-established scientific mechanism with great explanatory power but in the context of this study, it does not cross the boundaries of science into philosophy. Any further reference to biological evolution is in reference to its role in the study of science.

Although biological evolution is often solely accredited to Darwin, this is not actually the case. Two of the earliest contributors to the concept we now know as evolution were actually Darwin's grandfather, Eramus Darwin, as well as Lamarck (Ruse, 2007). Both of these scientists believed that organic life was indeed changing over time, often in an upward direction of complexity. As a result of Darwin's five year journey to South America on the *HMS Beagle*, and more famously his visit to the Galapagos Archipelago in the Pacific, he began to work on what we now know as, 'On the Origin of Species' (Darwin, 1859). Darwin's made three key observations (Newton & Joyce, 2010).

1. Variation: There is variety within a species
2. Birth rate: More offspring of a species are produced than the environment can sustain

3. Natures Balance: Each species appeared to maintain their numbers at a constant level.

The variation described in the first of Darwin's three observations is a direct consequence of random genetic mutation (Dawkins, 2009). According to Newton and Joyce (2010), as a result of these three observations, Darwin produced two important assertions which form the foundation of traditional Darwinian evolution. These include:

1. Struggle for existence: Due to excessive birth rate, and limited resources, there is a competition for survival

2. Survival of the fittest: The individuals with characteristics best suited to the environment have more chance of surviving and reproducing.

In essence, the theory of evolution implies that through various mechanisms, natural selection being a major contributor, gene frequencies are able to change over time (Prothero, 2007). In his book, 'Why Evolution Is True', Coyne (2009) summaries biological evolution in the following statement:

> Life of Earth evolved gradually beginning with one primitive species – perhaps a self-replicating molecule – that lived more than 3.5 billion years ago; it then branched out over time, throwing off many new and diverse species; and the mechanism for most (but not all) of evolutionary change is natural selection (2009, p. 3).

Coyne (2009) suggests that key topic areas within biological evolution are random genetic mutation; natural selection; and speciation. As with any area in science, there is also wealth of evidence supporting the theory of evolution (Dawkins, 2010).

2.4.3.1 Random Genetic Mutation

Since Darwin's book was published in 1859 several key additions to the theory of evolution have emerged and this has resulted in a modified version often referred to as neo-Darwinism (Prothero, 2007). One of the major differences between traditional Darwinism and neo-Darwinism is the incorporation of genetic inheritance in evolutionary theory. As a result of the inclusion of Mendelian genetics and the

discovery of the DNA molecule by James Watson and Francis Crick, evolutionary theory has grown in its explanatory power by focusing on gene frequencies and the changes in genotype (combination of alleles) rather than phenotypes (observable physical characteristics as a result of the genotype) (Coyne, 2009; Prothero, 2007). The source of the variety in genes, providing the raw material for evolution, is a direct result of random genetic mutation (Dawkins, 2010). Such mutations in DNA involve the rearrangement of nitrogen bases which have the capacity to produce new alleles. By definition these mutations are random, non-predictable changes in DNA which were not present in the parent gene pool (Newton & Joyce, 2010).

2.4.3.2 Natural Selection

As a consequence of random genetic mutation in DNA, a wealth of genetic diversity can exist within a particular species' gene pool. The presence of many alternative alleles will in turn result in the presence of many alternative phenotypes (physical characteristics) (Dawkins, 2010). It is this variety of phenotypes which provide the raw material for evolution to occur. Although evolution may be driven by several mechanisms such as the Founder Effect and Random Genetic Drift, it is Natural Selection which is most commonly discussed in association with driving evolution in secondary science curriculum (Newton & Joyce, 2010).

Natural selection is a mechanism which allows the organisms with favourable phenotypes (characteristics) to survive in a particular environment and therefore pass these characteristics on to the next generation (Newton & Joyce, 2010). Members of the species who do not possess the favourable trait would be less likely to survive and produce offspring, consequentially reducing in number. This in turn would shift the allele frequencies in the gene pool in favour of the organisms with the beneficial trait (Dawkins, 2010).

2.4.3.3 Speciation

If random mutations could be said to provide the raw material for evolution, and natural selection is the mechanism by which evolution takes action, speciation would be the final destination of evolution, resulting in a new, genetically unique species (Dawkins, 2010). When defining the term 'species' it is important to highlight that it is an organism's inability to interbreed with another and produce fertile offspring,

which classifies it as separate species (Newton & Joyce, 2010). Therefore for speciation to occur, there must be a difference in environmental pressure on various members of the same species. This difference in environmental pressure, along with natural selection, must be significant enough to drive two members of the same species in such different directions that they are no longer able to produce fertile offspring together. At this point speciation has occurred (Coyne, 2009). One key feature of the process of speciation which has not yet been described is the presence of some form of barrier between the two previously mentioned species. Such a barrier would prevent the mixing of their gene pools along the course of their evolution. Some examples of common barriers may be a river, desert, canyon or mountain range. After several generations of separation and natural selection, the two populations, which were at some point in the past genetically very similar, are now unique and can be classified as exclusive species (Dawkins, 2010).

2.4.3.4 Evidence for evolution

According to the Human Biological Science 3A/3B document (Curriculum Council, 2009) the evidence for evolution, which is relevant in the Western Australian Curriculum, includes comparative studies and the fossil record. The evidence for evolution is an area of particular interest as it is regularly targeted by critics of the theory and undermined by the abundance of religiously motivated anti-evolution literature (Batten, 1999; Bergman, 2004; Doyle, 2014; Ham, 1987; Oard, 2014; Sarfati, 1999; Walker, 2014). This has resulted in several publications being produced rigorously defending such evidence, by respected scientists including palaeontologists (Prothero, 2007), cellular biologists (Miller, 1999), geneticists (Collins, 2006; Coyne, 2007), physicists (Giberson, 2008) and evolutionary biologists (Dawkins, 2010).

Comparative studies

In the book, 'The Greatest Show on Earth: The Evidence for Evolution', evolutionary biologist Richard Dawkins (2010) provides a multitude of examples of comparative studies, including analysis of DNA, endogenous retrovirus' and protein sequences, demonstrating the similarities between species which indicate common ancestry. By comparing the embryos, homologous structures and vestigial organs of modern animals, the patterns of resemblance are exactly what would be expected if they had all descended from a common ancestor (Dawkins, 2010).

The fossil record

The book, 'Evolution: What the Fossils Say and Why It Matters', written by palaeontologist Donald Prothero (2007) provides a detailed account of the evidence for biological evolution according to the fossil record, much of which is based on his own research and scholarship. According to evolutionary theory the fossil record should contain a diversity of organisms of which many have been following a path in which may result in a modern species well adapted to its current environment. This is the case, as established by the work of 150 years of palaeontology (Prothero, 2007). As one would expect, the fossil record reveals many fossils which indicate common ancestry in addition to the observation that as each fossil is placed in chronological order (based on modern dating methods such as radioisotope dating) a significant pattern can also be observed, in many cases increasing in complexity (Coyne, 2009).

2.4.3.5 An example of evolution in bacteria

A particularly relevant example of evolution can be found in an experiment conducted in Michigan State University involving the E.coli bacteria (Lenski & Travisano, 1994). The experiment continued for twenty years and was essentially the observation of 12 'lines' of E.coli all which shared one single common ancestor. The first generation of all 12 lines were genetically identical while after 45,000 generations, each line, which had been kept separate from the other 11 had evolved in a slightly different way. One 'line' in particular had evolved in a significantly different way, being able to metabolise citrate as well as glucose. This mutation, or in this case two mutations, were able to allow the E.coli in this particular line to flourish and continuously produced a higher population density compared with the other 11 'lines'. This experiment is a wonderful example of evolution by natural selection occurring at an incredibly fast rate (Dawkins, 2010).

2.5 ACCEPTANCE OF BIOLOGICAL EVOLUTION

This section provides a review of the literature on acceptance of evolution. It begins by providing a rationale for the study of acceptance of biological evolution in an Australian context followed by a general description of the factors affecting student acceptance of the theory. These include: religious factors; scientific factors; social and emotional factors; critical thinking and epistemological views; and demographic

factors. The final part of this section describes the methods used to measure the acceptance of biological acceptance.

2.5.1 Placement of the Study in Acceptance of Biological Evolution Literature

According to Sinatra et al. (2003, p.512), acceptance 'refer[s] to a learner's personal assessment of the validity of a construct' based on a 'systematic evaluation of the evidence'. Ingram and Nelson (2006) summarise the general consensus that understanding of evolutionary biology is more important than acceptance although the significance of acceptance should not be underemphasised. A more favourable attitude towards biological evolution tends to result in higher academic achievement as well as there being an overall negative impact on higher learning of biology as a consequence of rejection of biological evolution (Ingram & Nelson, 2006; McKeachie, Lin, & Strayer, 2002).

The rejection of biological evolution is an international issue that exists in a variety of versions. Staggering statistics such as 50% of adults in Turkey, 40% in the United States and 15% in the United Kingdom, reject the theory of evolution as an explanation for the diversity of life on Earth, have been revealed in recent studies (Lawes, 2009; Miller et al., 2006). Considering the incorporation of biological evolution in the science education curriculum, the current situation has been described as easily being the biggest failure of science education from top to bottom in recent times (Branch & Scott, 2008; Miller et al.,2006).

The Australian Institute of Biology conducted a national poll in 1992, including a sample of 4225 students across seventeen Universities, revealing that 12.6% of first year biology students in Australian universities believed that, "God created man within the last 10,000 years" (Price, 1992). According to a 1986 survey of the Australian general public, across a sample of 30,000 individuals, 65% of the sample believed that God created the world in six days (Numbers, 2004).

These statistics confidently place Australia within the context of concern, for both university students and the general public. Unfortunately the vast majority of studies researching acceptance of evolution have been conducted in the United States with a small but steadily growing interest in the United Kingdom. Very few articles have

been published in the context of Australian educational institutions which is a gap potentially reduced by this research (Ferguson & Kameniar, 2014).

2.5.1 Factors influencing student acceptance of biological evolution

Although the major influence on students' acceptance of evolution is regularly cited as being based on religious convictions, it is not the only factor being discussed in current research (Wiles & Alters, 2011). Based on a review of current literature, Wiles and Alters (2011) compiled a list of factors which appear to be linked to students' rejection of biological evolution including: religious factors; scientific factors; social and emotional factors; critical thinking and epistemological views; and demographic factors.

2.5.1.1 Religious factors

According to Woods and Scharmann (2001), religious factors appeared to be the highest ranking factor affecting students' attitudes towards biological evolution in their sample. The perceived relationship between science and religion varies greatly from complete hostility to complementarity (Meadows et al., 2000; Shipman et al., 2002). The group of students who view science and religion as being in direct conflict hold particular significance (Shipman et al., 2002) as it is likely they will be more resistant to learning about biological evolution (Meadows et al., 2000). These students tend to interpret scripture literally (Lawson & Worsnop, 1992) and when scripture and the content being taught in the science classroom are seemingly in conflict, students will generally adopt their interpretation of scripture which they often believe supersedes scientific theory (Alters & Alters, 2001).

The religious belief system and scriptural interpretation being discussed in relation to evolution is most commonly described as 'young-earth creationism'. This in essence describes the notion that natural evolutionary explanations of the known universe are rejected in favour of explanations involving creation by a supernatural entity over a short period of time (Alters & Alters, 2001).

2.5.1.2 Scientific factors

Wiles and Alters (2011) identify several scientific factors which appear to be directly linked to students' acceptance of biological evolution. These include: overall

understanding of evolutionary theory; understanding of evidence for evolution and; understanding of the mechanisms of evolution.

In reference to students' overall understanding of evolutionary theory, there are several key misconceptions that have been identified. These comprise ideas related to inheritance of acquired traits (Banet & Ayuso, 2003; Dagher & BouJaoude, 1997), ideas based on the notion that evolution is driven by the needs of an organism (Bishop & Anderson, 1990; Jensen & Finley, 1996; Jimenez-Aleixandre, 1992) and the similar notion that evolution is driven by the conscious choice of an organism (Clough & Wood- Robinson, 1985; Hallden, 1988).

A second scientific factor identified by Wiles and Alters (2011) as contributing to students' acceptance of biological evolution was related to evidence for evolution. The research reviewed indicates that increased acceptance of biological evolution could be achieved by effectively presenting the evidence for evolution to students while directly comparing such evidence with common misconceptions associated with creationism (Alters & Nelson, 2002; Alters, 2005; Ingram & Nelson, 2006; Nelson, 2007; Scharmann, 2005; Verhey, 2005).

The third possible factor affecting students' acceptance of evolution is a poor understanding of the mechanisms of evolution (Wiles & Alters, 2011). Some researchers (Alters & Alters, 2001; Miller et al., 2006) have identified misconceptions related to natural selection and other mechanisms of evolution to be linked with rejection of evolution.

Although the previously mentioned misconceptions have been consistently identified throughout the relevant literature, their relationship with acceptance of biological evolution has been inconsistent. According to several researchers (Rutledge & Warden, 1999, 2000; Trani, 2004) a significant correlation was identified while others (Bishop & Anderson, 1990; Demastes et al., 1995; Lord & Marino, 1993; Sinatra et al., 2003) found no such evidence.

2.5.1.3 Social and emotional factors

According to Woods and Scharmann (2001), the second most influential factor influencing students' attitudes towards biological evolution is personal relationships with parents, friends, teachers etc. This is consistent with findings from Demastes,

Good, and Peebles (1995) who also identified acceptance of evolution as being significantly influenced by friends, parents and teachers etc.

An emotional factor which was identified by Brem, Ranney, and Schindel (2003) focused on the idea that widespread acceptance of evolutionary theory might lead to a variety of negative personal and social consequences. These included heightened selfishness and racism as well as diminished spirituality and sense of self purpose.

2.5.1.4 Critical thinking and epistemological views

Woods and Scharrmann (2001) along with Lawson and Worsnop (1992), and Alters and Nelson (2002) identified a significant correlation between a student's ability to think critically and their acceptance of biological evolution. Sinatra et al. (2003) found students with a more developed epistemology and open-minded cognitive disposition were also more likely to accept evolution.

2.5.1.5 Demographic factors

Although several studies exploring demographic factors affecting students' acceptance of evolution have been conducted, researches have not identified any significant correlation between gender (Lord & Marino, 1993; Woods & Scharmann, 2001) or race (Woods & Scharmann, 2001) and acceptance of evolution. Academic standing at a college degree level has been linked with acceptance of evolution by some research (Baker, 2013; Lord & Marino, 1993) which is likely a function of having more sophisticated epistemological views (Wiles & Alters, 2011)

2.5.2 Measuring Acceptance of Biological Evolution

There are several instruments available throughout the literature pertaining to students' acceptance of biological evolution. Two of those which are fairly common include the Measure of Acceptance of the Theory of Evolution instrument (MATE) (Rutledge & Warden, 1999) and the Evolution Attitudes Survey (Ingram & Nelson, 2006).

The MATE instrument consists of 20 statements related to various aspects of evolutionary theory and misconceptions commonly held by individuals who reject evolution. Participants indicate their level of agreement with these statements on a five-point Likert scale. The MATE instrument was developed for use among high

school biology teachers but has been validated and employed for use among high school students (Donnelly, Kazempour, & Amirshokoohi, 2009).

The validity of the MATE instrument has been consistently established in several studies (Donnelly, Kazempour, & Amirshokoohi, 2009; Rutledge & Warden, 1999; Rutledge & Sadler, 2007) in addition to it producing a high degree of reliability (Rutledge & Warden, 1999; Rutledge & Sadler, 2007).

2.6 RELATIONSHIPS BETWEEN CHRISTIAN WORLDVIEW AND BIOLOGICAL EVOLUTION

This section provides a review of the literature describing the relationships between a Christian worldview and scientific practice and thinking, including acceptance of biological evolution. It begins by describing four perspectives regarding the relationship between science and a Christian worldview based on the research of Barbour (1990). The concept of a 'conflict' model is then expounded identifying two groups of individuals who hold this view, namely 'young-earth' creationists (Batten, 1999; Doyle, 2014; Ham, 1987; Oard, 2014; Sarfati, 1999; Walker, 2014; Weiland, 1997) and a small group of atheist scientists and philosophers (Coyne, 2015; Dawkins, 2006; Dennet, 1995; Holliday, 2006). The perspectives of these two groups are summarised, followed by a synthesis of Barbour's (1990) second, third and fourth groupings which is are collectively those of 'non-conflict'. This final part includes a rationale for accepting a 'non-conflict' perspective and an analysis of some common critiques of the 'conflict' model found in current scholarship.

2.6.1 Discussion of the relationship between Science and Christian Worldview

There is currently a large amount of literature available on the relationship between science and religion (Barbour, 2000; Brooke, 1991; Gould, 1990; Reiss, 2009). In recent times it has become more acceptable to describe the *relationships* between science and religion, indicating the complexity and variety in its approach. Brooke (1991) comments on this complexity, stating "There is no such thing as *the* relationship between science and religion. It is what different individuals and communities have made of it in a plethora of different contexts." (1991, p. 321)

Among the most frequently cited concepts in the science/religion field is Barbour's (1990) four interactions of science and religion. These models could be summarised as Conflict, Independence, Dialogue, and Integration.

2.6.1.1 Conflict model

The conflict model is best described as a struggle between the two worldviews where they cannot both exist. Barbour (1990, p.4) describes this visually stating, 'In a fight between a boa constrictor and a wart-hog, the victor, whichever it is, swallows the vanquished. In scientific materialism, science swallows religion. In biblical literalism, religion swallows science'.

This view has been adopted by two diverse groups, both expressing agreement as to the incompatibility of science and religion. On one side of the 'battle' are 'young-earth creationists' (Doyle & Reed, 2013; Ham, 1987; Sarfati, 1999) who passionately oppose evolutionary theory and equally oppose its compatibility with a Christian worldview, while on the other side are a group of self-professing atheists (Coyne, 2015; Dawkins, 2006; Dennet, 2006) who use evolutionary biology to justify their anti-religious beliefs and equally support the notion that biological evolution is incompatible with a Christian worldview.

2.6.1.2 Independence

The second grouping described by Barbour (1999) is one of independence. The supporters of this view suggest that both a religious worldview and science are valid but aim to address different questions doing so using different methods. They essentially function as different languages and could be seen to examine the same issues but in diverse ways. Jones and Reiss (2007) use a comparison between science and aesthetics as an example, examining various aspects of a building. Questions such as, 'Is it constructed safely?' compared with 'Is it beautiful?' aim to reveal different features of the building and do so using unique methods. Neither is superior nor inferior, they are simply independent but equally acceptable. Barbour states that,

> Each has its own distinctive domain and its characteristic methods that can be justified on its own terms. Proponents of this view say there are two jurisdictions and each party must keep off the other's turf (1990, p. 10).

This approach has been described by Gould (1999) as NOMA or non-overlapping magesteria. Gould's definition of magesteria refers to spheres of authority and a key aspect of his distinction is the belief that science is but one way on knowing while religion is simply another. Both are equally valid but seek to answer different questions (Gould, 1999).

2.6.2.3 Dialogue

Barbour's (1990) third grouping could be summarised by the idea that the religious and worldview and Science occupy their own spheres of authority and generally use differing methods to develop understanding, but the line between the two worldviews and their methods is questionable. It could be possible that one worldview may add depth to the other, provoking questions which may not have arisen otherwise (Polkinghorne, 2005). Reiss (2009) states that the point is not so much that such questions depend on the other worldview but that in some individuals, scientific questions may give rise to religious ones and vice versa. An example provided by Barbour (1990) refers to the orderliness of the universe and how it has provoked many scientists to reflect on the initial conditions present to allow it to evolve. The question which one may ponder at this point is not necessarily 'how' but rather 'why' thus dialogue between the two worldviews has been established.

2.6.2.4 Integration

The final grouping described by Barbour (1990) is one of integration. This perspective could be described as suggesting that both science and a religious worldview may contribute to a comprehensive metaphysical worldview. Such a worldview allows the complete integration of scientific laws as well as the laws of God. There is a large body of literature which describes this particular group and theologians such as McGrath (2011), Panneberg (1976) and Blocher (1984) argue that insights of the natural sciences can illuminate the Christian understanding and although the two disciplines are distinct, they can mutually interact to the benefit of both. Individuals who attempt to integrate their scientific and religious worldviews may approach the same situation using different aspects of each respective worldview. An example of this could be in relation to health, where recovery from illness may be promoted by the consumption of appropriate nutrients but it must also be according to the will of God.

2.6.2 The ‘conflict’ between biological evolution and a Christian worldview

The conflict model of the relationship between religion and science has fervently been adopted by two prominent groups of individuals: those with a Christian worldview who claim the earth is less than 10,000 years old and reject biological evolution; and those who describe themselves as atheists and adamantly argue that religion and science are totally incompatible. Both groups contain highly distinguished scientists and produce an abundance of literature albeit in direct conflict.

2.6.2.2 Conflict between Biological evolution and the Christian worldview – young-earth creationist writers

The conflict between biological evolution and a Christian worldview has been greatly intensified by specific groups of evangelical Christians who identify themselves as ‘Creationists’ or ‘young-earth creationists’ (Ham, 1989; Sarfati, 1999). From these ‘Creationist’ individuals, several organisations such as ‘Creation Ministries’ and ‘Answers in Genesis’ have emerged, which have a strong presence in Australia. ‘Creation Ministries’ publish an ongoing magazine and release several books on a regular basis in addition to regularly speaking at local church meetings and maintaining a current website.

Many ‘young-earth creationist’ authors (Doyle & Reed, 2013; Ham, 1987; Sarfati, 1999) passionately oppose evolutionary theory and equally oppose it’s compatibility with a Christian worldview. In one of the earlier books published by Ham (1987), ‘The Lie: Evolution’, Ham states his belief in the importance of ‘combating’ evolution,

> When are Christians in the nations around our world going to wake up to the fact that we need to re-aim our weapons and aggressively and actively fight the issue of evolution by restoring the foundation of creation? In Western nations most churches compromise with evolution. Many Theological and Bible colleges teach that the issue of creation/evolution does not matter. They teach that you can believe in both evolution and the Bible because you do not need to bother about taking Genesis literally. This compromising stand is helping to destroy the very structure they claim to want to remain in society – the structure of Christianity (Ham, 1987, p. 111).

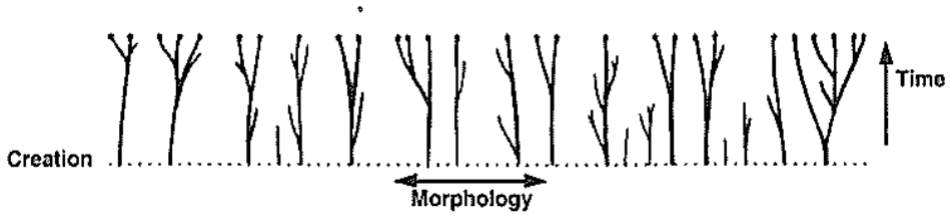
2.6.2.2.1 Summary of young-Earth Creationism

Sarfati (1999) in his book 'Refuting Evolution' provides a fairly clear summary of the beliefs of 'young-earth creationists' regarding the origin and development of life on Earth. He suggests that the book of Genesis from the Christian Bible provides a literal account of the events leading to the origin of life on Earth taking place in a location known as Eden over six 24-hour days. The literal view of the Genesis days was first made famous by Archbishop Ussher (1581-1656) from Northern Ireland (Lennox, 2011). Sarfati (1999) goes on to suggest that God instantaneously created different kinds of organism which reproduced and from them further biodiversity developed. He clarifies that these original 'kinds' would have had large amounts of genetic diversity to allow for their descendants to adapt to their environments. Furthermore he clarifies that Creationists believe the original creations by God were perfect and over time as a result of human sin have genetically deteriorated and any mutations and adaptations which have occurred have resulted in the loss of genetic 'information'.

Not only does this model take into account the process and specific timeline of the origin of organic life, it uses the book of Genesis in the Christian Bible as a historic account of the age of the Earth and consequently the Universe. The time periods described in the Bible can allegedly be added up, assuming no gap in genealogies, and the result is an age of approximately six thousand years (Batten, 1999). An article in Creation magazine focusing on the work of Archbishop Ussher is even more specific stating that the origin of the Universe could be traced back to October 23rd 4004 BC (Pierce, 1998).

The creationist explanation of life's origin and its current diversity can be aptly summarised by *Figure 2.1* from 'Refuting Evolution' (Sarfati, 1999, p 39). The diagram depicts the idea that beginning with a special creation event many 'kinds' of organism were generated and over time these 'kinds' went through limited natural selection resulting in modern biodiversity.

Figure 2.1 *The Creationist 'Orchard' diagram presenting modern diversity as a consequence of minor changes within a created 'kind'.*



According to several Creation Ministries publications (Batten, 1999; Ham, 1987; Sarfati, 1999; Weiland, 1997) some key reasons the authors encourage the rejection of biological evolution among the Christian community, in no particular order, are as follows:

1. Acceptance of evolution is the underlying foundation of immorality in society (Bergman, 2006; Cosner, 2010; Ham, 1987; Weiland, 1998; Zimmermann, 2008).

2. Acceptance of biological evolution is the rejection of the authority of the Bible (Batten, 1999; Doyle & Reed, 2013; Grigg, 1996; Sarfati, 1999).

3. Acceptance of biological evolution undermines the concept of original sin and therefore salvation through Christ (Batten, 1999; Cosner, 2008; Cosner, 2009; Ham, 1987; Sarfati, 1999; Smith Jr, 2007).

4. The evidence supporting the occurrence of biological evolution and the mechanisms driving it are unsatisfactory (Austin & Humphreys, 1990; Batten, 1999; Bergman, 2004; Doyle, 2014; Grigg, 1998; Ham, 1987; Oard, 2014; 2003; Sarfati, 1999; Snelling, 1992; Swenson, 2001; Walker, 2010; Walker, 2014; Weiland, 1997; White, 2001; Williams, 1995).

2.6.2.2.2 The foundation of many of societies 'problems'

In his book 'The Lie: Evolution' Ham (1987) describes what he believes to be the 'evils' of evolution. Ham refers to specific examples to establish the concept that acceptance of evolution is directly related to immorality such as: Nazism; racism; drug abuse; abortion; and male chauvinism. According to Ham (1987), Adolf Hitler and the Nazi regime were a prime example of what the acceptance of evolution into one's personal philosophy could result in, namely, genocide. He states that Hitler believed

his persecution of the Jews was an extension of Darwinian evolutionary thinking and natural selection providing evidence of the link between evolution and immorality. In Zimmemann's (2008) article, 'The Darwinian Roots of the Nazi Legal System' this theme is expounded in great detail. Another relevant publication by Cosner (2010) drew a direct correlation between acceptance of evolutionary theory and Germany's anti-Christian ethical system, justifying their militarism leading to World War One.

Ham's (1987) second idea focused on the rise of racism as a result of acceptance of biological evolution. He claims that even a school child would be inclined to draw a link between human ape –like ancestors and modern Indigenous Aborigines. He uses the example below.

> At one school a teacher said to her students that if ape-like creatures had evolved into people, then this should be seen to be happening today. Some of the students told her that this was happening today because some aborigines are primitive and therefore, still evolving. Regrettably, the teaching of evolution had relegated the Australian Aborigines to a subhuman level (Ham, 1987, p. 103).

In the article, 'Evolutionary Racism' Wieland (1998) describes the mistreatment of Aboriginal people throughout Australia's history and claims evolutionary theory is inherently racist.

Another interesting link made by Ham (1987) was between acceptance of biological evolution and the rise of illicit substance abuse. The evidence for such a link is found in a letter from a Western Australian man who accounted for his addiction to 'dope' with his acceptance of evolution. The man stated,

> Drug-taking seemed to me to make sense because in principle it fitted with what I had been taught about the nature and origin of man. "From chemical reactions hast thou come and unto chemical reactions thou shalt return". And so I did (Ham, 1987, p. 104).

A final example of an 'evil' propagated by acceptance of biological evolution is male chauvinism, feminism and sexual immorality. Ham states that there are many writers who are using Darwinian evolution to justify male superiority and an equal number of

writers who are doing the complete opposite and promoting feminism. Ham states that it is the Bible that teaches that men and women are equal in direct contrast to biological evolution. In an article describing the philosophy and life of Alfred Kinsey, Bergman (2006) draws a direct link between the rise of sexual deviancy and adoption of Darwinian evolutionary thinking.

2.6.2.2.3 The rejection of the authority and erroneous reading of the Bible

One of the more serious implications of the acceptance of biological evolution suggested by Batten (1999) is the rejection of the authority of Biblical Scripture. This is based on the assumption that biological evolution has occurred over millions of years whereas the book of Genesis allegedly teaches that the earth is less than 10,000 years old.

Batten argues that those who interpret the 'days' described in Genesis as anything other than literal 24 hour days have been influenced by ideas outside the scripture itself and concludes that this will ultimately lead to the whole of scripture being reinterpreted and the text becoming subjective rather than objective truths. Such concerns are based on the fear that Christianity will eventually be diluted by secular ideas and inevitably become indistinguishable from other secular philosophies (Batten, 1999).

Numerous publications by young-earth creationist authors (Batten, 1999; Doyle & Reed, 2013; Grigg, 1996; Sarfati, 1999) provide various sources of evidence that any interpretation of the 'days' in Genesis as periods of time other than 24 hours are simply erroneous. A common argument describes the Hebrew term *yom* as used in the original translation of Genesis 1 as clearly referring to one literal 24-hour day. Batten (1999) quotes Dr Barr (Regius Professor of Hebrew, at Oxford University) stating:

> …so far as I know, there is no professor of Hebrew or Old Testament at any world-class university who does not believe that the writer(s) of Gen. 1-11 intended to convey to their readers the ideas that (a) creation took place in a series of six days which were the same as the days of 24 hours we now experience… (Barr, as cited in Batten, 1999, p. 27).

This particular young-earth creationist argument creates an ultimatum for any interested party where either the reader accepts biblical scripture as true or they reject it as false. The implication is that either the process of creation by God happened in six 24-hour days or it didn't happen at all, in which case God is fictional rather than historic (Doyle & Reed, 2013). An extension of this idea proposed by authors such as Sarfati, is that evolution is inherently atheistic or anti-biblical. "Many people do not realise that the teaching of evolution propagates an anti-biblical religion" (Sarfati, 1999, p. 20).

2.6.2.2.4 Undermining the concept of original sin and salvation

Other than the controversy surrounding the meaning of the word 'day' in Genesis 1, the implications of such an interpretation have also been the focus of a large number of young-earth creationist writings (Batten, 1999; Cosner, 2008; Cosner, 2009; Ham, 1987; Sarfati, 1999; Smith Jr, 2007). Possibly the most pivotal implication is the undermining of the concept of original sin and salvation.

Several writers (Batten, 1999; Cosner, 2008; Cosner, 2009; Sarfati, 1999; Smith Jr, 2007) suggest that if one accepts the age of the Earth to be billions of years old rather than approximately six thousand, this means that one must accept death, bloodshed, disease and suffering before Adam's original sin. The literature claims that on many occasions the Bible describes the introduction of death, bloodshed, disease and suffering as a consequence of Adam's original sin. Adam, said to be the first human, was responsible for introducing sin into human history followed by its consequences (Cosner, 2008; Cosner, 2009; Smith Jr, 2007). This sin was said to separate mankind from God the creator and the only way to atone for the sins of mankind was through sacrifice and ultimately the crucifixion of Jesus Christ (McGrath, 2011).

The conclusion is that if death and suffering existed before Adam's original sin it is contradictory to suggest that they could be the consequence of sin. If physical death existed before Adam's original sin, this undermines the Biblical concept that the consequence of sin is death. Therefore, if sin carries no consequence then there is no need for a saviour in Jesus Christ, and ultimately the concept of salvation has also been undermined (Cosner, 2008; Cosner, 2009; Smith Jr, 2007).

Ham (1987) elaborates by stating that acceptance of biological evolution is accepting that mankind was produced by suffering and death while acceptance of a literal Genesis explains that suffering and death was a consequence of mankind's sin. The original sin, with death and suffering as the consequence, is the basis of the salvation message.

Many creationist writers on the topic of original sin (Batten, 1999; Ham, 1987) draw a clear link between acceptance of biological evolution and the consequential redundancy of the salvation of Jesus Christ. They conclude that the core belief of the Christian worldview, the salvation of Christ, is incompatible with the acceptance of biological evolution. Sarfati states, "A God who "created" by evolution is, for all practical purposes, indistinguishable from no God at all" (Sarfati, 1999, p. 22).

2.6.2.2.5 Scientific Criticism of Biological evolution

Other than the apparent philosophical clash between the Christian worldview and biological evolution described by young-earth creationist writers such as Batten (1999) and Ham (1987), a series of powerful arguments have surfaced in the form of genuine scientific criticism of the theory of biological evolution (Austin & Humphreys, 1990; Batten, 1999; Behe, 1996; Bergman, 2004; Doyle, 2014; Grigg, 1998; Ham, 1987; Oard, 2014; Sarfati, 1999; Walker, 2014; Weiland, 1997; White, 2001). This critique tends to come in two forms; namely the assertion that biological evolution is a 'historical' or 'forensic' science rather than empirical or operational and; the systematic undermining of the commonly accepted evidence for biological evolution professed by the mainstream scientific community (Austin & Humphreys, 1990; Bergman, 2004; Grigg, 1998; Weiland, 1997; White, 2001).

Ham (1987) explains in his book, 'The Lie: Evolution', that the study of biological evolution has been incorrectly adopted into the sciences and would more fittingly be described as a worldview or religion. Focus is drawn to what is described as 'observational science' in which conclusions and theory are formulated based on observations of the five senses: touch, sight, smell, sound, and taste, and such observations can be repeated. The study of evolution has not been 'observed' in this way as it occurred in the past and cannot be repeated. For these reasons many young-earth creationist writers (Batten; 1999; Ham, 1987; Sarfati, 1999) conclude that

biological evolutionary theory does not meet the criteria of the 'observational' sciences and therefore should not be given the same authority.

In addition to questioning the authority of biological evolution as a science, possibly the most abundant topic in young-earth creationist literature would be criticism of the evidence. There is a wealth of information available from young-earth creationist publishers providing methodical and comprehensive rebuttals of the common evidence produced by the mainstream scientific community supporting biological evolution (Austin & Humphreys, 1990; Bergman, 2004; Doyle, 2014; Grigg, 1998; Oard, 2014; Sarfati, 1999; Walker, 2014; Weiland, 1997; White, 2001).

In his book, 'Refuting Evolution' Sarfati (1999) systematically argues each piece of evidence published in the National Academy of Science (NAS) educator's guidebook entitled, 'Teaching about Evolution and the Nature of Science'. The guidebook was distributed to American schools to encourage educators to teach evolution correctly and with more confidence. Sarfati's (1999) response to this publication was concise and comprehensive. Several areas that Sarfati (1999) draws attention to are comparative studies, the fossil record and evidence hoaxes.

Comparative studies

Sarfati (1999), Lightner (2010), and Bergman (2001) explain that similar physical features in comparative studies do not necessarily indicate common ancestry and therefore should not be considered evidence for evolution. Focus is drawn back the idea that the evidence is not a direct finding but an interpretation of data. Sarfati (1999) suggests that an alternate explanation could be a common designer. He uses the example of an architect using the same building materials for all houses or a carmaker using the same parts for all the cars which are produced. Such similarities indicate a 'common designer' rather than a common ancestor. This principal has been used to rebut virtually all comparative studies including homologous structures, biochemistry and embryology. In addition, Bergman and Tomkins (2012) describe exaggerations of similarities in comparative studies published in evolutionary biology literature. They focus on the alleged percentage of identical DNA in chimpanzees and humans highlighting discrepancies in the published data and proposing much lower numbers.

The fossil record

Criticism of the authenticity of the fossil record comes in many forms throughout young-earth creationist literature. It varies from accusations that the classification of the fossil is grossly incorrect to the condemnation of the dating methods used or questions the authenticity of the fossil itself. Sarfati (1999) highlights the diverse opinions of expert palaeontologists describing the contradictions and creating uncertainty in regards to the general consensus of the details of specific transitional fossils such as *Archaeopteryx* and *Basilosaurus*. Considering the importance of the age of the transitional fossils, this is also a target for many young-earth creationist writers. Many articles (Snelling, 1992; Swenson, 2001; Walker, 2010; 2003; Williams, 1995) have been produced suggesting that the fossil dating methods (e.g. Carbon Dating, K-Ar Dating) are inaccurate and not to be given any scientific authority. The purpose of such arguments is to demonstrate that there is no significant pattern of transition throughout the fossils, drawing no observable link to a common ancestor (Sarfati, 1999).

Hoaxes and Frauds

Another commonly documented topic in young-earth creationist literature is the apparent abundance of hoaxes and frauds within evolutionary theory (Bergman, 2004; Grigg, 1998; White, 2001). Throughout the literature it is difficult to avoid at least one reference to a hoax or fraud publicised by an overzealous scientist trying to produce evidence for evolution such as Ernst Haeckel and his embellishments throughout a comparative embryology diagram (Grigg, 1998) or the infamous Piltdown man fossil hoax (Bergman, 2004). More recent examples include *Archaeoraptor* and *Ichthyosaurus* fossil misfortunes (Sarfati, 2000; White, 2001) which along with other hoaxes and errors in classification have cast an unfortunate shadow of doubt on the authority of palaeontologists and added confirmation for young-earth creationist writers that biological evolutionary theory continues to be founded on questionable evidence (Bergman, 2004).

Evidence for a young Earth

The young-earth creationist movement is not only engaged refuting current evolutionary theory but produces many publications promoting evidence for a young

Earth and a global flood (Austin & Humphreys, 1990; Doyle, 2014; Oard, 2014; Walker, 2014; Weiland, 1997). Such evidence ranges from the red blood cells discovered in a *Tyrannosaurus* fossil, inferring a fossil age of several thousand years (Weiland, 1997), to the lack of salt in the sea, producing a maximum age of sixty-two million years rather than several billion (Austin & Humphreys, 1990). Sarfati sums up the general consensus of many young-Earth authors stating, "…90 percent of the methods that have been used to estimate the age of the earth point to an age far less than the billions of years asserted by evolutionists." (1999, p. 112)

Irreducible Complexity

A final argument which has grown in popularity over recent years, reintroduced by biochemist Behe (1996) in the book, 'Darwin's Black Box', is one of 'irreducible complexity'. This concept has been used to combat biological evolution as an explanation for the diversity of life and allegedly acts as evidence for an 'Intelligent Designer' or in the case of Behe's personal beliefs, God. Behe (1996) used the example of the bacterial flagella motor as evidence of an irreducibly complex mechanism which could not function if any component was not fully formed and present. He asserts that the mechanism could not have been formed by biological evolution through natural selection as it is too complex and had therefore been created by an intelligent designer (Behe, 1996). The essence of the argument is one of improbability and although not a new concept, has recently been given the context of biochemistry (Miller, 1999). The classic 'argument from design' infers that it is too improbable for biological evolution to produce a mechanism of such great complexity and therefore another explanation is required (Behe, 1996). Many other publications have been released from colleges of Behe, Meyer (2013) who is a geophysicist and philosopher of science and mathematician William Dembski (2004) providing additional evidence for the movement most commonly referred to as 'Intelligent Design'. It is worth noting that these particular authors do not necessarily reject a 4.5 billion year old Earth but insist there are definitive examples in both modern biology and palaeontology which are 'irreducibly complex' (Miller, 1999).

2.6.2.1 Conflict between Biological evolution and the Christian Worldview – Atheist writers

The apparent conflict between the Christian worldview and acceptance of biological evolution is not solely publicised by young-earth creationists. An equally vocal cohort of atheist writers have over recent times been reinforcing the fundamental young-earth creationist dogma, evolution and religious faith are incompatible (Coyne, 2015; Dawkins, 2006). In the same way individuals who identify themselves as young-earth creationists do not necessarily represent the greater Christian community, it is important to note that the atheist scientists which are to be discussed in this chapter also do not represent the larger community of atheists nor scientists. They are, however, some of the most vocal about their perspectives regarding the conflict between science and religion.

Within the literature there appears to be two major implications regarding the relationship between a Christian worldview and acceptance of biological evolution, the second being much broader in scope but equally significant. These are:

1. Biological evolution explains organic diversity without the need for the supernatural. Even more so it acts as evidence for the non-existence of god (Coyne, 2015; Dawkins, 1996, 2006).

2. Scientific practice is incompatible with a religious worldview (Coyne, 2015; Dawkins, 2006; Holliday, 2006).

2.6.2.1.1 The redundancy of the supernatural in evolutionary biology.

In the chapter titled, 'Why there almost certainly isn't a god', evolutionary biologist Richard Dawkins (2006) writes in his book, 'The God Delusion' of how science has not only replaced the need for religion but evolution provides the evidence needed to finally remove God from rational thought.

Dawkins (2006) describes with insight and intellectual rigour how natural selection is a perfectly adequate explanation for the diversity of life, removing any need for the supernatural. In particular, he targets the argument from improbability, and its modern incarnation, described as 'irreducible complexity' by Behe (1996). It is clear that Dawkins has prioritised addressing this particular argument not only as it seeks to

undermine biological evolution but it claims to provide evidence for the existence of God. In his book 'Climbing Mount Improbable', Dawkins (1996) systematically refutes the argument from improbability, describing the power of natural selection and its ability to drive small, gradual, slightly improbable changes in the direction of one large and highly improbable change. He focuses on the bacterial flagellum motor in addition to many others, producing a satisfactory rebuttal of the argument from improbability, removing the need to invoke the supernatural in an explanation of the development of life (Dawkins, 1996).

In 'The God Delusion' Dawkins goes one step further, stating, "The argument from improbability, properly deployed, comes close to proving that God does *not* exist." (Dawkins, 2006 p. 113) The idea that there exists mechanisms, organisms or chemical processes that are so finely tuned that it seems highly improbable that they could have arisen without divine guidance, is the essence of the 'irreducible complexity' argument (Behe, 1996). Dawkins (2006) uses the same logic to highlight that:

> ...any God capable of designing a universe, carefully and foresightfully tuned to lead to our evolution, must be a supremely complex and improbable entity who needs an even bigger explanation than the one he is supposed to provide (Dawkins, 2006, p. 147).

Dawkins concludes that as natural selection is a satisfactory explanation for the diversity of life there is no longer a need to invoke the supernatural, and therefore 'design' can no longer be used as evidence for God. He summarises that even if a supernatural designer is invoked to explain the complexity of a particular organic mechanism, the existence of a supernatural designer is even more complex and therefore even more improbable. In this way, Dawkins (2006) along with several other well-known evolutionary biologists such as Wilson (1978) and Coyne (2015), use biological evolution as evidence for the non-existence of God. An article published by Australian geneticist, Holliday (2006), elaborates on this stating:

> In short, living cells consist of complex chemicals and even more complex chemical interactions. There is absolutely no place for a "vital force" or any non-material entity, either in the egg, sperm, fertilised egg, embryo, child or

> adult. Thus there is no non-material soul and therefore no afterlife (Holliday, 2006 p. 40).

In his book, 'Darwin's dangerous idea', philosopher Dennet (1995) describes Darwin's theory of biological evolution as a form of 'universal acid' that, as an explanatory concept, can dissolve its way through biology and into other fields such as moral reasoning and sociology. Dennet (1995) proposes that Darwinism can be expected to revolutionize thinking in all spheres of knowledge including art, ethics and politics. He claims that evolutionary theory will eventually negate any non-materialistic explanation of human culture including but not limited to religion.

2.6.2.1.2 A Religious worldview is unscientific

In a similar fashion to Dawkins' (2006) book, 'The God Delusion', geneticist Coyne (2015) authored a book titled, 'Faith Versus Fact: Why Science and Religion Are Incompatible'. Both writers identify themselves as atheists and document the incompatibility of scientific thinking and practice with a religious worldview.

Although biological evolution is not the focal point of Dawkins (2006) and Coyle (2015), assertions about the incompatibility of science with a religious worldview, it can by default be applied to the various fields of study within science, such as biological evolution.

The underlying theme in Dawkins' (2006) and Coyne's (2015) writings is that religion and consequently a Christian worldview, teach that is it a virtue to be satisfied with not understanding and is therefore fundamentally unscientific. Dawkins states:

> As a scientist, I am hostile to fundamentalist religion because it actively debauches the scientific enterprise. It teaches us not to change our minds, and not to want to know exciting things that are available to be known. It subverts science and saps the intellect (2006, p. 284).

Focusing on the superiority of scientific knowledge, Holliday states that "[e]xperimental science has established itself as rational and reproducible, and there is no place for the contravention of natural laws, such as religious myths, superstition and the occult." (2006, p. 40).

This particular argument is one that holds great significance as it does not simply target young-earth creationists but the entire religious community whose faith according to Dawkins is, "blind trust, in the absence of evidence, even in the teeth of evidence." (2006, p.198). Incidentally, many individuals with a Christian worldview are deeply offended by the writings of Dawkins (2006) and Coyne (2015) and are well aware of the links they have drawn between their atheism and their commitment to science. . These individuals are presented with an ultimatum where they must submit to either religious or scientific authority.

2.6.3 The non-'conflict' of biological evolution and a Christian worldview.

Babour's (1999) second, third and fourth descriptions of the relationship between a scientific thinking and a religious worldview all have one major theme in common: they are not in conflict. The 'independence' group supports the view that both religion and science are valid but aim to address different questions and do so using different methods and occupy different spheres of authority (Gould, 1999). Barbour's (1990) third grouping, 'dialogue', could be summarised by the idea that the line between the two worldviews and their methods is questionable. One worldview may add depth to the other, provoking questions which may not have arisen otherwise (Polkinghorne, 2005). Barbour's (1990) fourth grouping, termed 'integration', holds the perspective that both scientific and religious worldviews contribute to a comprehensive metaphysical worldview allowing the complete integration of scientific laws as well as the laws of God. This perspective claims that God is not only the author of scientific laws but plays an active role in the workings of the world. The two disciplines are distinct but they can mutually interact to the benefit of both (McGrath, 2011; Panneberg, 1976).

The purpose of this section is not single out one particular grouping from the final three proposed by Barbour (1999) but rather to highlight the shortcomings of the 'conflict' model and suggest how adoption of one of the other three models would be beneficial in an Australian secondary education setting.

2.6.3.1 Benefits of rejecting a 'conflict' model of the relationship between biological evolution and a Christian worldview

According to current science education literature, it is clear that a large portion of students who claim to have a Christian worldview experience some degree of difficulty in accepting biological evolution as an explanation of the diversity of life (Jones, 2007; Meadows, 2007; Reiss, 2007). Several writers suggest that this is due to the perceived conflict between their religious worldview and their understanding of biological evolution. As outlined in the previous subchapter, this conflict is greatly amplified by available young-earth creationist literature and certain atheist scientist publications.

It is also important to note that the 'conflict' model is a fairly new phenomenon in the history of science regardless of the implications made by many modern writers. This is aptly consolidated by historian of science, Russell (1989), stating that, "[t]o portray them as persistently in conflict is not only historically inaccurate, but actually a caricature so grotesque that what needs to be explained is how it could possibly have achieved any degree of respectability" (1989, p. 5). A similar point is made by Cantor (1991) claiming, "…the conflict thesis is like a great blunderbuss which obliterates the fine texture of history and sets science and religion in necessary and irrevocable opposition. Much historical research has invalidated the conflict thesis" (1991, p. 290f).

Several authors such as Meadows (2007), Jones, (2007) and Reiss (2007) have suggested adopting a non-conflict model regarding the teaching of biological evolution and the religious worldview of the students in the classroom. Meadows (2007) suggests managing perceived conflict rather than attempting to resolve it, while Jones (2007) focuses on teaching for understanding rather than acceptance. Reiss (2007) provides several strategies for approaching the situation which respects a student's personal belief system while still delivering essential biology concepts such as evolutionary theory. All three writers highlight the importance of delivering the biological evolution content to students and suggest that this can only be done effectively if the students do not feel threatened and are made aware that it is possible for them to engage in such a study without abandoning their Christian worldview.

2.6.3.2 Response to criticism of a non-conflict model

The greatest critics of Barbour's (1990) other three models of the relationship between a religious worldview and a scientific one and consequently biological evolution, tend to be those who adamantly support the 'conflict' model. For this reason it would be logical to summarise some of the most common and effective responses to the arguments presented by opponents of a non-conflict model. These arguments have been adopted by both 'young-earth' creationists and certain atheist scientists and if any non-conflict model is to be successful there must be an adequate response to such accusations (Jones, 2007; Poole, 2007).

1. Acceptance of biological evolution is not significantly linked to immorality in society (Alexander, 2008; Miller, 1999).

2. Acceptance of biological evolution and an old earth does not undermine the authority of the Bible (Dickson, 2009; Giberson, 2008; Lennox, 2011; Miller, 1999; Osborn, 2014; Poole, 2007; Rana & Ross, 2005; Walton, 2009).

3. Acceptance of biological evolution does not undermine the concept of original sin (Alexander, 2005; Blocher, 1984; Collins, 2006; Lennox, 2011; Longman III, 2005; Osborn, 2014; Rana & Ross, 2005).

4. Biological evolution does not act as evidence for the non-existence of god (Alexander, 2005; Lennox, 2011; McGrath, 2007; Ruse, 2007; Walton, 2009).

5. Scientific practice is compatible with a religious worldview (Alexander, 2005; Collins, 2006; Lennox, 2011; McGrath, 2007; Walton, 2009).

2.6.3.2.1 Acceptance of biological evolution is not significantly linked to immorality in society

The young-earth creationists' claims that evolutionary theory has been used by many ideological groups to further their malevolent agenda is one grounded in history. Alexander (2008) describes the ideological transformations of Darwinism from George Bernard Shaw's ideas of a universe ascending toward ultimate perfection to Hitler's justification of eugenics. It is accurate to state that in these cases and many others, Darwin's theory of biological evolution has been adopted in various fashions other than biology and in some cases the result has been immoral. The question posed

by Alexander (2008) is if biological evolution, as a scientific theory, should have been applied outside of its intended field. The fact that Adolf Hitler used Darwin's 'survival of the fittest' model to justify his immoral actions does not make the explanatory theory of evolution inherently evil but when taken out of the context of biology and placed in philosophy, it certainly has the capacity to be distorted and misused. The same could be said for the accusations of racism and sexism where the theory has been taken out of context or more commonly misunderstood and as a consequence is abused by an ideological group to further their agenda (Alexander, 2008; Miller, 1999).

2.6.3.2.2 Acceptance of biological evolution and an old earth do not undermine the authority of the Bible

One of the more serious implications of the acceptance of biological evolution suggested by Batten (1999) is the rejection of the authority of Biblical Scripture. This argument is in direct relation to the interpretation of the 'days' described in Genesis and their literal 24 hour day in one week account of creation. Batten (1999) argues that acceptance of biological evolution over a long period of time is not compatible with his interpretation of the Genesis account of creation. There is however an abundance of literature suggesting otherwise (Dickson, 2008; Lennox, 2011; Longman III, 2005; Rana & Ross, 2005; Walton, 2009).

In an article titled, 'The Genesis of Everything: An Historical Account of the Bible's Opening Chapter', Dickson (2008) claims that Genesis' account of creation must be read taking into account literary genre and the cultural setting of the author rather than reading it as an actual materialistic historic account of the creation event. Dickson stresses his assertion that the book of Genesis does not support an old-earth, nor young-earth creationism as it was not meant to communicate chronological history but rather theology. Identifying the genre of the text is essential and Dickson concludes that the Genesis account of creation is not written in a style which is generally associated with historical narrative. As a consequence of this model of interpretation one could surmise that biological evolution and an old-earth are not in conflict with the book of Genesis, although it is worth mentioning that it does not support such assumptions either.

> My rejection of the literalistic reading of Genesis 1 offers no direct support of old-earth, progressive creationism (or 'theistic evolution', as it is sometimes

> called), nor is it intended to do so. In fact, the case made below is consistent with virtually any scientific account of origins (Dickson, 2009, p. 3).

Dickson's perspective is also supported by Tremper Longman III (2005) in his book, 'How to Read Genesis', who states,

> It appears that Genesis itself is not interested in giving us a clear and unambiguous understanding of the nature of the creation days. This ambiguity fits in with the overall impression we get of the passage, that it is not concerned to tell us the process of creation. Rather it is intent on simply celebrating and asserting the fact that God is creator (Longman III, 2005, p. 104).

This literary interpretation of the early chapters of Genesis has also been adopted by many Christians practicing science such as neurochemist Alexander (2008), geneticist Collins (2006), physicist Giberson (2008) and cellular biologist Miller (1999). Each who have released publications describing the compatibility between biological evolution and the Genesis account of creation.

Walton (2009), in his book, 'The Lost World of Genesis One: Ancient Cosmology and the Origins Debate', argues that Genesis' account of creation is functional and not material. In particular, Walton suggest that the young-earth creationist interpretation of the Hebrew word *yom* being 24 hour literal days is indeed correct but that they have incorrectly read the Hebrew words *bara* and *asa* meaning 'create' and 'made' respectively. He suggests that these words be interpreted in a non-materialist context, implying the Genesis account describes the allocation of function to the cosmos rather than the creation of the material cosmos. Walton highlights the compatibility between evolution and theological thought.

> I am not suggesting a wholesale adoption of evolution, merely suggesting that neither Genesis 1 specifically nor biblical theology in general give us any reason to reject it as a model as long as we see God as involved at every level and remain aware of out theological convictions. (2009, p. 136).

In the book, 'Seven Days that Divide the World: The Beginning According to Genesis and Science', Lennox (2011) claims that the Genesis account describes a historical

event in a literary medium. His major assertion is that God's actions occurred in 6 distinct 24 hour days but the time between each day is undisclosed and therefore may have been extended periods of time, allowing for an old earth. Although this is his assertion, he clearly affirms the notion that such a belief is in the larger picture inconsequential.

> No major doctrine of Scripture is affected by whether one believes that the days are analogical days or that each day is a long period of time inaugurated by God speaking, or whether one believes that each of the days is a normal day in which God spoke, followed by a long period of putting into effect the information contained in what God said on that particular day (Lennox, 2011, p. 58).

It is important to note that Lennox (2011) does not necessarily endorse biological evolution and frequently criticises the selective power of natural selection. Lennox advocates the concept of several key interventions of God in the history of the earth, including the origin of the first homo sapien. In a similar fashion, the book, 'Who was Adam?: A Creation Model Approach to the Origin of Man' by Rana and Ross (2005) presents a model where God also repeatedly intervened in Earth's history, initiating new lifeforms, including humans. In this model, the Genesis creation days were long periods of time allowing for the earth to be described as being millions of years old but the traditional biological evolution explanation is not accepted.

2.6.3.2.3 Acceptance of biological evolution does not undermine the concept of original sin

One implication of accepting an age of the earth to be 4.5 billion years would be the apparent undermining of the concept of original sin and salvation. Several young-earth creationist writers (Batten, 1999; Cosner, 2008; Cosner, 2009; Sarfati, 1999; Smith Jr, 2007) suggest that if one accepts the age of the Earth to be billions of years old, one must accept death, bloodshed, disease and suffering before Adam's original sin.

Lennox (2011) addresses this issue by drawing attention to the scriptural reference in Genesis which describes the entry of 'death' into the world and highlights the fact that, according to his interpretation, the verse states that death became a consequence in *human beings* as a result of Adam's sin rather than animal death in general. Lennox

asserts that humans are moral beings and the death of a moral being is far more significant than the death of another animal or plant which would not be described as moral. According to this line of thought, Lennox's perspective allows for millions of years of animal (non-human) and plant death before the sin of Adam which brought about the 'death' of humanity. Rana and Ross (2005) continue this notion suggesting that the hominin organisms preceding 'Adam', the first homo-sapien, were not human beings in the biblical sense of the word and therefore their deaths before Adams original sin are inconsequential. Both Lennox (2011) and Rana and Ross (2005) assume that Adam was a real historical homo-sapien and the first of his kind. Furthermore both writers argue that his appearance in natural history was an act of supernatural intervention. These approaches create a model of compatibility with an ancient earth and a degree of biological evolution although both writers do not endorse the latter (Lennox, 2011; Rana & Ross, 2005).

A different approach is taken by Osborn (2014) in his book, 'Death Before the Fall: Biblical Literalism and the Problem of Animal Suffering'. Osborn expansively critiques biblical literalism and young-earth creationism focusing specifically on the issue of animal suffering and death before 'Adam's' original sin. In reference to the problem of animal suffering, Osborne highlights that the introduction of animal suffering after 'Adam's' sin compared to millions of years before does not alleviate its implications. He suggests that,

> [i]t is time that biblical literalists at least candidly acknowledge that the challenges they face are not only scientific but theological and moral as well, and that these problems are no less great for them than for process creationists or theistic evolutionist (Osborn, 2014, p. 128).

Consequently, in agreement with Lennox (2011), animal death before 'Adam's' sin is inconsequential and holds no bearing on the salvation story. Osborn asserts that for this reason, and several others, the Genesis account needn't be in conflict with biological evolution.

Longman III (2005) and Blocher (1984) adopt a literary interpretation of the book of Genesis and the entry of 'death' into humankind and as a result find no conflict with an ancient earth and evolutionary biology. This 'death' that is described in the early

chapters of Genesis is, according to Longman III and Blocher, reference to figurative death, or more plainly, separation from a relationship with God. The possibility of physical animal death before the first homo sapien walked the earth presents no conflict with the Genesis story nor the implications of the redemptive action of Christ.

In his book, 'Creation or Evolution: Do We Have to Choose?' Alexander (2008) echoes the sentiment laid out by theologians Longman III (2005) and Blocher (1984), drawing a clear distinction between physical death and what he describes as 'spiritual death'. Alexander comments on the biblical understanding of death stating that, "[n]owhere in the Old Testament is there the slightest suggestion that the physical death of either animals or humans, after a reasonable span of years is anything other than the normal pattern ordained by God for this earth." (2005, p. 246) While he adds that the term 'spiritual death' is not found within the biblical text it is an appropriate way to describe the alienation from God caused by sin described in Genesis 3. In the same vein, Collins (2006) regards the creation account in Genesis as allegory and similarly regards the act of 'original sin' to have resulted in separation from God rather than the transition from immortality to mortality. Both writers agree that physical death before 'Adam' as a result of millions of years of biological evolution is inconsequential in the Genesis creation story and holds no bearing on the redemptive sacrifice of Jesus Christ (Alexander, 2005; Collins, 2006).

2.6.3.2.4 Biological evolution does not act as evidence for the non-existence of god

An apparently compelling argument presented by several atheist writers such as Dawkins (2006) and Coyne (2015) presents the idea that biological evolution has the capacity to not only remove the need for the supernatural from the study of biology but goes further and undermines the foundation of many Christian's belief in God, namely the argument from improbability. In his book, 'The Dawkins Delusion: Atheist Fundamentalism and the Denial of the Divine', McGrath (2007) addresses this argument simply and effectively. McGrath explains that appeals to gaps in scientific understanding as evidence for the existence of God was a, "foolish move, and was increasingly abandoned in the twentieth century" (McGrath, 2005, p. 10). McGrath goes on to describe this type of reasoning as misguided and a failed apologetic strategy which has for the most part been rendered obsolete. Consequently, if for most modern Christian theologians the argument from improbability is no longer in circulation, the

attacks on it from certain members of the atheist community are of little concern. This is echoed by Alexander, who states:

> Whether we have a current gap in our scientific knowledge or not is irrelevant to the question of God's creative actions, and least of all should that gap in our knowledge be utilised as an argument for God. Christians have no hidden theological investments in scientific ignorance! (2005, p. 184).

This is confirmed by mathematician Lennox (2011) who states:

> As a scientist I am sensitive to the danger of falling into a "God of the gaps" mentality and running the risk of intellectual laziness. For that reason I hasten to say that I do not find the main evidence of God's activity in the current gaps in the scientific picture. I see evidence of God everywhere in the science we do know – indeed, I see it in the very fact that we can do science (2011, p. 165).

Another response to the idea that biological evolution could support atheism is presented by Walton (2009) who summarises that the absence of scientific evidence for a supernatural God is not in itself evidence of its non-existence. He proclaims that,

> Even when a divine hand cannot be observed through scientific methods that is insufficient reason to conclude that a divine hand does not exist or is active. Science is designed only to operate within the closed system of the material universe-it ought not therefore to pass judgement on whether or not there is anything outside the material universe (2009, p. 154).

The assertion that the study of science will eventually lead a scientist to integrate atheism into their worldview is countered by McGrath (2007) who describes his own experience with his atheist colleagues as follows:

> Most unbelieving scientists of my acquaintance are atheists on grounds other than their science; they bring those assumptions to their science, rather than basing them on their science. Indeed, if my own personal conversations with scientist are anything to go by, some of Dawkins' most vociferous critics within their number are actually atheists. His petulant, dogmatic insistence that all "real" scientists ought to be atheists has met fierce resistance from precisely

> the community that he believes should be is fiercest and most loyal supporter (McGrath, 2007, p. 21).

McGrath's sentiment is supported by atheist philosopher Ruse who claims, "you can argue – as I have argued many times, privately and publically – that Darwinism is a scientific theory and that you can hold it whether you have Christian belief or not" (Ruse, 2007, p. 39).

2.6.3.2.5 Scientific practice is compatible with a religious worldview

The claim that scientific practice is incompatible with a religious worldview is professed to be founded on the notion that Christians actively corrupt the scientific enterprise, teaching its followers not to change their minds or want to know exciting things about the natural world around them (Dawkins, 2007). This is also closely linked to Dawkins' belief that all individuals with a Christian worldview strongly adhere to celebrating gaps in scientific understanding and use these gaps as evidence for their faith in God.

Walton (2009) comments of the importance of the scientific method as an explanatory power and explains the danger of invoking a supernatural agent when attempting to explain a scientific phenomenon. He states:

> If scientists simply threw up their hands and admitted that a metaphysical, teleological explanation was necessary, they would be departing from that which is scientific (2009, p. 129).

Walton goes on to highlight the logic in using scientific explanations to describe natural cause and effect processes, in contrast to the attitude that is occasionally attributed to Christians by atheist writers. Walton articulates that Christians believe that,

> God creates each human in the womb, but we do not object when embryologists offer a natural cause-and-effect process. We believe that God controls the weather, yet we do not denounce meteorologists who produce their weather maps day to day based on the predictability of natural case and-effect processes (Walton, p. 135).

Many scientists with a Christian worldview claim that their belief in God does not hinder their explorative desire but that,

> Nature is open to many legitimate interpretations. It can be interpreted in atheist, deist, theist and other ways – but it does not demand to be interpreted in any particular manner. One can be a 'real' scientist without being committed to any specific religious, spiritual or anti-religious view of the world (McGrath, 2007, p. 23).

Furthermore, many, "believe that all biological descriptions without exception are attempts to understand God's world. Scientists are engaged in a voyage of discovery of discovery through the universe that God has brought into being and continues to sustain." (Alexander, 2005, p. 185).

Highlighting the false dichotomy between a Christian worldview and scientific practice, famous evolutionary biologist Gould (1992), in an otherwise insignificant book review, states that "[s]cience simply cannot by its legitimate methods adjudicate the issue of God's possible superintendence of nature. We neither affirm nor deny it; we simply can't comment on it as scientists" (1992, p. 118). This line of thought is repeated by Collins (2006) who proclaims that Dawkins' claim that science demands atheism goes beyond the evidence. He clarifies that God is outside of nature, and therefore science can neither prove nor disprove His existence.

A final point regarding the compatibility of scientific practice with a Christian worldview can be found in the many publications, such as Bovey's (2008), 'God, the big bang and Bunsen-burning issues' and Berry's (2009) 'Real scientists real faith', which document over thirty prominent scientists' perspectives on the compatibility of their Christian beliefs and their scientific careers. Simply listing the many practicing scientists who profess to have a Christian worldview is not evidence of compatibility itself but it does certainly lead one to inquire how these great scientific minds have reconciled two apparently conflicting perspectives. A final point of interest is that the majority of the scientists in both publications also find no conflict between biological evolution and their Christian faith (Berry, 2009; Bovey, 2008).

2.7 SUMMARY OF CHAPTER

Chapter 2 consisted of an exploration of the literature based around the three research questions.

1. What effect does attitude and acceptance of the Christian worldview have on a student's understanding of the theory of biological evolution?

2. What effect does attitude and acceptance of the Christian worldview have on a student's acceptance of the theory of biological evolution?

3. What effect does attitude and acceptance of the Christian worldview have on a student's science-related attitudes?

Section 2.1 introduced the five areas of research that were addressed in this chapter: Christian worldview, science-related attitudes, biological evolution in science curriculum, acceptance of biological evolution and the relationships between Christian worldview and acceptance of biological evolution.

Section 2.2 provides a review of the literature on Christian worldview. It begins by providing a rationale for faith-based schooling in Australia followed by a general description of the concept of a worldview. The concept of a Christian worldview is then expounded identifying six core beliefs associated with such a worldview. These include: the Holy Trinity; the 'Kingdom of God'; salvation by grace; the love ethic; the ritual of Baptism; and the ritual of the Eucharist. Following this was a brief description of three major denominations within the Christian worldview, namely: Roman Catholic, Protestant and Orthodox. The final two parts of this section include a brief discussion on the factors contributing to worldview formation, such as parents, community, teachers and the school sector and finally a framework for the measurement of a Christian worldview.

Section 2.3 offers a review of the literature on science-related attitudes. It begins by providing a rationale for the study of science-related attitudes, primarily the decline in students pursuing scientific careers and the increasing scientific illiteracy in the general public. Following this was a general description of the definition of science-related attitudes as clarified by Klopfer (1971) into seven specific groups. The factors affecting science-related attitudes are then expounded identifying thee relevant factors

affecting science-related attitudes. These include: gender, classroom/teacher factors and curriculum variables. There is currently a gap in the literature regarding the impact of a Christin worldview on science-related attitudes and this study could possibly aid in reducing such a gap. The final part of this section includes a brief discussion on the methods used to measure science-related attitudes.

Section 2.4 delivers a synthesis of the literature pertaining to biological evolution in secondary science curriculum. It begins with an account of the historical development of biological evolution in Secondary science education, particularly in the United States, followed by a description of the placement of biological evolution in the Western Australian Curriculum (2009). Within this description some of the educational benefits of including Biological evolution in Science Curriculum are highlighted. The key conceptual ideas of the theory itself are then clarified as: Random genetic mutation, natural selection, speciation and evidence for evolution.

Section 2.5 provides an analysis of the literature on acceptance of evolution. It begins by identifying a gap in the research which is specifically the lack of an Australian context in the study of acceptance of biological evolution, which provides a clear rationale for this specific study. Following this is a general description of the factors affecting student acceptance of the theory including: religious factors; scientific factors; social and emotional factors; critical thinking and epistemological views; and demographic factors. The research suggests that religious factors appear to be the highest ranking factor affecting acceptance of biological evolution adding further value to this particular study. The final part of this section describes the methods used to measure the acceptance of biological acceptance.

Section 2.6 provides a review of the literature describing the relationships between a Christian worldview and science, which accepts biological evolution. It begins by describing four perspectives regarding the relationship between science and a Christian worldview based on the research of Barbour (1990) namely conflict, independence, dialogue and integration. The concept of a 'conflict' model is then expounded identifying two groups of individuals who hold this view, namely 'young-earth' creationists (Batten, 1999; Ham, 1987; Sarfati, 1999; Weiland, 1997) and a small group of atheist scientists and philosophers (Coyne, 2015; Dawkins, 2006; Dennet, 1995). The perspectives of the first group, young-earth creationists, are

described and the key areas of contention are summarised as acceptance of biological evolution being related to: a link with immorality, the rejection of the authority of the Bible, the undermining of the concept of original sin, and having a severe lack of evidence provided by the scientific community. The second group of individuals who possess this perspective are atheist scientists such as Dawkins (2009) and Coyne (2015) and their perspectives are discussed and their evidence for a conflict model can be summarised as: biological evolution acts as evidence for atheism, and the incompatibility of a science with a religious worldview. Following this a synthesis of Barbour's (1990) second, third and fourth groupings is made, collectively describing them as 'non-conflict' models. The final part of this section includes a rationale for accepting a 'non-conflict' perspective and provides an analysis of the current rhetoric to some common critiques of the 'conflict' model found in current scholarship lending credibility to the conclusion that fostering a 'non-conflict' model is not only possible but perhaps beneficial in an education setting.

This chapter is followed by Chapter 3, which describes how the research project was designed and then implemented to address the three research questions under investigation in this study. It outlines the research approach and the research design used in the study, including the procedures used in the collection and analysis of the data.

Chapter 3: Research Method

3.1 INTRODUCTION

The purpose of this study was to develop an understanding of students in a faith-based school's acceptance and understanding of the theory of biological evolution and its relationship to their own personal Christian worldview in an Australian context.

Research Questions:

1. What effect does attitude and acceptance of a Christian worldview have on students' understanding of the theory of biological evolution?
2. What effect does attitude and acceptance of a Christian worldview have on students' acceptance of the theory of biological evolution?
3. What effect does attitude and acceptance of a Christian worldview have on students' attitudes to science?

The importance of documenting methodology lies in the justification of using various methods to address the research questions. Without such justification, the reader loses confidence in the relevance and meaning of the research. It is also important to identify the bias which will be present throughout the conducting of the research. This thesis was conducted from an 'interpretivist' paradigm (Willis, 2007) which immediately reveals a set of preconceived ideas and bias. It is not necessarily the purpose of this chapter to justify such a bias but rather to identify and document it. A key theme in the interpretivist paradigm is that interpretation of experiences is critically important in a humans understanding of the world.

Furthermore, to address the research questions a 'case study' research method has been adopted (Merriam, 2009). The case consists of Western Australian students from a specific Christian faith-based school in the context of the biological evolution curriculum area. The research design used in this thesis is an 'Explanatory mixed methods' design. Creswell (2014) describes a mixed methods design as one where both quantitative and qualitative data are collected and analysed, and together they provide a deeper understanding of the phenomenon than either could by themselves. The quantitative data was collected in the form of questionnaires while the qualitative

data was in the form of interviews and participatory observations. The questionnaire was divided into four main scales. These included:

1. Understanding and attitudes towards the Bible and religious faith
2. Science-related attitudes
3. Understanding of the theory of evolution
4. Acceptance of the theory of evolution.

Scales 2, 3 and 4 were to be compared with scale 1 which correlates directly with the three research questions. The interviews were conducted using open ended questions which gave the participating students the opportunity to explain their own interpretations of their experiences in their own words. The data sample includes Year 8, 10, 11 and 12 students from a non-denominational Christian secondary school where the researcher is employed, located in metropolitan Perth, Australia. Students from Year 11 and 12 were studying either 2A/2B/3A/3B Human Biological Science while all students from Year 8 and 10 were invited to take part in the study. Quantitative student questionnaire data was coded and statistically analysed using the SPSS software package to identify any correlation between the factors in the research questions. Qualitative data, in the form of interview transcripts and classroom observations were examined for emergent themes to develop a deeper understanding of any correlation which was identified by the quantitative data analysis.

3.2 RESEACRH METHODOLOGY

Methodology can be described as the broad process by which a researcher will abide to test or obtain knowledge (Cohen et al., 2013). The paradigm from which this research has been conducted is that of an Interpretivist. The word ‘paradigm’ has been described as being a series of general theoretical assumptions and laws which may be applied in a variety of situations (Willis, 2007). This would imply that an ‘interpretivist paradigm’ is a set of theoretical assumptions, laws and techniques linked together by a common idea termed interpretivism. Interpretivism has been described as a paradigm which acknowledges that, ‘humans are (also) influenced by their subjective perception of their environment – their subjective realities’ and that, “…what the world means to the person or group being studied is critically important…” (Willis, 2007, p.6). To

further clarify the concept it could be said that the interpretivist believes that humans interpret their sensations rather than directly experiencing the sensual world as it actually is (Willis, 2007). As this research thesis is written from the interpretivist paradigm it is important to draw attention to some of the advantages and limitations of using such a paradigm.

In the context of this research thesis, the interpretivist paradigm has several advantages. As outlined by Cohen et al. (2013), the use of an interpretivist paradigm ensures that the students' sense of choice, freedom and individuality are upheld, acknowledging that they are unique and difficult to generalize. Research question 2 is specifically related to student's acceptance of biological evolution and this notion of acceptance is a choice which is deeply affected by context. Depending on the student's environment, which may consist of a fundamentalist Christian family or perhaps an anti-theist family, their interpretation of situations will vary greatly. This is best communicated through rich descriptions and the opportunity for the students to interpret their own experiences. The focus of the research, as outlined in research question 2, is the relationship between a personal Christian worldview and attitude towards biological evolution. The researcher is not simply interested in what the correlation is but in acknowledging that the factors influencing such a correlation are strongly related to the students' interpretation of their personal experiences. This is a distinct advantage of the adoption of an interpretivist paradigm in this thesis. There are some limitations of the interpretivist paradigm in relation to this thesis including the problems associated with verification (Cohen et al., 2013). Fortunately this can be minimized by adopting a mixed methods research design which includes both quantitative and qualitative data, allowing for triangulation.

Arriving at an interpretivist paradigm is not done without deeper philosophical considerations into concepts such as ontology and epistemology. It could be said that it is these two philosophical stances which heavily influence an individual's eventual paradigm (Cohen et al., 2013). Ontology has been described as the philosophical stance regarding the nature of existence or more specifically the "characteristics of reality" (Willis, 2007, p. 9). This could be paraphrased by stating that ontology is an individual's perception of what dictates reality and the specific characteristics of what exists and what does not exist. This research thesis has been written from a

interpretivist ontology, inferring that the world does exist but different people understand it and interpret it in very different ways giving rise to multiple realities, rather than a single universal reality (Willis, 2007). In relation to a student's acceptance of biological evolution as a consequence of personal Christian worldview, this is clearly linked to the idea that different people understand and interpret scientific events in different ways, based on personal values and perspectives. This is a strongly interpretivist ontology, and clearly reflects the idea that reality is unique, individual, subjective and complex. When attempting to obtain understanding and meaning, in the context of this research thesis, it is vital to acknowledge that there are many realities, each one a combination of tangible and material singularities which are being influenced by personal experience. Prominent young-earth creationist Sarfati (1999) states, "It is a fallacy to believe that facts speak for themselves – they are always interpreted according to a framework." (1999, p. 15).

Epistemology can be described as the philosophical stance regarding the acquisition of knowledge and what factors lead an individual to trust in such methods (Willis, 2007). Regarding the interpretivist epistemology it has been suggested that knowledge may be subjective, spiritual or even transcending based on experience and interpretation of situations and events. These experiences provide insight of a unique and deeply personal nature (Cohen et al., 2013). Such an epistemology allows an individual with strong religious convictions to consolidate events and meaning in their lives. Rather than the heavy emphasis of the 'empirical/positivist' epistemology on knowledge which is established through the traditional scientific method, the interpretivist paradigm fosters a more 'rational/anti-positivist' epistemology, which infers that knowledge can be developed through reasoning and reflection (Cohen et al., 2013). This research has been designed in such a way that the participants in the research are not simply labelled as 'incorrect' as a consequence of their perception of reality being based on a type of experience and rational knowledge as opposed to one which is material and can be verified empirically. This is particularly relevant as one of the core themes in this research is religious worldview, which by nature, does not need empirical validation to be established as dependable knowledge.

The research aimed to reveal meaning and understanding regarding a student's attitudes towards biological evolution as a result of a personal Christian worldview.

To disregard a student's experiences as a form of data due to the fact that the knowledge is not empirical, could be described as ignoring the very nature of the social sciences. The interpretivist paradigm holds at its core the idea that humans do not necessarily experience stimuli from their environments but rather their interpretation of them (Wills, 2007). Each human will interpret these stimuli slightly differently based on their personal experiences and beliefs. The interpretive paradigm does not necessarily attempt to discover 'truths' but rather associate meaning with these personal experiences.

3.3 RESEARCH METHOD

For this research thesis an 'Instrumental Case Study' research method was adopted (Merriam, 2009). Merriam (2009, p. 40) describes a case study as 'an in-depth description and analysis of a bounded system' which is very similar to Creswell's (2014) description which includes the idea that a case study is an approach where the investigator explores a bounded system using multiple sources of information and reports a case description and case-based themes. With reference to these two definitions, both Merriam (2009) and Creswell (2014) use the term 'bounded system'. It is therefore important to discuss the meaning of this particular term. A bounded system, according to Merriam (2009) is described as a system where the unit of analysis is clearly confined and very specific. The system has clear boundaries which should provide a very distinct context. In relation to this research thesis, the bounded system consists of Western Australian students from a specific Christian faith-based school in the context of the biological evolution curriculum area. The case is described as 'instrumental' (Merriam, 2009) as it is not the case itself which is of particular importance but rather its ability to facilitate understanding of a deeper issue.

Concerning the research questions, Question 1 and 2 were designed to describe the interaction between a student's personal Christian worldview and their acceptance and understanding of biological evolution, while Question 3 focused on the relationship between the student's personal Christian worldview and their attitude to science lessons in general. Undoubtedly it is impossible to separate these variables from their context.

The purpose of this case study was to provide a rich, thick description of the particular phenomenon present among students studying biological evolution in a faith-based school, allowing the reader to develop a deeper understanding of the phenomenon itself. These features of a case study have been described by Merriam (2009, p. 43) as 'particularistic, descriptive and heuristic'. The implication is that a case study has the potential to focus on a particular situation or event, provide a detailed description of the phenomenon and deliver the opportunity for new or greater understanding.

Clearly the context of this thesis is narrow but it is this very feature which acts as a benefit rather than a limitation. The case itself is intrinsically interesting and therefore provides an opportunity for the researcher and readers to discover new meaning and insight. Although it may be possible to make generalizations and possibly transfer developed conclusions from this study to another, that was not its primary purpose.

3.4 RESEARCH DESIGN

For this research thesis an 'Explanatory Mixed Methods' research design was adopted (Creswell, 2014). A mixed methods design has been described as one where, "you have both qualitative and quantitative data and both types of data, together, provide a better understanding of your research problem than either type by itself" (Creswell, 2014, p.552). Specifically, within the mixed method design, an 'explanatory design' was adopted. This has been described by Creswell (2014, p. 560) as a process of, 'first collecting quantitative data then collecting qualitative data to help explain or elaborate on the quantitative results'. The quantitative data ideally provides broad generalisations and allows the researcher to gain a general understanding of the trends and patterns among student responses to the research questions. This data was collected from student questionnaires. It is important to note however, that this was only a starting point as it was the qualitative data which allows the researcher to gain specific understanding and interpret the meanings behind the responses provided by the participants in the quantitative data. This data was collected from student interviews and participatory observations.

The explanatory mixed method research design has several advantages. As outlined by Creswell (2014) the use of an explanatory mixed method research design produces

specific numerical data which can be statistically analysed, revealing correlations between factors in the research questions such as a student's acceptance of faith and their acceptance of biological evolution. Continuing from that point, the qualitative data can provide actual words of students in the study and offer many different perspectives not described in the quantitative data. By providing an opportunity for the students to explain their own understanding and acceptance of biological evolution, different perspectives which were not predicted by the researcher may emerge creating a more accurate, complex picture of the situation. The decision to collect the quantitative data before the qualitative data was based on the idea that the quantitative data creates a general picture, highlighting key generalisations, while more detailed and specific information may be gained by following up the quantitative data with qualitative data collection. As mentioned previously, a mixed method research deign also allows a degree of validation between the two sources of data.

One of the key limitations of the 'Explanatory Mixed Methods' research design is its labour intensive nature and the requirement of expertise and time in both qualitative and quantitative data collection. The collection and analysis of both qualitative and quantitative data is time consuming and the limited time has the capacity to restrict the amount of data collected and the depth of analysis.

3.5 SAMPLE

The data sample included Year 8, 10, 11 and 12 students from a non-denominational Christian secondary school where the researcher was employed, located in metropolitan Perth, Australia. Students from Year 11 and 12 were studying a Human Biological Science course (either 2A/2B/3A/3B) while all students from Year 8 and 10 were invited to take part in the study. The significance of selecting Year 10, 11 (2A/B HBS) and 12 (3A/B HBS) students is related to the fact that they would at some time in the year be taught specifically about biological evolution. The Year 8 group was selected as in many Western Australian schools Year 8 marks the beginning of secondary school and this initial introdution to secondary school Science makes the group significant. The Year 9 cohort was excluded from the sample as the Researcher had no direct teaching contact with students from this group. The complete secondary school (Year 7-12) consisted of approximately 321 students in 2011 and ran an almost

identical curriculum to a Western Australian State school with some important differences. The Australian Curriculum: Science consisted of four major Science Understanding sub-strands. These include 'Chemical Sciences', 'Biological Sciences', 'Physical Sciences' and 'Earth and Space Sciences' (Australian Curriculum, Assessment and Reporting Authority, 2011). In Year 8 the biological science substrand consisted of topics such as 'Plant and Animal cells' and 'Body Systems' while in Year 10 the students learnt specifically about the topic of evolution. In reference to Year 11 and 12, the relevant Course of Studies were called '2A/B Human Biological Science' and '3A/B Human Biological Science' respectively. Both courses may culminate with the completion of an external examination. The topic of human evolution was comprehensively taught in 3A/B HBS while it was an underlying theme in 2A/B HBS.

The key variances between a Western Australian state school and the Christian faith-based school from which the sample was obtained was heavily based on the Christian nature of the school. It was compulsory for the students to take part in a 1.5 hour class known as 'Biblical studies' which was the equivalent of Religious Education in a Catholic Education School. The purpose of the Biblical studies class was to edcucate students in the teachings of the Bible. The class was designed to challenge students to understand and apply these teachings, providing a safe environment to discuss their questions and concerns while encouraging them on their own journey of faith. On occasions controversial issues relating to Christian faith may aso be discussed in Biblical studies such as biological evolution. The outcome of such a discussion was usually at the discretion of the teacher. Each form class was required to begin the day with a biblical devotion, often at the discretion of the form teacher. Each individual class began with a prayer, spoken by either student or teacher. Every fortnight the students attended a 'Chapel Service' which tended to continue for approximately 30 minutes. The service usually consisted of some form of Christian message presented by the Chaplain or a special guest. Regarding student enrollments, the school had an 'open policy' meaning that the students enrolled did not need to be a practicing Christian to attend but the parents must have agreed to support the Christian values and 'Statement of faith' professed by the school. The teaching staff, who must be practicing Christians, were also expected to integrate their Christian values into the context of their lessons on a regualr basis. The school had no official statement

regarding biological evolution except that it was part of the Australian Curriculum and must be taught. The Science staff had varying opinions regarding biological evolution, from complete acceptance to complete rejection, and would teach the topic according to the Western Australian curriuculum.

3.6 DATA SOURCES

The first data source consisted of performance / attitudinal questionnaires including four distinct scales: Understanding and attitudes towards the Bible and religious Faith, Test of Science-related Attitudes (TOSRA), Understanding of the Theory of Evolution and Measure of the Acceptance of Evolution. The second and third data sources consisted of student interviews and participatory observations.

3.6.1 Performance / Attitudinal questionnaire

The questionnaire sample included Year 8, 10, 11 and 12 students. Students from Year 11 and 12 were studying either 2A/2B/3A/3B Human Biological Science while all students from Year 8 and 10 were invited to take part in the study. Only those students whose parents signed the consent forms were able to take part in the study. The Year 8, 10, 11 and 12 groups included 49 students, 25 students, 15 students and 12 students respectively. The researcher was the teacher of all students involved in the data collecion except one class of Year 10 students. This would likely explain the lower number of Year 10 participants as collecting consent forms was apparently very difficult for the assisting Year 10 teacher. These questionnaires were completed in May 2011. Under the supervision of the researcher, the students were allowed up to 20 minutes to complete the questionnaire but the majority were finished between 10-15 minutes. This was done during class time after approval from the Learning Area coordinator had been granted. During the completion of the questionnaires certain students had difficulty understanding particular words such as ‘contradict’, ‘ambiguous’, divine’, ‘speculation’, and ‘beneficial’. These words were either explained to the student asking the question or a definition was written on the board for all of the students to see. In the same way, several students had difficulty with certain statements in the questionnaire stating that they agreed with half of the statement but disagreed with the other half. In these instances the researcher instructed the students to select the ‘not sure’ option in the questionnaire. Further difficulty was

experienced when aspects of a statement in a questionnaire were amusing to individual students who would make silly comments or jokes about the 'obviously incorrect' nature of the statement. If this was overheard by other students it may have affected their choices in the questionnaire. Students who were absent during the original questionnaire time period were placed in a separate isolated room and allowed to complete the questionnaire privately, with a teacher in the near vicinity.

Table 3.1 *Male/Female students in each year group sample for questionnaire*

Year group	Age	Number of students		
		Male	Female	Total
8	13-14	25	24	49
10	15-16	11	13	24
11	16-17	8	7	15
12	17-18	6	6	12

The performance/attitudinal questionnaires were used to assess the students' understanding of biological evolution and the attitudinal measures were used to gather data regarding the students' attitudes towards biological evolution specifically and science in general. Similarly, these methods also provided some insight into the student's general 'development of their faith' and their attitude towards a Christian worldview.

Some of the strengths of a performance / attitudinal questionnaire as a form of quantitative data collection, as outlined by Creswell (2014) include the ability to make useful generalisations based on empirical data and the lack of bias of the researcher. This is important as the generalisations provide a useful starting point for the qualitative data collection as well as minimising the researcher's bias during this stage of the research. The main limitations of using a performance / attitudinal questionnaire as a form of data collection, such as the exclusion of notions of choice, freedom, individuality, are overcome as a result of the mixed methods research design which includes the use of interviews and participatory observations.

The questionnaire was divided into four scales (See appendix A).

1. Understanding and attitudes towards the Bible and religious Faith
2. Test of Science-related Attitudes:
    a. Attitudes of Scientific Enquiry
    b. Adoption of Scientific Attitudes
    c. Enjoyment of Science Lessons
3. Understanding of the Theory of Evolution
4. Measure of the Acceptance of Evolution

The four scales were presented in this order to represent a logical thought process. As the three research questions were focused on the effect of a Christian worldview on Science-related attitudes (RQ3), understanding of biological evolution (RQ1) and acceptance of evolution (RQ2) it was thought to be logical to first establish a student's acceptance and understanding of a Christian worldview. The scale containing Science-related attitudes was perceived to be less confrontational and therefore placed before the two biological evolution scales. The Understanding biological evolution scale was placed before the acceptance of biological evolution scale as it appeared logical to allow a student to establish their understanding of the theory of biological evolution before revealing their acceptance of it.

The statements were written from either a negative perspective or a positive perspective, allowing students to respond on a scale of 1-5, where 1: Strongly Disagree; 2: Disagree; 3: Not sure; 4: Agree; 5: Strongly agree. The following table lists the statement breakdown per scale. Copy of the questionnaire is presented in Appendix 1.

Table 3.2 *Scales, link to Research Questions and Number of questions in Questionnaire*

Scale	RQ	Number of Questions		
		Positive	Negative	Total
1. Understanding and attitudes towards the Bible and religious Faith	1,2,3	16	9	25
2. TOSRA: Attitudes of Scientific Enquiry	3	5	5	10
TOSRA: Adoption of Scientific Attitudes	3	5	5	10
TOSRA: Enjoyment of Science Lessons	3	5	5	10
3. Understanding of the Theory of Evolution	1	10	10	20
4. MATE: Acceptance of the Theory of Evolution	2	10	10	20

3.6.1.1 Understanding and attitudes towards the Bible and religious Faith

Regarding the formation of the questionnaire statements in the first scale, these were formulated from Pope (2014) in the form of a questionnaire titled 'Biotechnology Attitudes and Religious Belief Questionnaire' (BARBQ) with amendments. The BARBQ consisted of three sections: Demographic Information, Attitudes towards Biotechnology and Christian Worldview. Only the third section, Christian Worldview, was included as it was relevant to Research Questions 1, 2 and 3. The amendments made were based on feedback from various sources. These sources included four staff in the faith-based school the researcher was employed at, including the Chaplin, and two Christian Ministers at a local Christian fellowship. These individuals were provided with a copy of this scale of the questionnaire and requested to write feedback on the individual statements. These sources provided valuable feedback regarding the wording and terminology used and such feedback was taken into account when making amendments to the questionnaire. The majority of the changes were made to

make the statements clearer and simpler as well as specific to a Christian worldview. Some examples of these changes are statement 1, 2 and 3 in Table 3.3. The original questionnaire had an equal focus on attitudes towards the Bible and attitudes towards a religious worldview while the questionnaire used in this research thesis made more of an emphasis on understanding and attitudes towards a Christian worldview. Therefore some statements regarding the Bible were removed and replaced with statements which reveal a student's understanding of the doctrine of the Christian faith. Some examples of these changes are statements 4 and 5 in Table 3.3. Additional changes regarding the accuracy of a statement were made with reference to the University textbook, 'An Introduction to Christian Theology' (McGrath, 2011). An example of this includes statement 6 in Table 3.3. Some of the original statements were completely removed as they were too ambiguous. An example of this is, 'The Biblical account of creation is accurate'. The problem with a statement like this, particularly in reference to this thesis, was the false dichotomy it created. An accurate scale cannot be applied, as strong disagreement or strong acceptance does not necessarily correlate with acceptance or rejection of a Christian worldview.

Table 3.3 *Modifications/Replacements in Faith scale of questionnaire*

Statement	Original Statement	Modified/Replacement Statement
1.	I would consider myself a religious person	I am a Christian
2.	Jesus Christ was the Divine Son of God	Jesus Christ is the Divine Son of God
3.	There is no such thing as a God who is aware of man's actions	God is not always aware of man's actions

4.	The Bible is the product of man's imagination	The Bible was written by men from men's imagination. It was not inspired by God.
5.	Quotations appearing in the Bible are true	The Holy Trinity (God the father, Jesus and the Holy Spirit) are all God.
6.	The Bible contains religious truth	Mary and Joseph, the parents of Jesus, conceived Jesus naturally and there was nothing supernatural about His birth.

3.6.1.2 Test of Science-related Attitudes (TOSRA)

The second scale was taken directly from Fraser (1981) in the form of a pre-validated questionnaire titled 'Test of Science-related Attitudes' (TOSRA). The TOSRA scales were based on Klopfer's (1976) taxonomy of the affective domain related to Science education (Fraser, 1981). The original TOSRA questionnaire consisted of seven subscales, each with 10 items.

These consist of:

1. Social implications of Science
2. Normality of Scientists
3. Attitude to Inquiry
4. Adoption to Scientific Attitudes
5. Enjoyment of Science Lessons
6. Leisure Interest in Science
7. Career Interest in Science

Subscales 3-5 were selected to be used in this questionnaire due to their specific relevance to Research Question 3, 'What effect does attitude and acceptance of Christian faith have on students' attitudes to Science?' As the TOSRA questionnaire

was selected to address only one of the three research questions, if all 70 items were to be included this would make the questionnaire too time consuming. It was decided to remove subscales 1, 2, 6 and 7 as the core student attitudes to Science could be established through the remaining three subscales. The TOSRA questionnaire was selected for use for two main reasons. The first was its well established reliability. After its development (Fraser, 1981) the TOSRA questionnaire has been used many times in Science education research consistently demonstrating strong reliability (Bui & Alfaro, 2011; Clewett & Tran, 2003; Joyce & Farenga, 1999; Santiboon, Chumpolkulwong, Yabosdee, & Klinkaewnarong, 2012). For this reason no amendments were made. The second reason the TOSRA questionnaire was selected was due to the useful format of the items. TOSRA was able to yield separate scores for distinct attitudinal aims rather than one overall score.

The TOSRA questionnaire was able to provide direct insight into students' Science-related attitudes which when correlated with the data collected from the 'Understanding and attitudes towards the Bible and religious Faith' scale address Research Question 3 with strong reliability.

3.6.1.3 Understanding of the Theory of Evolution

The third category was created from various sources including but not limited to Year 10 topic tests, examinations, chapter review questions (Rickard, 2009), 2A/B and 3A/B Human Biological Science topic test, examinations, and chapter review questions (Newton & Joyce, 2010) with amendments to make the questions into either negative or positive statements. The content areas selected to be included in the scale were directly related to the Western Australian Curriculum: Science course documents.

According to the Australian Curriculum: Science content descriptors it was a curriculum requirement that biological evolution be taught at the Year 10 level in Science stating, 'The theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence (ACSSU185)' (Australian Curriculum, Assessment and Reporting Authority, 2011). This content descriptor clearly mandated the teaching of biological evolution through natural

selection including the evidence for evolution. The Human Biological Science 3A/3B document (Curriculum Council, 2009) included 'Variation and Evolution' as a compulsory component of the course. Specifically the 3A Unit description stated, "Gene pools are affected by evolutionary mechanisms including natural selection and chance occurrences. The main evidence for evolution comes from comparative studies in anatomy and biochemistry, and the fossil record" (Curriculum Council, 2009). The Unit 3A description went on to elaborate by detailing concepts such as changes in allele frequencies being due to mutation; natural selection; random genetic drift including Founder effect; and migration. The evidences for evolution which were directly referenced include: comparative studies of DNA, protein sequences, anatomy including embryology, homologous structures and vestigial organs and the fossil record (Curriculum Council, 2009).

This scale was designed to address research question 1 and covered all of the major concepts in biological evolution as recommended by the Western Australian and Australian Curriculum: Science documents.

3.6.1.3 Acceptance of the Theory of Evolution (MATE)

The fourth scale was taken directly from Rutledge and Warden (1999) in the form of a questionnaire called 'Measure of Acceptance of the Theory of Evolution Instrument' (MATE). The instruments validity and reliability have been repeatedly established (Donnelly, Kazempour, & Amirshokoohi, 2009; Rutledge & Sadler, 2007). Although the MATE instrument was originally designed for use among Secondary high school biology teachers, it has been validated and employed for measuring acceptance in high school students (Donnelly, Kazempour, & Amirshokoohi, 2009). The MATE instrument consists of 20 statements related to several aspects of evolutionary theory, including its validity, and common misconceptions or disagreement of the statements on a five-point Likert scale. This scale was unaltered and specifically related to research question 2.

3.6.2 Student Interviews

The interview sample included 3 Year 10 students, 2 Year 11 students and 3 Year 12 students from the questionnaire sample. There was a third Year 11 student interviewed but the audio recording device malfunctioned and their audio recording was corrupted.

Each student was interviewed individually. These interviews were completed during February and March 2012. The interviews were conducted either during the students lunch break or after school. Generally the interviews ranged from 10 to 25 minutes and were conducted in one of the Science Laboratories at the College. Only the student and researcher were present during the interview although other teaching staff members were present in the neighbouring rooms. The interviews were recorded using a 'ZOOM' microphone recorder onto an SD card.

Table 3.4 *Male/Female students in each year group sample for interview*

Year group	Age	Number of students			Pseudo names
		Male	Female	Total	
10	15-16	1	2	3	Sally, Lucy, Dan
11	16-17	1	1	2	Annabelle, Boris
12	17-18	2	1	3	Francis, Harry, Tatiana

The interviews allowed the researcher to reveal meaning and the reasons behind the participant's responses in the questionnaires drawing specific attention to the relationships between the data on 'acceptance of biological evolution' and the data on 'Understanding and attitudes towards the Bible and religious Faith (Creswell, 2014). Students for this phase were selected based on their responses in the questionnaires, where there were students representing the whole spectrum.

Some of the strengths of conducting interviews as a form of qualitative data collection, as outlined by Creswell (2014) include the supply of richly descriptive and in depth interpretations of data, the notion that the individual's sense of choice and individuality are upheld and the opportunity of the student to use their own words to describe personal experiences. These strengths are particularly relevant as when combined with the quantitative data provided by the performance/attitudinal questionnaires, produce a rich, descriptive picture of the student's experience. The use of interviews as a form of qualitative data collection is not without its limitations and these are accurately outlined by Creswell (2014). One of these includes the researcher's strong bias, as the information is interpreted by the researcher. The very nature of the interpretivist paradigm requires in depth description and interpretation of

experiences. This includes that of the student participants as well as the researcher. The presence of a bias is inevitable although its identification is of great importance.

There is also the possibility of the interview data being deceptive, as the students could be providing the response the student perceives the researcher wants to hear as well as the researcher's very presence possibly affecting the student's response. In all cases the researcher had also been the student's classroom teacher and therefore had a rapport with the participating students. Ideally this would create a degree of trust and increase the likeliness of a student producing an honest response. It was also made clear that the student's responses would not be included in any form of assessment or reporting which would reduce the likeliness of a student responding untruthfully. It is worth noting that another limitation of an interview is the unclear, poorly articulated responses of certain student participants. This was a difficulty but satisfactorily overcome with requests of elaboration and further explanation.

The questions used for the interviews were open ended allowing students the opportunity to elaborate on their responses and explain the reasons behind their reactions to the questions. The interviews were divided into the same four categories as the questionnaires but the order was altered. This was due to the fact that discussing personal worldview tends to be a very personal topic and therefore would be too intrusive to be the first topic of the interview. The questions were presented in the following format:

Figure 3.1 *Student Interview Questions*

1. Do you generally enjoy Science as a subject? What is it about Science that you like/dislike?
2. Do you see the knowledge gained from Science as useful to society? Why is this?
3. This picture [referring to a photograph] is of a polar bear in the snow. An adaptation of the polar bear is its white fur. According to biological evolution, could you explain the process which resulted in the polar bears fur being white? (Mechanisms of evolution)
4. Could you describe some of the reasons the general scientific community believes biological evolution has occurred? (Evidence for evolution)

5. Do you accept biological evolution as an acceptable explanation for the diversity of life on Earth? What reasons do you have for your acceptance/rejection?
6. Do you believe that biological evolution is compatible with a Christian worldview? What reasons do you have for this belief?
7. Could you explain what being a Christian means to you?
8. Would you consider yourself a Christian? What reasons do you have for your decision?
9. Do you have anything else that you would like to add relating to this topic?

Interview questions 1 and 2 were directly related to research question 3 exploring student's science-related attitudes. In specific the first interview question provided the participant the opportunity to elaborate on the TOSRA subscale 5, referring to their enjoyment of Science lessons. The second interview question was selected to allow discussion of TOSRA subscales 3 and 4, which include student's attitudes to inquiry and adoption of scientific attitudes. Both interview questions gave the student the opportunity to allocate value to scientific knowledge and ideally revealed some ways in which the student's interpretations of their experiences have influenced their attitudes.

Interview questions 3 and 4 were directly related to understanding biological evolution which is the focus of research question 1. Both interview questions were designed to focus on two major concepts in biological evolution curriculum, namely the mechanism of biological evolution through natural selection and the evidence for evolution. The specific example of polar bear evolution was selected to narrow the participant's explanations and also add a descriptive context for the participants to build their discussions around.

Interview questions 5 and 6 attempted to investigate the participant's acceptance of biological evolution which was directly related to research question 3. These two questions were drawn from the MATE scale and ideally instigated a discussion revealing the reasons underlying the participant's level of acceptance of biological evolution. As a result of the interview questions the participant may be inclined to

share some insight into their personal interpretation of the scientific evidence for biological evolution and explain how such perspectives may have been formed.

All three research questions aimed to understand the impact of the student's Christian worldview which was the focus of interview questions 7 and 8. These two interview questions allowed the participants to elaborate on their own worldview and comment on what they interpreted a Christian worldview to comprise of. The interview questions were intentionally open ended giving the participant the freedom to choose how much depth they desired to provide in their respond.

The final interview question was designed to provide a platform for students to clarify or elaborate on any of their responses to the other questions.

3.6.3 Participatory Observations

The participatory observations were conducted during the teaching of the biological evolution component of the curriculum in Year 10 and 3A/B Human Biological Science in 2011 and 2012. The Year 10 groups generally consisted of between 20-30 students while the 3A/B HBS groups consisted of between 10-20 students. The year 10 groups were taught biological evolution in Term 1 (February-April) while the 3A/B HBS groups were taught biological evolution in Term 3 (August-October).

The purpose of the participatory observations was to consolidate the data acquired from the other two research methods, possibly providing further insight into the research questions. Such observations were conducted during the teaching of the biological evolution component of the curriculum in Year 10 and 3A/B Human Biological Science. These groups were observed between 2011-2012.

Some of the strengths of participatory observation as outlined by Creswell (2014) include the opportunity to record information as it occurs in the classroom during the teaching of biological evolution and the opportunity to study individuals who have difficulty verbalizing their ideas in an interview setting. One limitation includes the difficulty in taking written notes while teaching the class during a lesson.

3.7 DATA ANALYIS

Quantitative student questionnaire data was coded and statistically analysed using the SPSS software package to answer research questions 1-3. The response for each positive statement was coded from 1-5, representing 'strongly disagree' to 'strongly agree' for each questionnaire if the statement was a negative the values were inverted. This data was then entered into an excel spreadsheet and later transferred into the SPSS software. Qualitative data, in the form of interview transcripts and classroom observations were examined for emergent themes to answer research questions 1-3.

3.7.1 Choice of Unit for Statistical Analysis

Statistical analysis was performed using the individual student (private beta press) as the unit for analysis rather than the class mean (consensual beta press). The level of analysis is important as it can affect the interpretation of the data, the magnitude of the relationships between variables, and the ability of the data to yield statistically significant results (Field, 2005).

The choice to use the individual as the unit for analysis was based on the specific research questions and the interpretivist paradigm from which this thesis was written. The research questions aimed to reveal an understanding of the relationships between student attitude towards the Bible and a Religious worldview and their understanding and acceptance of biological evolution. The Questionnaire was designed to allow students to give personal responses based on their own experiences and perceptions drawing focus to the individual student. Therefore statistical analysis of the individual as the unit for analysis was the logical choice.

3.7.2 Validity and Reliability of the Questionnaire Scales

To examine the reliability and validity of the Questionnaire scales, 'Cronbach alpha reliability' and 'ability to differentiate between classes' were used. It was necessary to establish that each item in a scale was assessing a common construct or had internal consistency. The internal consistency reliability of each of the six scales were analysed using the Cronbach's alpha coefficient. Upon initial analysis of the alpha coefficients, two questionnaire statements were removed to increase reliability. The first statement

was from the ‘TOSRA: Adoption of Scientific Attitudes’ scale while the second was from the ‘Understanding of the Theory of Evolution’ scale. This reduced the number of items in the questionnaire from 95 to 93.

To determine whether there was any statistically significant difference between the classes, a one-way analysis of variance (ANOVA) with class membership as the independent variable was calculated for each scale. The proportion of variance accounted for by class membership was calculated using the F statistic (the ration of ‘between’ to ‘within’ variability)

3.7.4 Associations between Questionnaire Scales

To analyse associations between Attitude and Acceptance of a Christian worldview and the other three scales, a simple correlation analysis, multiple correlation analysis and standardised regression analysis were used. The specific associations being analysed were:

1. Attitude and acceptance of a Christian worldview on students’ understanding of the theory of biological evolution? (RQ 1)

2. Attitude and acceptance of a Christian worldview on students’ acceptance of the theory of biological evolution? (RQ 2)

3. Attitude and acceptance of a Christian worldview on students’ attitudes to Science? (RQ 3)

Regarding the simple correlation analysis, the Pearson correlation coefficient (r) produced was indicative of a linear relationship between two variables, where the closer the value is to 1, (+ or -) the closer the variables were to having a perfect linear relationship. This relationship was described as positive or negative. This form of analysis is useful as it can provide information on whether a relationship is statistically significant as wells the basic nature of the relationship. An example could be an r value of -0.70, which reveals a strong negative linear relationship between the two variables.

The standardised regression coefficient was also a measure of the relationship between variables but more specifically its predictability. A β value of 0 implies a change in the predictor variable results in no change in the predicted value of the outcome. This is a different test to the simple correlation analysis but it would be expected to produce similar results. In both simple correlation and standardised regression analyses, for the coefficient to be statistically significant the *p* value, which represents the probability the data occurring by chance, must be less than 0.05.

The multiple correlation coefficient (R^2) was used to provide an indication as to the percentage of the variance of multiple variables likely to have been caused by the predictor. This type of test may aid in providing an overall picture of the effect of a students' understanding and acceptance of Christian faith on understanding and acceptance of evolution and Science-related attitudes (Field, 2005).

3.7.5 Qualitative data analysis

The first stage of the qualitative data analysis consisted of the researcher transcribing the interview tapes and typing up field notes of classroom observations. These transcriptions were then read by the researcher multiple times and notes made in the margins allowing a general sense of the material to develop. This has been described by Creswell (2014) as a 'Preliminary exploratory analysis'. After this stage the data was coded. This process has been described as 'segmenting and labelling text to form descriptions and broad themes in the data' (Creswell, 2014). Generally the texts were divided into segments, the segments were labelled with descriptive codes, and eventually these re-emerging codes were collapsed into themes and described.

3.8 ETHICAL CONSIDERATIONS

It was important to ensure that the aims of the research, the position of the researcher and the use of the results were clearly made available to all involved parties before the fieldwork commenced and during the data collection. The parents/guardians were made aware of the opportunity they had to be present during any interviews, as well as the participant's right to withdraw from the study at any time. The participants were also informed that participation or non-participation would not affect the student's academic progress in any way. It was also made clear that the privacy, confidentiality,

and anonymity of participants would be maintained through the separation of personal information from the raw data and the use of pseudonyms in interview transcripts. This information was communicated through a 'participant information sheet' (See appendix 2). Throughout the period of data collection, feedback was also provided to the interviewed participants such as the progress of the study and any interim results which may have been relevant. At the end of each interview, a brief period of time to allow the participants the opportunity to review notes was provided and participants were encouraged to make additional comments.

Permission

Written permission was obtained from all parties before the researcher began to collect any form of data. In addition, ethics approval was sought from Curtin University and approved (see Appendix No 3). Permission to conduct the study was obtained from the Principal, while a clear and legible 'consent form' was signed by all participants and relevant parents/guardians.

Consideration

The students' general wellbeing was of great importance and as beneficence is a basic value in ethics, it was imperative that all participants be only minimally exposed to any risk of harm. The researcher strived to maintain a relationship of trust and negotiation, recognising that there was a power relationship between participant and researcher. An unequal power relationship may hinder participant consent as well as willingness to participate. Particularly in this research thesis, where the sensitive topic of personal faith was discussed, extra care was taken to avoid excessive confrontation. If a student appeared to be uncomfortable with a particular issue of discussion then it was decided that the researcher would either take a different angle of conversation or skip over the topic completely. Fortunately this was not the case and none of the participants appeared to be uncomfortable, either emotionally or psychologically. The interviews were generally kept under 15 minutes rather than having a long interview which may be physically uncomfortable.

Triangulation

Cohen et al. (2013) describes triangulation as the use of two or more methods of data collection in the social sciences to explain more fully, the richness and complexity of

human behaviour. In reference to establishing concurrent validity, triangulation is an effective technique. A key benefit of using triangulation as a means of establishing validity is the circumstance where both quantitative and qualitative data are supportive and produce similar results (Cohen et al., 2013). Assuming the data triangulates, the correlations found between the factors in the research questions from the questionnaires will also be evident in the themes produced from the interview analyses. The ability to triangulate data as a means of establishing validity is a strong benefit of the mixed methods research design.

3.9 SUMMARY OF CHAPTER

The purpose of this study was to explain procedures for developing an understanding of students in a faith-based school's acceptance and understanding of the theory of biological evolution and its relationship to their own personal Christian worldview in an Australian context. This study was conducted from an 'interpretivist' paradigm, (Willis, 2007) and a key theme in the interpretivist paradigm is that interpretation of experiences is critically important in a humans understanding of the world. To address the research questions a 'case study' research method was adopted (Merriam, 2009) consisting of Western Australian students from a specific Christian faith-based school in the context of the biological evolution curriculum area. The research design used in this thesis was an 'Explanatory mixed methods' design (Creswell, 2014) where both quantitative and qualitative data were collected and analysed, in the form of questionnaires, interviews and participatory observations. The questionnaire was divided into four main scales including: Understanding and attitudes towards the Bible and religious faith, Science-related attitudes, Understanding of the theory of evolution and Acceptance of the theory of evolution.

The data sample included Year 8, 10, 11 and 12 students from a non-denominational Christian secondary school where the researcher was employed, located in metropolitan Perth, Australia. Students from Year 11 and 12 were studying either 2A/2B/3A/3B Human Biological Science while all students from Year 8 and 10 were invited to take part in the study. Quantitative student questionnaire data, consisting of 101 questionnaires, was coded and statistically analysed using the SPSS software package to identify any correlation between the factors in the research questions.

Qualitative data, in the form of eight interview transcripts as well as multiple classroom observations were examined for emergent themes to develop a deeper understanding of any correlation which was identified by the quantitative data analysis.

Chapter 4: Data analysis and Results

4.1 INTRODUCTION

In this chapter the results and analysis for the three research questions are addressed. The research questions include:

1. What effect does attitude and acceptance of a Christian worldview have on students' understanding of the theory of biological evolution?

2. What effect does attitude and acceptance of a Christian worldview have on students' acceptance of the theory of biological evolution?

3. What effect does attitude and acceptance of a Christian worldview have on students' attitudes to Science?

The research questions will be addressed through the presentation of statistical analysis carried out on the associations between the independent variable, which was the students' 'Attitudes towards the Bible and Religious Faith' and the dependent variables, which were the remaining five scales. These scales included understanding of biological evolution (RQ1), acceptance of biological evolution (RQ2) and students' attitude to Science (RQ3). The 'students' attitude to Science' scale was further broken down into three subscales (Attitude to Science inquiry, adoption of scientific attitudes and enjoyment of Science lessons). The questions will also be addressed through a presentation of the qualitative data in the form of emergent themes identified during the interview process with eight student participants.

Following the introduction, Section 4.2 is a description of the validity and reliability of the questionnaire including descriptive statistics, internal consistency reliability and the ability to differentiate between classes. Section 4.3 presents an overall analysis of the associations between questionnaire scales while Sections 4.4 through to Section 4.6 provide a detailed analysis of these associations according to the relevant research question. Section 4.4 addresses Research question 1, Section 4.5 addresses Research question 2 while Section 4.6 addresses Research question 3. Within these sections the

emergent themes associated with each research question are described and analysed. The final section (Section 4.7) provides a summary of the results and key findings presented in this chapter.

4.2 VALIDITY AND RELIABILITY OF THE QUESTIONNAIRE

The validity and reliability of the questionnaire is presented with reference to descriptive statistics and internal consistency reliability. The Cronbach alpha reliability coefficient was used as an index of scale internal consistency and is reported in Table 4.1. Following this, the ability to differentiate between classes is presented in Table 4.2 using an analysis of variance (ANOVA) with class membership as the main effect.

4.2.1 Descriptive Statistics and Internal Consistency Reliability of the questionnaire

With reference to Table 4.1 it can be observed that the mean response in the 'Understanding and Attitudes towards the Bible and Religious Faith' scale (4.05) was fairly high. Similarly the mean responses in the three 'Test of Science-related Attitudes' means were also notably high (3.48, 3.72 and 3.74). Furthermore, the mean responses in the 'Understanding of the Theory of Evolution' and 'Acceptance of the theory of Evolution' scales were notably low (2.21 and 2.81).

Internal consistency reliability (Cronbach alpha coefficient) is a measure of the extent to which items in the same scale measure a common construct (Field, 2005). The Cronbach alpha reliability coefficient was used as an index of scale internal consistency. Table 4.1 reports the Cronbach alpha coefficient for the revised 93-item questionnaire. The scale reliability estimates ranged from 0.55 to 0.92 with the individual as the unit of analysis. As a reliability coefficient of 0.70 or higher is considered to be 'acceptable' in most social science research situations (Streiner & Norman, 2003) five of these reliability coefficients can be considered satisfactory while the 'Understanding of evolution' scale was particularly low (Alpha reliability = 0.55). The sample included students from Year 8 to Year 12, where the Year 8 students had no formal education regarding Evolutionary theory compared with the Senior School students (Year 10, 11 and 12) who had studied the topic extensively. It is also

important to note that the questionnaire used in this study was likely the first time the Year 8 students had been presented with such detailed questions regarding evolutionary theory and were likely being challenged by a new way of thinking. The mean correlations were also analysed but none of these values were statistically significant.

Table 4.1 *Scale, Number of Items, Mean, Standard Deviation and Internal Consistency (Cronbach Alpha Reliability) for the questionnaire*

Scale	No of Items	Mean	SD	Alpha Reliability
Understanding and Attitudes towards the Bible and Religious Faith	25	4.05	0.61	0.92
Attitude to Scientific Inquiry	10	3.48	0.64	0.80
Adoption of Scientific Attitudes	9	3.72	0.50	0.70
Enjoyment of Scientific lessons	10	3.74	0.82	0.94
Understanding of the Theory of Evolution	19	2.21	0.23	0.55
Acceptance of the Theory of Evolution	20	2.81	0.69	0.91

n= 101 students

4.2.2 Ability to Differentiate between Classes

To examine the ability of each scale of the questionnaire to differentiate between attitudes and understanding of students in different classes, an analysis of variance (ANOVA) with class membership as the main effect was used. Table 4.2 reports the ANOVA results, which indicated the extent to which students in the same class demonstrate similar attitudes and understanding, while perceptions varied from class to class. By a comparison of the means it can be seen that certain classes clearly produced different responses to the different scales. This observation was supported by the F- test on Table 4.2. The F value is the ratio of the between-group variability and the within-group variability (Field, 2005). A ratio of 1:11 (Attitude towards Religion) implies very little comparative variability while a ratio of 1:21.96 (Understanding of Evolution) implied a high level of comparative variability. The analysis demonstrated significant differences between students' attitudes and understanding in different classes for four of the six scales. 'Attitude Towards

Religion' and 'Attitude to Scientific Enquiry' demonstrated no significant difference between classes, while 'Adoption of Scientific Attitudes' and 'Enjoyment of Scientific Attitudes' demonstrated a significance of $p<0.05$. 'Understanding of Evolution' and 'Acceptance of Evolution' demonstrated strong significance with $p<0.001$. As represented in Table 4.2 it can be seen that in the 'Understanding of Evolution' and 'Acceptance of Evolution' scales the year 12 class consistently demonstrated higher means (2.50 and 3.56) while the Year 8 class demonstrated the lowest means (2.07 and 2.64).

Table 4.2 *Ability to Differentiate between Classes (ANOVA results)*

Scale	Mean				S D				F
	Yr 8	Yr 10	Yr 11	Yr 12	Yr 8	Yr 10	Yr 11	Yr 12	
Attitude Towards the Bible and Religious Faith	4.02	4.10	3.89	4.30	0.54	0.69	0.60	0.71	1.11
Attitude to Science Inquiry	3.59	3.31	3.48	3.35	0.61	0.73	0.69	0.48	1.27
Adoption of Scientific Attitudes	3.63	3.66	3.91	4.02	0.51	0.47	0.53	0.37	3.01*
Enjoyment of Science Lessons	3.61	3.59	4.06	4.07	0.91	0.81	0.50	0.51	2.68*
Understanding of the Theory of Evolution	2.07	2.26	2.31	2.50	0.14	0.16	0.22	0.26	21.96***
Acceptance of the Theory of Evolution	2.64	2.75	2.89	3.56	0.59	0.74	0.69	0.54	6.78***

*p<0.05, ***p<0.001 n=Total 101 students, Yr 8=49, Yr 10=25, Yr 11=15,Yr 12=12

4.3 ASSOCIATIONS BETWEEN QUESTIONNAIRE SCALES

Associations between Attitude and Acceptance of Christian worldview, and acceptance and understanding of biological evolution and Science-related attitudes were analysed next and were in direct relation to the three research questions:

1. What effect does attitude and acceptance of a Christian worldview have on students' understanding of the theory of biological evolution?

2. What effect does attitude and acceptance of a Christian worldview have on students' acceptance of the theory of biological evolution?

3. What effect does attitude and acceptance of a Christian worldview have on students' attitudes to Science?

Each variable in a research question was directly related to a scale in the questionnaire. Using a simple correlation analysis, multiple correlation analysis and standardised regression coefficient the associations between the scales were deemed statistically significant. In all three tests the independent variable was the students 'Attitudes towards the Bible and Religious Faith' while the dependent variables were the remaining five scales. This is consistent with the three research questions where the researcher is attempting to understand the effect that attitude and acceptance of Christian faith has on understanding of biological evolution (RQ1), acceptance of biological evolution (RQ2) and students' attitude to Science (RQ3). The 'students' attitude to Science' scale was broken down into three subscales (Attitude to Science inquiry, adoption of scientific attitudes and enjoyment of Science lessons).

The results indicated the multiple correlation coefficient between Attitudes towards the Bible and Religious Faith scale and the other five scales were not statistically significant. This was likely due to the large variance described previously in the Understanding of Biological Evolution scale. The results of these tests are presented in Table 4.3 and most effectively reported under the heading of the research question they address.

Table 4.3 *Associations between Questionnaire Scales with Attitudes towards the Bible and Religious Faith in terms of Simple Correlations (r), Multiple Correlation (R) and Standardised Regression Coefficient (β)*

Scale		Attitudes towards the Bible and Religious Faith	
		r	β
Attitude to Scientific Inquiry		-0.18	-0.13
Adoption of Scientific Attitudes		0.18	0.13
Enjoyment of Scientific lessons		0.12	0.10
Understanding of the Theory of Evolution		0.17	0.37***
Acceptance of the Theory of Evolution		-0.53**	-0.70***
Multiple Correlation	*R*	0.70	
	R^2	0.50	

**p<0.01, ***p<0.001

4.4 DATA ANALYSIS OF RESEARCH QUESTION 1: What effect does attitude and acceptance of the Christian worldview have on students' understanding of the theory of biological evolution?

The data collected to address Research Question 1 was both quantitative and qualitative. The following quantitate data was analysed in the form of associations between scales while the qualitative data consisted of the analysis of emergent themes throughout participant interviews.

The presentation of the qualitative data included direct quotations where the participants' actual names were replaced with pseudonyms to protect their identities. The key emergent categories which were identified were subdivided into mechanisms of biological evolution and evidence for biological evolution. Within the mechanisms

of biological evolution category, several themes were identified. These included: mutation as a source of variety; natural selection; speciation and other minor themes. Within the evidence for biological evolution category, several themes were also identified including: the fossil record; comparative anatomy; comparative DNA and several other minor themes. Finally the influence of an adoption of a Christian worldview on responses regarding understanding of biological evolution was discussed.

4.4.1 Associations between Attitudes towards the Bible and Religious Faith and Understanding of the Theory of Evolution

For the simple correlation reported in Table 4.3, the Understanding of the Theory of Evolution scale was not statistically significant, producing an r value of 0.17. The results for the standardised regression coefficient, using the individual as the unit of analysis, demonstrated strong significance ($p<0.001$) with a β value of 0.37. Both values indicated a positive association.

4.4.2 Emergent themes in qualitative data

The interview questions regarding understanding of biological evolution were structured in such a way that participants were requested to discuss two major concepts within the larger theory of biological evolution. These two concepts included mechanisms of biological evolution and evidence for biological evolution. The second concept, evidence for evolution was more open, allowing participants to recall any information they desired regardless of context.

4.4.2.1 Mechanisms of Biological Evolution

Regarding the understanding of biological evolution, participants were asked to discuss their understanding of the mechanisms by which biological evolution works. In general all participants made some form of reference to the concept of Natural selection when attempting to explain the process of biological evolution. A point of interest was the variety in the level of depth provided and consequently the gaps in participant understanding. When probed for elaboration, several themes across the participants emerged. These themes included, but were not limited to descriptions of: sources of variety; characteristics providing a survival advantage; speciation and the

presence of a common ancestor. These themes have been presented in *Table 4.4* to illustrate the overall picture of the qualitative data.

Table 4.4 *Broad categories of emergent themes in understanding the mechanisms of biological evolution and number of participant responses*

Discussion Theme	Nº of Responses	% of Participants
Source of Variety: Mutation	6	75
Natural Selection & Survival Advantages	8	100
Speciation & Common Descent	5	63

n = 8 students

4.4.2.1.1 Sources of variety: Mutation

A key concept in understanding biological evolution and natural selection is the identification of the major source of genetic diversity. Although random genetic mutation was not mentioned by all participants, the majority made some inference to the vital role it plays in creating diversity. Very few participants actually defined the term 'mutation' but it is implicit by the context of the term that the students had a satisfactory understanding of the term. One particular 16 year old student, Boris, described mutation as, *'a sort of random effect that just causes some species, or some individuals in a species, to be more likely to survive although not always more likely to survive'*, highlighting that Boris acknowledged the random nature of genetic mutations although the vague nature of his response implies a fairly surface understanding of the process. Boris' response was typical of the participants where the term 'mutation' was frequently used and implied to create variety but rarely actually explained. Tatiana, a 16 year old student studying Human Biological Science 3A/B, struggled to explain the variety found among bears initially but at the end of the interview she was given the opportunity to make concluding remarks and she clarified her understanding by stating:

> *'Evolution happens over a period of time, normally takes quite a long time to happen, through the process of natural selection and mutation. I forgot about mutation. Dang it! That could've been why the polar bears were brown and white because it had a mutation, oh my gosh. Ok, that's the one I forgot'.*

4.4.2.1.2 Natural Selection

The concept of gradual change occurring over time as a result of the selective pressure of the environment within a species was consistently discussed by participants and often in great detail. Dan, a 15 year old student, provided such an explanation stating:

> *'Well, it's natural selection because of its environment. The, because the bear needs to hunt for its food, for it to hunt it can't let the prey escape, so it needs to blend in with the snow. And all the black bears... cause, well if the bears were different colour than the snow, the prey could see them and it would be pretty obvious. So then they won't have enough food to eat cause they can't catch the prey, so the ones that are whiter they would survive and eventually the black ones would get wiped out and the white ones stay.'*

This explanation provided by Dan reveals a strong understanding of the mechanism of natural selection and although there are certain gaps, such as the lack of a reference to reproduction, he has summarised the process effectively. Other students, such as 17 year old Francis, presented a more brief discussion although the key elements, such as the mentioning of a survival advantage, were still evident. Francis said:

> *'Well, I would say that, um, the white fur started as a mutation. Um, which allows a greater ability to survive. Favourable survival advantage which um, led to, um, natural selection kept them alive, and eventually the ratio of white polar bears to other coloured polar bears changed over time.'*

After a little more probing, Francis elaborated:

> *'Obviously a black polar bear would stand out inside a snow like environment. Meaning that they're more likely to get eaten or fatally wounded, than the polar bear that would blend in.'*

Both Francis and Dan made reference to the survival advantage of white fur in an Artic environment as it allowed the animal to camouflage. A subtle difference between their responses which is worth pointing out is the role of the camouflage suggested by both students. Francis suggested that the polar bear would be less likely to be *'eaten or fatally wounded'* while Dan described the camouflage as being beneficial for the white bear as it would be able to hunt and eat its prey without detection. Considering the position of the polar bear in the food chain, Dan's response was more accurate possibly

indicating a deeper level of understanding in the general field of biology. Boris, a 16 year old student enrolled in Human Biological Science 2A/B, described a similar scenario to Francis but added at the end, *'although I'm not sure what predators there would be of a polar bear'* adding a degree of validity to his previous claims.

Another important concept in natural selection is the movement of favourable characteristics from one generation to the next. This is possible through reproduction, where the individuals within a species who possess the survival advantage reproduce and pass that advantage on to their offspring. Of the participants interviewed only one individual mentioned the importance of reproduction. While describing natural selection, 16 year old Anabelle stated:

> *'So as the polar bear evolved the bears with lighter fur would generally survive longer and the ones that had darker fur would die or get killed off. Therefore the white, lighter fur was passed on to their children.'*

This is a vital part in the process of natural selection and surprising to the researcher that only one student would mention it in their explanation.

4.4.2.1.3 Speciation

The term 'speciation' was only mentioned by a few individuals and in particular the discussion of a geographic barrier separating gene flow was only mentioned by two participants. Harry, a 17 year old student studying Human Biological Science 3A/B, mentioned the term with limited elaboration stating:

> *'There would have had to of been a mutation to begin with, um [pause]. And then there would have had to be some form of geographical barrier which separated this white polar bear and uh, all the other polar bears and it would have had to have some, selective advantage over the others, and it just creates the new species, if you like.'*

Although Harry didn't provide an example of such a geographic barrier he was able to clarify that it is essential in separating the population into two groups, if a new species is to be formed. Similarly, only Harry actually mentioned the formation of a new species as a result of natural selection which is the completion biological

evolution. It would appear that the vast majority of participants could describe natural selection but failed to identify its final product, a new species.

4.4.2.1.4 Other themes in mechanisms of biological evolution

Throughout the interviews several other themes emerged but with less detail or frequency. One such theme was the mention of Darwin and his early discoveries. Occasionally a participant would make statements such as, *'Darwin's theory'* or '*Darwin said'* but the reference to Darwin's classification of finches by 15 year old Lucy was indicative of her placement of importance of the scientist who first theorised biological evolution rather than the theory itself. Lucy's actual description of natural selection was very simplistic using general statements such as,

> *'Like the process of, um [pause] like developing and adaptation or, um, characteristics over time due to things that happen to it.*

Another briefly mentioned concept was random genetic drift. Although only mentioned by one student, Tatiana, she listed it as a mechanism of evolution but gave no further explanation. This implied that perhaps she was able to recall the significance of the term but could not recall anything more. This was a common theme throughout the interviews where participants would begin a sentence but not finish it as they either found it too difficult to articulate or simply could not remember the details. An example of this from Tatiana was in her statement,

> 'Chance…Genetic drift…Things happen. How does it happen? [laugh]'

Another particularly interesting theme which appeared in the interview with 15 year old Sally was the presence of subtle Lamarckian evolutionary ideas. While describing the white fur of a polar bear, Sally said:

> *'Something to do with it needing camouflage, and into the snow, I think. Um, because they were getting hunted by other things, so it like kind of faded their skin, maybe?'*

Such a statement tends to imply that the adaptation or physical characteristic arose as a result of environmental pressure rather than the environment selecting a particular trait from existing variety to thrive. Such an understanding of evolution is often

described as Lamarckian rather than Darwinian and is a notable misconception among evolutionary theory.

4.4.2.2 Evidence for Biological Evolution

In reference to the second major concept in biological evolution, participants were asked to discuss their understanding of the evidence for evolution. In general the participants were all able to verbalise some form of evidence for evolution but with varying levels of depth and clarity. A significant discovery in this section of the interviews was the overall lack of detail and understanding provided by the majority of the participants. This was in stark contrast to the participant's discussion of mechanisms for evolution which revealed a fairly high level of understanding. When pressed for more details, several themes across the participants did however emerge including the frequent reference to a common ancestor throughout most pieces of evidence discussed, indicating that the majority of the participants understood the theme of common descent to some degree. These themes included, but were not limited to: the fossil record; comparative anatomy; comparative DNA; and comparative embryology. These themes have been presented in a *Table 4.5* to illustrate the overall picture of the qualitative data.

Table 4.5 *Broad categories of emergent themes in understanding the evidence for biological evolution and number of participant responses*

Discussion Theme	Nº of Responses	% of Participants
Fossil Record	3	38
Comparative Anatomy	2	25
Comparative DNA	4	50
Other (Embryology, Vestigial Organs)	2	25

n = 8 students

4.4.2.2.1 Fossil Record

Throughout the interviews three individuals made reference to the fossil record as a source of evidence for biological evolution. These participants discussed the gradual changes over time which can be observed throughout the fossil record, often increasing

in complexity, but consistently as a result of fine tuning to the environment. Dan stated:

> *'Aww, well there's, uh, fossil and stuff and you can see the different stages of evolution from all the creatures, to see, because of their adaptations they have changed over time to suit the environment, so that, yeah, makes evolution.'*

Dan's brief statement was not particularly detailed but revealed a basic understanding. Similarly, Harry mentioned the fossil record in addition to stating the importance of a common ancestor, saying:

> *'Uh, It could be through fossils and studying of what they do believe to be a common ancestor for us such as the um primate. As they move down the line from the less advanced to more advanced there's a common trend that seems to change until we get to us.'*

Harry was fairly vague, referring to the 'primate' order rather than any particular Family or Genus while the third participant to refer to the fossil record made specific reference to some examples of transitional fossils. Indicating a significantly higher level of understanding, Annabelle stated:

> *'People say there's a lack of evidence for transitional forms but there are evidence of it, like you said, the, um, australopithecine and that bird-reptile.'*

She later referred to '*homo erectus'* and '*homo africanus',* of which the latter was likely intended to be *australopithicus africanus*.

4.4.2.2.2 Comparative Anatomy

A second source of evidence mentioned in select interviews included comparative anatomy. A few participants mentioned the presence of homologous, or with similar structure, features throughout particular groups of organisms which they suggested reinforces the idea that the organisms may be related. Francis summarises this idea in reference to homologous structures, stating:

> *'Their presence across the board in, um, mammals, for example, such as, um, phalanges, um, being present in a lot of different, um, species or, um, the pelvic bone, or the spinal column. Uh, which generally, um, would provide evidence*

enough for a scientist to infer that we could possibly come from a common ancestor.'

Francis was the only participant who actually provided any examples, such as the phalanges or the pelvic bone, indicating that this was a memorable piece of evidence for him but not necessarily for the other participants.

4.4.2.2.3 Comparative DNA

The most common example of evidence for evolution cited by the participants was the similarities in DNA found throughout various organisms indicating their relation to each other. In at least some capacity, all participants described DNA as a compelling indication of common ancestry. Tatiana is a good example of a participant who could make generalisations but struggled using the correct terminology. She described the evidence as:

'Our genes, like our, uh, [pause] DNA. Our DNA is very similar to chimpanzees and um, and gorillas I think.'

She went on to reference Endogenous Retrovirus's (ERV's) as further evidence found in DNA but was confused by the name calling them '*MRV's*'. ERV's are a type of virus which inserts itself into the host's genome and therefore demonstrates ancestry between species. Tatiana concluded:

'And so if we have common [pause] and also MRV's or something. They, I remember, they, like if we have the same as some, another animals we would obviously have to come from something that shares it. Because how else are they meant to have the same ones that we did. So that's another one. MR things. MRV's.'

Another student, Harry, also mentioned ERV's but in less detail. He described a particular technique, saying*:*

'ERV's able to match DNA, Endrogenous? Retrovirus from primates to us. Uh, DNA sequencing I think it's called, and then they take out a part of a chimpanzee and then put some of ours in and see how much it matches up.'

4.4.2.2.3 Other themes

Other sources of evidence for biological evolution did appear throughout the interviews although infrequently or without clarification. Some of these themes included comparative embryology and vestigial organs. The mention of comparative embryology came from Tatiana who said:

> *'Okay, so remember how a lot of species have a lot of embryonic same shapes, like, um, when they start off they have like little tail things and stuff like that. So that's one. Because we all have very similar, okay so they're all very similar when they, we, start off.'*

In this situation, Tatiana was describing the idea that when various vertebrate embryos are compared, certain similarities become evident and these similarities indicate some form of common ancestry. Another piece of evidence which was only mentioned by one individual, Francis, was the presence of vestigial organs. Francis said:

> *'Obviously if it's there and it could have served a purpose at some point time and evolution could have nullified the need to have that in your body but the genetics, genetically it's still growing.'*

Francis was explaining that the existence of certain organs which appear to have diminished size or purpose could be evidence of the link between an organism and its ancestors as it may have served a greater purpose in them but over time has become redundant.

Throughout the interviews multiple participants described examples of natural selection as evidence for evolution. This highlights certain gaps in understanding as, in the case of Harry, he began to describe the Peppered Moth and the effect of the Industrial revolution on the species' distribution. Harry stated:

> *'Um and then there's the whole, the different moths through the industrial age or industrial thing, and the black moths seems to outlive the white moths because they were well camouflaged and stuff.'*

The peppered moth is an excellent example of natural selection and could be used as evidence to support the occurrence of natural selection as a mechanism for evolution. However, Harry failed to complete his description by discussing speciation and

common descent. The example of the peppered moth does not provide evidence for speciation nor common descent and in this way is only a portion of the evidence for the greater action of biological evolution. Harry's use of natural selection was also emulated by several other participants in a very similar fashion revealing an area of confusion in this particular topic.

A further significant theme was the abundance of difficulty in articulation and general confusion of the participants. It was common for students to at some point in their explanation of the evidence for evolution to make statements such as Dan's, *'I know there's a lot more because I've studied it but I kind of forgot'* or Lucy's *'Yeah, the evidence for evolution…ah, there's a lot. Um, I don't really know what to say'*.

Many participants were only able to give one example such as Sally who said,

> *'Ah, Yep, because we're like so similar to other animals. And yeah like, chromosomes or something like similar, like percentage in different ones and the way things change, they're not the same any more. That's all I got right now.'*

It was also evident that several participants were misusing terminology or held subtle misconceptions such as the evolution of *homo sapiens* from modern apes. This was the case in the response of Boris:

> *'I think an example would be the closely related genetic ah, make-up of humans and ah, apes? I think. And how ah, they are sort of, you can see the similarities and also the differences, and how ah, they think that humans may have evolved from apes. Yeah, that's the main one I can think of.'*

4.4.2.3 Influence of Christian worldview on responses regarding understanding of biological evolution

One of the major purposes of the interviews was to reveal some of the factors which may have been influencing students' understanding of biological evolution which were not articulated in the questionnaires and explore a possible link between the participant's Christian worldview and such understanding. With reference to the interviews, no such relationship could be determined. In some situations, such as Dan, the students demonstrated a strong adoption of a Christian worldview and displayed a

high level of understanding of evolutionary theory while within the same year group were individuals such as Sally who had significant misconceptions and reservations about the Christian worldview but also demonstrated a high level of understanding of biological evolution. If there is a significant link between Christian worldview and understanding of evolution it was not evident in the interviews conducted during this research.

4.5 DATA ANALYSIS OF RESEARCH QUESTION 2: What effect does attitude and acceptance of the Christian worldview have on students' acceptance of the theory of biological evolution?

The data collected to address Research Question 2 was both quantitative and qualitative. The following quantitate data was analysed in the form of associations between scales while the qualitative data consisted of the analysis of emergent themes throughout participant interviews. The presentation of the qualitative data included direct quotations where the participant's actual names were replaced with pseudo names to protect their identities. The key emergent categories which were identified were subdivided into: complete rejection; complete acceptance; and partial acceptance of biological evolution. Within the partial acceptance category several themes emerged such as: common descent; involvement of God; alternate explanations; and teaching evolution in a Christian school.

4.5.1 Associations between Attitudes towards the Bible and Religious Faith and Acceptance of the Theory of Evolution

Regarding the simple correlation described in Table 4.3, the Acceptance of the Theory of Evolution scale was statistically significant ($p<0.01$), producing an r value of -0.53. The standardised regression coefficient, using the individual as the unit of analysis, also demonstrated strong significance ($p<0.001$) with a β value of -0.70. Both tests reported a negative association.

4.5.2 Emergent themes in qualitative data

Regarding student acceptance of biological evolution, participants were asked to discuss their degree of acceptance and describe the reasons for such acceptance. When questioned, it became clear that the participants held differing beliefs regarding their

own acceptance of biological evolution and each individual was able to justify their beliefs with a fair degree of clarity. In a similar way it was also clear that this topic was one which was challenging the students' preconceived ideas and creating a certain degree of internal conflict or confusion. When requested to elaborate, several themes across the participants emerged. These themes included: those who completely rejected biological evolution; those who completely accepted biological evolution; and finally those who accepted or rejected components of biological evolution but did not completely commit to complete acceptance nor rejection. These themes have been presented in a *Table 4.6* and *Table 4.7* to illustrate the overall picture of the qualitative data.

Table 4.6 *Number of responses indicating participant acceptance or rejection of biological evolution.*

Discussion Theme	Nº of Responses	% of Participants
Strong Rejection of biological evolution	1	13
Strong Acceptance of biological evolution	2	25
Partial Acceptance of biological evolution	5	63

n = 8 students

Table 4.7 *Broad categories of emergent themes and number of participant responses.*

Discussion Theme	Nº of Responses	% of Participants
Acceptance of Natural Selection	8	100
Acceptance of Common Descent from bacteria	2	25
Acceptance of Common Descent in general	5	63
Acceptance of God's action / involvement	6	75

n = 8 students

4.5.2.1 Strong Rejection

The interview process revealed that there was only one participant of the eight interviewed, who strongly rejected biological evolution as an explanation for the development of life and this was Boris. Boris was very clear about his belief that biological evolution was unacceptable and did not appear to demonstrate any observable personal conflict. He spoke with clarity and confidence and stated clearly

that his main reason for rejecting biological evolution was on the grounds of his Christian worldview.

When asked to discuss his perspectives regarding the compatibility of a Christian worldview with an acceptance of biological evolution he said:

> *'No. Um, mainly due to the fact that in Genesis it says that God created man and that was it. It doesn't say that God created some sort of other animal and then that animal developed into man as humans as we see it. So that's the main belief, or the main reason that I have my belief.'*

In this response, Boris was suggesting that the absence of a direct reference to evolution in the Bible was a reasonable motive for his rejection. This theme was not uncommon among other participants, who were less confident in their responses, also mentioning the absence of any reference to evolutionary mechanisms as an area or confusion or conflict.

Other than the absence of any reference to evolution in the Bible, Boris also mentioned the age of the Earth as an area of contention in his acceptance of biological evolution. Boris said*:*

> *'I find it a [pause] difficult concept to believe on the basis of my religion and that I believe the earth is only young and not many millions of years old. So I find it very difficult to believe that a species could have evolved in that short amount of time and yeah, have developed differences the way they have.'*

Throughout Boris' interview he had presented several typical 'young-earth creationist' arguments and was essentially stating that he rejected biological evolution as he believed it was in conflict with his interpretation of the Genesis account of creation in the Bible.

4.5.2.2 Strong Acceptance

The second group of individuals consisted of the participants who claimed that they completely accept biological evolution as an explanation for the development of life. There were only two individuals of the eight interviewed, who could be classified in this category and both individuals came from distinctly different backgrounds. The first participant, Sally, did not identify with the Christian worldview and expressed

that she was not convinced in the authenticity of Jesus Christ nor the existence of God in general. The second participant, Dan, identified himself as a Christian and affirmed his belief in Jesus Christ and God as the creator of life. An interesting note is that both participants, although possessing very different worldviews, provided very similar reasons for their perspectives namely the overwhelming scientific evidence for biological evolution. It is not surprising that Sally had no issue with acceptance as it a strong theme among the participants that those with a strong Christian worldview tend to be more likely to experience conflict with such an explanation, and Sally had no such conflict. Sally's response was fairly simple and although her use of terms such as 'created' and 'made' could be easily misinterpreted as creationism, she later clarified that this was not her intention. She had said:

> *'It just makes like, more sense in my mind that everything, like, was created in that way and things just got better, from the way it was originally made. It only just kept improving itself. And that's what like spread everything on'.*

Dan's response was also particularly revealing where he essentially expressed confidence in the rigour of scientific research and the integrity of the scientific community. He articulated his justification for acceptance by stating*:*

> *'It's a bit weird, because my book says so, and people smarter than me have found this out and I couldn't think of any other reasonable explanation.'*

This theme is certainly worth mentioning as it appears that one key factor in participant's acceptance or rejection of biological evolution is the notion that conclusions proposed by the scientific community are intelligent and rational and the scientists themselves can be trusted. When probed a little further, it became evident that in the case of Boris, he believed that the vast majority of the practicing biologists in the scientific community were and are simply wrong.

Although Dan was completely accepting of biological evolution he did not propose the process to be completely materialistic or without supernatural intervention. Dan suggested that it was possibly God's intention to create life through biological evolution and went on to use the same line of thought as Boris, suggesting that the Bible doesn't explicitly state that life was not created by evolution and therefore cannot be dismissed on these grounds. He elaborated on this idea stating:

'Well, I reckon God could have made all this stuff happen. With all the natural selection and stuff, he could have just let it happen. It doesn't even exactly say in the Bible that he just made animals straight like this.'

Dan also went on to suggest that he believed if people who hold a Christian worldview were more open-minded and educated they would come to the same conclusion as him, accepting biological evolution. He concluded his interview by saying:

'Most of the time they don't know anything about evolution, they never even studied it, and they're just going on about what the Bible is saying, or what they think the Bible is saying, and stuff. They're just saying all the wrong stuff. And convincing people that what they're saying is right. Even though they're not educated about it.'

Dan's perspective on this point is an interesting theme as it was also mentioned by several other participants. The idea that many of the individuals who reject biological evolution are poorly educated, was fairly common throughout the interviews but it is vital to mention this link was not a focus of the research questions in this study and therefore will not be further commented on.

4.5.2.3 Partial Acceptance / Rejection

This final group of individuals composed of the majority of participants and were categorized by being accepting of aspects of evolutionary theory but not in its complete format. The degree of acceptance varied drastically between participants where many had created alternate explanations which incorporated aspects of evolutionary theory and fused them with various 'creationist' ideas. Throughout this particular topic the interview data was rich and descriptive producing several themes which were not mentioned in the questionnaires. An important theme which was consistent across all of the participants who were in this category was one of personal conflict or the challenging of personal views. It became clear as the interviews progressed that the participants were aware of some form of conflict between the Christian worldview and acceptance of biological evolution. In some cases, such as Tatiana, this difficulty was clearly articulated saying:

'Just with [pause] the whole, you know how, um [pause] Yes. [laugh] Yes. I don't know. That's a very hard question. But it's a good question. A good hard question.'

Lucy spoke of her commitment to the authority of the Bible while still acknowledging an internal conflict, commenting:

> *'I go, um, by my belief of like how everything came to, um, exist by what the Bible says, and some of the, um, things that, um, evolution says contradicts the Bible and by my, um, standards the Bible is the truth and anything that contradicts that is pretty much wrong.'*

Clearly a priority for Lucy in determining acceptance or rejection was establishing the ways in which biological evolution contradict her interpretation of the Bible and the ways that it does not.

Some of the themes which provided a distinction within those who partially accepted biological evolution have been presented in a *Table 4.8* to illustrate the overall picture of the qualitative data.

Table 4.8 *Broad categories of emergent themes among students who partially accepted biological evolution and number of responses.*

Discussion Theme	N^{o} of Responses	% of Participants
Acceptance of Natural Selection	5	100
Acceptance of Common Descent from bacteria	0	0
Acceptance of Common Descent in general	3	60
Acceptance of God's action / involvement	4	80

n = 5 students

4.5.2.3.1 Common descent

Several participants revealed that they were happy to accept natural selection as a mechanism for directing change in an ecosystem but refused to accept the notion of common ancestry. Participants such as Lucy, when discussing her acceptance of certain aspects of biological evolution stated:

> *'Well, natural selection, the theory that...I don't know if I can explain it properly, um like stronger adaptations or, um, traits will be passed on or, um,*

yeah, by things that happen to the actual organism, yeah, they get passed on. But the weaker traits kind of [pause] get lost.'

Lucy continued, specifically identifying common descent as an area which she rejected. She said:

'Um, [long pause] the relation to the, um, the monkeys, the different types of species of like man and apes kind of mixed. Yeah, I don't believe that we all came from like the same [pause] I can't think of the word... Yeah, common ancestor. We were made separately, even though we are all really similar that doesn't mean we all came from a common ancestor.'

This theme was recurrent in several interviews where participants, such as Harry, would make statements like:

'I don't believe that evolution is that we all came from bacteria. I believe that evolution is just, um, the changing in species over generations.'

When asked to elaborate how they came to these conclusions several of the participants referred to the perceived contradiction with the book of Genesis that common ancestry posed, but no such contradiction was evident with natural selection. Students such as Harry and Lucy suggested that natural selection may have occurred and still be occurring after the special creation event which was described in Genesis. According to these two participants, common descent implies the process took longer than 7 literal days and is therefore incompatible with a Christian worldview. It was also evident that certain participants believed that common descent implies that God did not create the first humans, Adam and Eve as described in Genesis and is another reason for rejection of the concept. It would appear that the participants who described this perspective as their own held several 'young-earth creationists' views such the Earth only being a few thousand years old, rather than 4.5 million years and rejection of the fundamental concept of descent from a common ancestor.

4.5.2.3.2 Involvement of God

The involvement of God in the process of biological evolution was an important theme for many participants as even if they didn't describe themselves as 'young –earth creationists' many of them still had deep religious convictions and felt the need to

confirm that their partial acceptance of evolution did not imply their rejection of a Christian worldview. Students such as Francis, who was generally accepting of evolution, mentioned the possibility of God using evolution to action the events described in Genesis. He said:

> *'Because, as a Christian I can't, I don't feel it's my place to say, 'this is how God did it' and 'this is how God didn't do it' because I honestly don't know. And Christians really can't say they know. Nobody can actually say they know if God did it this way I don't know if he did do it this way. But if he did it this way, that's acceptable to me. That's believable. Who am I to say God didn't do it like that.'*

A similar thought process was revealed during Tatiana's interview where she stated,

> *'But through what I've seen, it actually, it kind of does seem like we actually really do have a common ancestor. So what if like God just like, [pause] Oh man, [laugh] what if God just like created one thing and we all came from that. But it doesn't say that in the Bible [pause].'*

Tatiana's response is particularly valuable as it reveals the inner tension she is experiencing while trying to reconcile her understanding of biological evolution with what she has read in the book of Genesis. Like Francis, she suggested that God is still the creator of all life but perhaps He used evolution as a means to create while her concluding remark *'but it doesn't say that in the Bible'* reveals her desire to reconcile both sources information.

The two participants who were clear about their rejection of the Christian worldview also suggested that this perspective was a possible way to consolidate an acceptance of evolution with Christian beliefs. Sally said:

> *'The Christian faith believes that God put us here on Earth but I don't think they put us here on earth like we are I think He guided the way it was done. So He was the one, He created it but He created it on Earth not just plopped something on Earth. He created it so the cells there and guided its way to get where we are now.'*

Annabelle, the second participant who mentioned that she would not describe herself as a Christian, stated:

'I think that you can find, you know, a middle ground, where it says that 'yes God did create everything but God created evolution'. And God created, meant for everything to evolve. And it evolved the way that he planned.'

4.5.2.3.3 Alternate explanations

Another significant theme that emerged throughout the interviews was the variety of ways the participants had attempted to reconcile their understanding of evolution with their interpretation of the book of Genesis. Three particularly interesting perspectives were presented by Annabelle, Harry and Tatiana.

Annabelle

Two key pieces of information regarding Annabelle's perspectives include the fact that she does not accept a Christian worldview and secondly her interest in 'Intelligent design' literature. Annabelle mentioned fairly early on in the interview that she had been reading about 'Intelligent design' and it is likely this influence which resulted in her partial acceptance rather than complete acceptance of evolution. When asked what areas she had difficulty with she said:

'Some things I think that you can't explain. Like [pause] you know people say the eye and that they're too complex, and, you know, that they wouldn't have evolved that way. Whereas it seems to be that something more is there. Something spontaneous that happened that made it occur that way. Cause, it just seems so amazing, so complex that perhaps there is something more to it.'

From statements such as this it would appear that Annabelle had generally accepted biological evolution in its completion but had not completely ruled out the influence of the supernatural.

Harry

Harry stated early on that his understanding of biological evolution did not include common descent from bacteria but what makes his perspective stimulating is that he did not reject the concept of some form of common ancestor as some point. This is evident in his statement:

'In my opinion it could have, we could have begun as lesser apes, um I mean as one of the hominis in saying that, and yeah we just got more suited to our

environment over time… I'd say that I believe God created um, every...not every species, cause that kinda contradicts what I was saying how different species are formed, but God created a common ancestor and from that, we've got more intelligent and the fittest survived.'

In essence Harry was suggesting that some form of special creation event took place involving God creating a series of animals, or 'common ancestors'. From this point evolution had occurred, allowing the degree of biodiversity we observe today to become evident. Throughout Harry's interview it was clear that he was deeply committed to his Christian worldview but also had a high regard for Science and evolutionary theory. In his concluding remarks he said,

'It's not until you actually dive into the subject and start to understand it, that you realise that it's not what they say it is, it's a legitimate and acceptable concept. And yeah, It's a shame that it's put to, for most Christians it's, 'oh evolution, bad' don't even consider it'.

Tatiana

Tatiana provided a rich description of her personal context, explaining the role of her parents and school experience in her acceptance of biological evolution. She describes her experience as:

'I think if you're a Christian, a lot of, growing up a lot of Christians are like, 'evolution, argh'. They're like, 'No, it's bad. We all evolved from monkeys'. That's like, that's growing up. That's what I was always taught. But then we did it in class and I think, it was really like a, you're really like, 'hang on a second?' Like, 'what the heck?' kind of thing. That's what I did anyway.'

Consequently, in her interview, Tatiana moves back and forth between two major explanations of the development of life. The first is a fairly standard biological evolutionary explanation with the inclusion of God as the creator of the process. The second is more interesting and includes the fusion of typical evolutionary biology ideas with specific Biblical references. One such example of this is when she says:

'There's, I think there's bits of evolution that happened but [pause] It's so hard [pause]. So yeah, There's bits of evolution that happened but there's also because of my [inaudible] faith in God, I also think like, I think speciation could

have occurred after the ark. Like, I think that could have happened, you know? And I think that like, ok God says clearly in the bible God created the heavens and the earth, then he goes to say which days he created the animals and man and stuff.'

It would appear that Tatiana was suggesting that in a special creation event God had created a series of organisms and following the events of Noah's ark and the global flood, mentioned in Genesis, evolution began to occur. Tatiana's conjecture was that speciation may have occurred after the global flood but not necessarily before. This interview was particularly interesting as it revealed the extent to which the participant had gone to consolidate her Christian worldview with her understanding of biological evolution and the resulting unique perspective.

4.5.2.3.4 Teaching Evolution in a Christian School

Throughout the interviews the participants were not directly questioned about their perspectives on the inclusion of biological evolution in Australian school curriculum. It is therefore noteworthy that several participants, specifically Boris and Anabelle, raised the issue in their concluding remarks. Both students suggested that it is important for Christian students to be taught about biological evolution although for slightly different reasons. Boris, who described himself as a Christian who was firmly convinced that the earth is very young and that life has not developed through evolution suggested:

'Personally I think that it is fair enough that, um, evolution is taught in Christian schools, because we, as Christians, do need to understand 'secular humanist' in quotation marks again, their point of view on how everything came to be that it is now so that we can also communicate to them our message and what we believe and not seem bigoted, I guess.'

Boris appeared to be suggesting that students who hold a Christian worldview need to be educated in evolutionary theory so they are able to inform and debate with critics effectively and intelligently. He is confident in his personal perspective and believes that to efficiently communicate his ideas to a peer, an understanding of the perspectives of his peer must first be established.

Furthermore, Boris' reference to *'secular humanism'* is also very revealing, as it is the first and only time Boris draws a link between biological evolution and a non-Christian philosophy. It reveals an underlying theme that Boris believes that biological evolution is a concept that lends itself to non-religious materialistic and potentially atheist worldview. The final words of Boris are also worth quoting as they reveal his desire for other students to also understand biological evolution but not to accept it. He says:

> *'Um, so I have no problem with it although I don't support it, but I do think that it is acceptable and good that it is taught in Christian schools, though not necessarily encouraged.'*

The other student who referred to the inclusion of biological evolution in Australian curriculum was Annabelle, who earlier explained that she does not identify with a Christian worldview. Annabelle mentioned that she believed biological evolution should be taught to Christian students to prepare them for later exposure to the concept, perhaps in University. She said:

> *'I think it should be covered in Christian schools because, you know, if you get to Uni and they start taking about it, and you're like 'what?''*

Essentially Annabelle is inferring that biological evolution is an almost universally accepted concept in the scientific community and it is unavoidable in tertiary studies, particularly in biology. She later reveals that her concern was that if the topic is not included in secondary curriculum the students will not only be at an academic disadvantage, they will inevitably have their Christian worldview challenged and perhaps it would be better for this to happen in a safe environment, such as a Christian school, rather than a secular university. Annabelle also mentioned that she felt it appropriate for concepts such as 'Intelligent design' to be mentioned in a 'religious studies' class as an opportunity to be exposed to a variety of perspectives.

4.6 DATA ANALYSIS OF RESEARCH QUESTION 3: What effect does attitude and acceptance of Christian faith have on students' attitudes to Science?

The data collected to address Research Question 3 was both quantitative and qualitative. The following quantitate data was analysed in the form of associations

between scales while the qualitative data consisted of the analysis of emergent themes throughout participant interviews. The presentation of the qualitative data included direct quotations where the participant's actual names were replaced with pseudo names to protect their identities. The key emergent categories which were identified were subdivided into enjoyment of Science classes and importance of Science in society. Within the enjoyment of Science classes category, several themes were identified. These included; personal relevance; expansion of knowledge; and factors hindering enjoyment of Science lessons. Within the importance of Science in society category, several themes were also identified including improvement of quality of life and improvement of current technology. Finally the influence of an adoption of a Christian worldview on responses regarding Science-related attitudes was discussed.

4.6.1 Associations between Attitudes towards the Bible and Religious Faith and Science-related Attitudes.

For the simple correlation reported in Table 4.3, the three Science-related Attitudes scales were not statistically significant. The results for the standardised regression coefficient were also statistically insignificant. As none of the scales produced statistically significant associations, the negative or positive nature of the values is irrelevant.

4.6.2 Emergent themes in qualitative data

The key emergent categories which were identified throughout the interviews were subdivided into enjoyment of Science classes and importance of Science in society. The interview questions for this section were very direct allowing students to give a definitive 'yes' or 'no' but also provided an opportunity for students to elaborate on their choice making the discussion more open.

4.6.2.1 Enjoyment of Science Classes

Regarding Science-related attitudes, participants were asked to discuss their enjoyment of Science lessons and the reasons for such enjoyment or lack of. When questioned, all interviewed participants responded positively. This was initially surprising to the researcher as it was not expected that all participants would have such an overwhelmingly positive attitude to the study of Science. When probed for

clarification, several themes across the participants emerged. These themes included, but were not limited to the personal relevance of Science and the expansion of knowledge. When asked to suggest any aspects of the study of Science that the participants did not enjoy, several themes also become evident. These themes have been presented in *Table 4.9* to illustrate the overall picture of the qualitative data.

Table 4.9 *Broad categories of Science-related attitudinal themes relating to enjoyment of Science and number of participant responses.*

Discussion Theme	Nº of Responses	% of Participants
Enjoyment of Science	8	100
Personal relevance of Science	6	75
The expansion of knowledge	7	88

n = 8 students

4.6.2.1.1 Personal Relevance

One reason for the enjoyment of Science lessons provided by several interviewed participants included a direct reference to the subject's relevance to their lives personally. Sally and Dan, respectively stated, *'It's something that I find I can relate to in other…other areas of life'* and *'I reckon it relates. I could use it for life'.*

In less explicit ways this same theme was revealed in several other participants who referred to themselves or their place in the natural world as a possible motive for their enjoyment of Science learning. Boris described how he liked to *'learn about the world around us and how we can discover more of who we are in the, ah, I guess natural world'.*

Although Boris was primarily describing the learning process in general and the joys of discovery, he also revealed the importance of his own personal significance and how the study of Science could possibly aid in understanding his position in the natural order.

4.6.2.1.2 Expansion of knowledge

Another feature of the study of Science which was consistently discussed by the interview participants was the satisfaction and exuberance experienced as a result of the development of their own scientific understanding. The participants consistently expressed their pleasure in internalising scientific explanations of the natural world making statements such as Anabelle's:

> *'I like it because you can tell things about how things work and it's generally fascinating to find out that, in relation to life. Um…and yeah, I just find it fascinating'.*

This sentiment is echoed by Harry, who states:

> *'I'm not one to take for granted that it is because what it is. I like explanations and Science often provides or seeks to provide such explanations'.*

Of the participants, the vast majority made reference to this theme at least once with certain individuals repeating themselves several times adding emphasis to its significance.

4.6.2.1.3 Factors hindering enjoyment of Science lessons

There were several hindering factors to student enjoyment such as: difficulty understanding complex concepts; displeasure in rote learning and lengthy assessment tasks. It is important to note that these were mentioned independently and often followed by some form of statement qualifying that the participant still enjoyed Science. An example of this would be from Francis, who said:

> *'I don't like long assignments. That would definitely be the highest on my not-liking list. I, um [pause] that's actually really the only thing I don't like. To be honest, I love Science in general. Chemistry, Physics, Human Biology, it's enjoyable.'*

4.6.2.2 Importance of Science in society

A second indicator of Science-related attitudes which was emphasised in the interviews was the participant's beliefs regarding the importance of Science in society. Much like the highly positive responses of participants in relation to their enjoyment of Science lessons, the participants unanimously agreed that Science holds great

importance in the community with responses varying from a fairly neutral '*yes'* to the more emphatic '*definitely'* or '*for sure'*. Regarding the justification of such agreement, it was possible for the Researcher to develop several themes based on participant responses including; the improvement of quality of life; and the improvement of current technology. These themes have been presented in *Table 4.10* to illustrate the overall picture of the qualitative data.

Table 4.10 *Broad categories of Science-related attitudinal themes relating to importance of Science and number of participant responses.*

Discussion Theme	Nº of Responses	% of Participants
Science is important	8	100
Improvement of Quality of Life	6	75
Improvement of Current Technology	7	88

n = 8 students

4.6.2.2.1 Improvement of Quality of life

An emergent theme throughout the interviews regarding reasons for participants placing importance on Science in society is the possible improvement in quality of life. In the words of Dan:

> *'Science helps us to make things that can, um, make life a lot easier and it could help us live longer and have a better quality of life, yeah'.*

Although Dan was the only participant to actually use the term 'Quality of life', the concept was repeated on several occasions by various participants. Most examples made reference to the ease with which common practices are done as a result of scientific technology or the comfort and luxury made available. Francis went a little further with this idea, referring to reduced cost, stating:

> *'By understanding how the world works we're able to live in it in a better way. In a more comfortable way. A more economic way'.*

One particular student, Tatiana, gave a more empathetic response:

> *'It sucks when people die when they are too young to die and so you can help them that way.'*

This same theme was evident in many of the responses and indicates a firm belief among participants that Science has the capacity to improve quality of life.

4.6.2.2.2 Improvement of current technology

An additional theme evident throughout the participant's responses was the improvement in current technology resulting from scientific advancement. Lucy made specific reference to the innovations which result from scientific research stating:

> *'We can invent new things, um, from what we already know and kind of expand on that. Um, so, like ideas that have been, um, supported in the past, um, we can build upon that and then create new things or find new ways to do things'.*

Anabelle mentioned the ability to improve a circumstance in addition to addressing challenges and correcting them by using scientific method. She states:

> *'It makes it easier to fix things. Yeah, just, in general it helps a lot more to know what you're dealing with. In that way it will be easier to fix'.*

Of the remaining participants who referred to improvements in current technology, the vast majority made specific mention to medicine or engineering as an example. Sally states:

> *'It helps us improve what we already have. Like, um, our technology improves, our medications improve, and it just, like, can make us look at things in new light and improve in other areas'.*

This type of response was fairly typical where participants drew a link between scientific advancement and certain ways that the study of medicine could help society. Tatiana summarised this sentiment stating:

> *'You've got, like, medical Science where they do, like, research. Research on, like, um, [pause] stuff, which they can use to help people'.*

4.6.2.3 Influence of Christian worldview on responses regarding Science-related attitudes

One of the purposes of the interviews was to identify some of the factors which may have been influencing student's attitudes to Science which were not articulated in the

questionnaires and specifically explore a possible link between the participant's Christian worldview and such attitudes. Throughout the interviews there was no indication of such a correlation. In one example a participant, Harry, mentioned that *'[s]ometimes Science doesn't always give you the answers that you want. And you try very hard to find em.'*

Such a statement indicates a challenge in Harry's preconceived views without significantly correlating to his Christian worldview. In general the participants made no reference to their beliefs in Christianity and as all participants communicated a positive response in both categories of the Science-related attitudes, there was no indication of any kind of significant relationship with their acceptance of a Christian worldview.

4.7 SUMMARY OF RESULTS AND KEY FINDINGS

Following the introduction, Section 4.2 provided a description of the validity and reliability of the questionnaire including descriptive statistics and internal consistency reliability and the ability to differentiate between classes. The mean response in the 'Understanding and Attitudes towards the Bible and Religious Faith' scale and the 'Test of Science-related Attitudes' were notably high. The mean responses in the 'Understanding of the Theory of Evolution' and 'Acceptance of the theory of Evolution' scales were notably low. Five of the reliability coefficients were considered satisfactory while the 'Understanding of evolution' scale, which was particularly low could not. The alpha reliability of this scale is likely low as a result of the students' academic level creating very high variability within the scale. The ANOVA results, which indicate the extent to which students in the same class demonstrate similar attitudes and understanding, revealed that in the 'Understanding of Evolution' and 'Acceptance of Evolution' scales with $p<0.001$, strong significance was demonstrated. In the 'Understanding of Evolution' and 'Acceptance of Evolution' scales the Year 12 class consistently demonstrated higher means while the Year 8 class demonstrated the lowest means.

Section 4.3 presented an overall analysis of the associations between questionnaire scales while Sections 4.4 through to Section 4.6 provided a detailed analysis of these

associations according to the relevant research question. Section 4.4 which addressed Research question 1, presented the simple correlation as being statistically insignificant while the results for the standardised regression coefficient, using the individual as the unit of analysis, demonstrated strong positive significance. The interview questions were structured in such a way that participants were requested to discuss mechanisms of biological evolution and evidence for biological evolution. All participants made some form of reference to the concept of Natural selection when attempting to explain the mechanism of biological evolution. There was great variety in the level of depth provided and consequently the gaps in participant understanding. Several themes across the participants emerged including: sources of variety; characteristics providing a survival advantage; speciation and the presence of a common ancestor. In general the participants were all able to verbalise some form of evidence for evolution but with varying levels of depth and clarity. A significant discovery in this section of the interviews was the overall lack of detail and understanding provided by the majority of the participants. Several themes across the participants emerged including the frequent reference to a common ancestor throughout all pieces of evidence discussed. Other themes included: the fossil record; comparative anatomy; comparative DNA; and comparative embryology. There did not appear to be any significant link between the participant's Christian worldview and their understanding of biological evolution throughout the interviews.

Section 4.5 which addressed Research question 2, presented the simple correlation and standardised regression coefficient, using the individual as the unit of analysis, as being statistically significant. Both tests reported a negative association. During the interview process it became clear that the participants all held differing beliefs regarding their own acceptance of biological evolution and it was also clear that this topic was one which was challenging the students' preconceived ideas, creating a certain degree of internal conflict or confusion. Several categories across the participants emerged including: those who completely rejected biological evolution; those who completely accepted biological evolution; and finally those who accepted components of biological evolution. The participant who completely rejected biological evolution described his main motivation as being based on his Christian worldview. Of the two participants who completely accepted biological evolution, both came from diverse perspectives where one described himself as a Christian and

the other did not. Both participants credited their acceptance to the overwhelming evidence of evolution and a general trust in the integrity of the scientific community. The third category, describing partial acceptance, consisted of participants who were in general involved in some form of personal conflict regarding the issue. Several themes emerged including: common descent; involvement of God; alternate explanations; and teaching evolution in Christian schools. Throughout the interview process it became clear that there was a significant negative correlation between Christian worldview and acceptance of biological evolution.

Section 4.6 which addressed Research question 3, presented the simple correlation and standardised regression coefficient, using the individual as the unit of analysis, as being statistically insignificant. During the interviews the participants were asked to discuss their enjoyment of Science lessons and all interviewed participants responded positively. Several themes across the participants emerged including; the personal relevance of Science and the expansion of knowledge. The participants also unanimously agreed that Science holds great importance in the community. Several themes based on participant responses emerged including: the improvement of quality of life; and the improvement of current technology. There did not appear to be any significant link between the participants' Christian worldview and their Science-related attitudes throughout the interviews. The next chapter discusses each of the three research questions with respect to the key findings presented in this chapter.

Chapter 5: Discussion of Research Results and Findings

5.1 INTRODUCTION

The major purpose of this study was to explore the relationship between students' acceptance of a Christian worldview and their understanding and acceptance of biological evolution within a Western Australian Faith-based School. To achieve this objective, three research questions were developed.

1. What effect does attitude and acceptance of a Christian worldview have on students' understanding of the theory of biological evolution?

2. What effect does attitude and acceptance of a Christian worldview have on students' acceptance of the theory of biological evolution?

3. What effect does attitude and acceptance of a Christian worldview have on students' attitudes to Science?

The previous chapter (Chapter 4) presented the results of a detailed study designed to address these three questions. In this chapter (Chapter 5) these results are synthesised and interpreted within the context of current relevant literature and in direct reference to the three research questions. Section 5.2 discusses the findings related to the first research question, Section 5.3 discusses the findings related to the second research question and Section 5.4 discusses the findings related to the third research question and the final section (Section 5.5) concludes with a summary of the chapter.

5.2 FINDINGS FOR RESEARCH QUESTION 1

Quantitative data demonstrated the simple correlation between the Attitudes towards the Bible and Religious Faith scale and the Understanding of the Theory of Evolution scale as positive but not statistically significant. The standardised regression coefficient, using the individual as the unit of analysis was also positive but demonstrated high significance ($p<0.001$).

In reference to the qualitative data, the key emergent categories which were identified were subdivided into mechanisms of biological evolution and evidence for biological evolution. Within the mechanisms of biological evolution category, several themes were identified. These included: mutation as a source of variety; natural selection; speciation and other minor themes. Within the evidence for biological evolution category, the following themes were identified: the fossil record; comparative anatomy; comparative DNA and several other minor themes. There did not appear to be any significant relationship between students' Christian worldview and their understanding of biological evolution although the interviews did reveal some interesting themes which will be discussed and interpreted based on the researcher's perspectives in addition to a comparison with relevant current literature.

5.2.1 Associations between attitude and acceptance of a Christian worldview and students' understanding of the theory of biological evolution

According to the data collected throughout this study the relationship between a student's Christian worldview and their understanding of biological evolution was negligible. The quantitative data indicated a positive relationship but its significance was inconsistent. The qualitative data produced similar results where students generally demonstrated a satisfactory level of understanding of biological evolution but this did not appear to be correlated with the students' acceptance of a Christian worldview. In general, the participant's discussion of the mechanisms of evolution was fairly in depth and appeared to demonstrate a high level of understanding. This was not the case for the evidence for evolution, which tended to be vague and simplistic. These two variations will be discussed in addition to finally describing some possible explanations for the overall lack of significant correlation related to Research Question 1.

The mechanisms for evolution, although primarily focused on natural selection, were generally described in detail and with accuracy. Participants were often able to use the specific example of the polar bear and elaborate on the process by which natural selection resulted in the beneficial adaptations of the animal. Regarding the evidence for evolution, the participants responses tended to be brief and usually with only one

example. This is noteworthy as one of the strengths of the theory of biological evolution is the variety of sources of evidence which support it. Only one participant was able to name any of the relevant fossils and this individual demonstrated very low acceptance of a Christian worldview. Of the remainder of the participants very few individuals provided information on more than one source of evidence revealing some significant gaps in the students understanding.

An interpretation regarding the students' higher understanding of the mechanisms of evolution than the evidence of evolution is possibly related to the nature of the topic. It is likely that these results are the consequence of a lack of interest in the evidence for evolution or perhaps even the perceived difficulty of the subject as it was clear that students had greater difficulty communicating their ideas. Typically the evidence for evolution consists of many sources and examples and it could be that students felt overwhelmed by the quantity of information while speciation through natural selection is a singular process with great explanatory power. This is consistent with several studies discussing the conceptual difficultly and complex nature of evolutionary biology theory (Sinatra et al., 2003).

A second interpretation is the perceived conflict that a student who demonstrates strong acceptance of a Christian worldview may experience with the evidence for evolution but not the mechanism of evolution. It is common throughout 'young-earth creationist' literature to make a clear distinction between natural selection and the evidence for evolution (Doyle, 2014; Oard, 2014; Walker, 2014). Throughout a review of the literature there were no cases where a 'young-earth creationist' author seriously critiqued the process of natural selection and many articles described the process in detail suggesting that it is completely acceptable and not a source of conflict with their perspectives (Bergman, 2004; Doyle, 2014; Oard, 2014; Sarfati, 1999; Walker, 2014; Weiland, 1997; White, 2001). For this reason it would be expected that students view the topic of natural selection as non-threatening and may only experience superficial conflict. In stark contrast, there was an abundance of 'young-earth creationist' literature directly refuting the current evidence for biological evolution suggesting that this is an area of the concept which is in direct conflict with their perspective (Austin & Humphreys, 1990; Bergman, 2004; Doyle, 2014; Grigg, 1998; Oard, 2014; Sarfati, 1999; Walker, 2014; Weiland, 1997 White, 2001). Considering the notion that the

majority of the interviewed participants demonstrated a high level of acceptance of a Christian worldview, it would not be surprising that these students have been exposed to typical 'young-earth creationist' arguments and therefore when being taught about the evidence for evolution in a classroom setting may have already formed a negative opinion on the matter. This becomes evident in the classroom when the topic is initially introduced and it is common for such students to ask questions which are designed to undermine the evidence for evolution and foster doubt in the legitimacy of the data (Swenson, 2001; Sarfati, 1999; Walker, 2010; 2003). Perhaps it is this conflict of seemingly scientific information which has caused confusion in the participants and consequently influenced their understanding of evidence for evolution.

Regarding an overall discussion of the results regarding the association between attitude and acceptance of a Christian worldview and students' understanding of the theory of biological evolution, the quantitative data revealed a positive, although inconsistently significant, association. This indicates that in some circumstances, as acceptance of a Christian worldview increased the understanding of biological evolution also increased. The positive nature of this relationship was likely due to the fact that many of the participants in the questionnaire had experienced no formal training in the topic and the level of academic scientific language was likely very confusing. According to the AVOVA results, the more mature students tended to demonstrate significantly higher levels of understanding than the younger ones, as would be expected. The 'attitude and acceptance of a Christian worldview' scale did not demonstrate any significant variance between classes. For this reason it may be possible to observe some form of positive relationship between the two scales although it does not necessarily indicate any direct causality.

Another interpretation of the non-significant association between the two scales which was highlighted in the interviews could be the participants' powerful motivation for understanding biological evolution. It could be concluded that there were two strong motivations for a students to gain a better understanding of biological evolution based on the results in this study and these included the desire to be confident enough in the topic to be able to engage in a debate and the genuine desire to better understand the concept.

A strong theme in 'young-earth creationist' literature is the notion that their perspectives are not only religious but scientific (Austin & Humphreys, 1990; Batten, 1999; Behe, 1996; Bergman, 2004; Doyle, 2014; Grigg, 1998; Ham, 1987; Oard, 2014; Sarfati, 1999; Walker, 2014; Weiland, 1997; White, 2001;). It became apparent throughout the interview process that certain students, who were strongly accepting of a Christian worldview, revealed a desire to engage in debate or discussion with their non-believing peers regarding the topic of biological evolution. These students communicated ideas such as their desire to defend their beliefs and make a stand for their faith. For them to be effective in this process they recognised that they must first become competent in an understanding of biological evolution. Therefore it cannot be assumed that students who reject biological evolution as an explanation for the diversity of life have no interest in understanding it and quite possibly the opposite. These students are being encouraged by the 'young-earth creationist' movement to intellectually equip themselves and thus be prepared for the inevitable debate.

A second motivation, which was common among participants who both accepted and rejected a Christian worldview was the genuine desire to better understand the concept of biological evolution. For these students it may have been genuine interest, perhaps the social or historical relevance of the subject, possibly the desire to achieve academically in the next assessment or in many cases the desire to explore their own perspectives and interpretations. Among the participants who rejected the Christian worldview, it appeared that their main motivation for developing understanding was one of genuine interest or academic success in the unit of study. These participants described the concept of biological evolution as being logical and enlightening. Other students identified the relevance of the topic and its explanatory power, not to mention its inclusion in the final examination.

Of the students who strongly accepted a Christian worldview, many expressed a genuine desire to challenge their own interpretations of biological evolution and in doing so felt motivated to deepen their understanding of the concept. This was not necessarily linked with their willingness to accept the theory but more so to be open to its explanation. Many of these students described the process of learning about biological evolution as being challenging but fulfilling. For some it reinforced their

perspectives while for others it resulting in some deep challenges and conflict management.

5.2.2 Summary for research question 1

In general, the current literature has not identified any significant link between students' acceptance of a Christian worldview and their understanding of biological evolution (Kim & Nehm, 2011; Nehm et al., 2009) and this is consistent with the results of this study. The results of this study indicated that students demonstrated a higher level of understanding of the mechanisms of evolution compared to the evidence for evolution and this could likely have been due to two possible factors. These factors included a general lack of interest or greater conceptual difficulty of the topic; and the distinction made by 'young-earth creationist' literature that the mechanisms of evolution are compatible with their perspective but the evidence for evolution is not. Furthermore, the results have demonstrated a weak positive association as most students, regardless of their acceptance of a Christian worldview, were motivated to deepen their understanding of biological evolution. This may have been as a result of their desire to be successful in a debate or alternatively the genuine desire to better understand the concept.

5.3 FINDINGS FOR RESEARCH QUESTION 2

Quantitative data demonstrated, negative and statistically significant correlation between the Attitudes towards the Bible and Religious Faith scale and the Acceptance of the Theory of Evolution scale. The standardised regression coefficient, using the individual as the unit of analysis was also negative and demonstrated high significance ($p<0.001$).

In reference to the qualitative data, students confirmed that there was a strong negative relationship between students' acceptance of a Christian worldview and their acceptance of biological evolution where students who were highly accepting of a Christian worldview were more likely to reject all or a portion of biological evolutionary theory. The key emergent categories which were identified were subdivided into: strong rejection; strong acceptance; and partial acceptance of biological evolution. Within the partial acceptance category several themes emerged

such as: common descent; involvement of God; alternate explanations; and teaching evolution in a Christian school.

5.3.1 Associations between attitude and acceptance of a Christian worldview and students' acceptance of the theory of biological evolution

According to the data collected throughout this study the relationship between a student's Christian worldview and his or her acceptance of biological evolution was negative and statistically significant. The qualitative data produced similar results where students who demonstrated a high level of acceptance of a Christian worldview were more likely to reject all or a portion of biological evolutionary theory. Although the quantitative results indicate a negative relationship it is important to note that this does not necessarily indicate causality but rather a statistically significant link. Such a negative correlation between acceptance of Christian worldview and acceptance of biological evolution was as expected and is strongly supported by current literature (Alters & Alters, 2001; Lawson & Worsnop, 1992; Meadows et al., 2000; Miller, Scoot, & Okamoto, 2006; Shipman et al., 2002; Wood & Scharmann, 2001).

In their study involving high school students, Wood and Scharmann (2001) identified religious factors as the leading influence of rejection of biological evolution and in particular the research of Alter and Alters (2001) revealed a strong link between students who interpreted Biblical scripture literally and the rejection of biological evolution. Furthermore, Miller et al. (2006) identified that when young-earth creationist perspectives are in direct conflict with scientific evidence, students will regularly reject Science in favour of their religious perspectives. Studies involving Scottish biology university students (Downie & Barron, 2000) and American Biology teachers (Aguillard, 1999) revealed similar results concluding that metaphysical or religious commitments appeared to have a more profound effect on acceptance of biological evolution than understanding of the theory. These studies reveal a strong negative link between acceptance of a Christian worldview and acceptance of biological evolution which is consistent with the results of this study.

In a study conducted by Ferguson and Kameniar (2014) in Victoria, Australia, four high school students who were identified as holding religious worldviews were

interviewed regarding their perspectives about their study of Science and in particular biological evolution. It was concluded that these students were able to reach a satisfactory level of understanding of biological evolution but demonstrated strong internal conflict regarding its acceptance. Their research suggested that, "religious students of Science are unlikely to be deeply engaging with Science as a discipline when, as this paper proposes, they employ a binary cultural model that subordinates Science to religion, non-humans to humans and learning to believing" (Ferguson & Kameniar, 2014, p. 2572).

The qualitative data provided further insight into the relationship between acceptance of a Christian worldview and acceptance of biological evolution. The results were categorised into those participants who: strongly rejected evolution; strongly accepted evolution; and those who demonstrated partial acceptance of evolution. The individuals who professed strong rejection made statements which were consistent with a 'young-earth creationist' perspective while the individuals who demonstrated strong acceptance of a Christian worldview and strong acceptance of biological evolution made statements which were consistent with an 'evolutionary theist' perspective. The final category of participants who demonstrated strong acceptance of a Christian worldview but partial acceptance of biological evolution revealed deep personal conflict and a strong desire to integrate their Christian beliefs into their understanding of the development of life through biological evolution without completely disregarding the evidence of modern Science.

5.3.1.1 Young-earth Creationism

Although only a small minority of participants described themselves as 'young-earth creationists' it became clear throughout the interviews that the vast majority of participants were well educated in current 'young-earth creationist' literature and most had integrated a significant number of the concepts into their own interpretations. Specifically in this study several indicators of such a perspective arose, coming in the form of references to: a literal interpretation of the timescale in the book of Genesis (seven 24 hour days); the absence of any description of an evolutionary process in the Bible; and the age of the earth being estimated as approximately 6,000 years old.

The belief that the days described in the book of Genesis are intended to be interpreted literally as 24 hour periods was a strong theme among certain participants and several were very passionate about this particular point, stressing the importance of interpreting scripture this way. This is consistent with the literature where Batten (1999), a young-earth creationist, fervently argues that those who interpret the 'days' described in Genesis as anything other than literal 24 hour days have been misled and such an interpretation will ultimately lead to the whole of scripture being reinterpreted and the text becoming subjective. Batten (1999) implies that if this interpretation is adopted, Christianity will eventually be diluted by secular ideas and inevitably become indistinguishable from other secular philosophies. Numerous publications by young-earth creationist authors (Doyle & Reed, 2013; Sarfati, 1999; Grigg, 1996) provide additional evidence that any interpretation of the 'days' in Genesis as periods of time other than 24 hours is erroneous. This sentiment was clearly identifiable in the participant responses. Another indicator of the 'young-earth creationist' perspective was the direct reference to a geologically young earth. According to Pierce (1998), the idea that the Earth is approximately 6,000 years old rather than 4.5 billion years old was made famous by Archbishop Ussher (1581-1656). The time periods described in the Bible can allegedly be added up, assuming no gap in genealogies resulting in a very young earth. Multiple participants suggested that the earth isn't old enough to allow for biological evolution to have happened which is further evidence for its non-occurrence.

A possible interpretation of the strong emphasis of the participants who held a 'young earth creationist' perspective on a literal 24 hour Genesis day and 6,000 year old earth interpretations could be linked with the fear of rejecting the authority of the Bible. Numerous publications by young-earth creationist authors (Batten, 1999; Doyle & Reed, 2013; Sarfati, 1999) suggest that any interpretation of the 'days' in Genesis as periods of time other than 24 hours is erroneous. As a result of such a conclusion, it is very likely that the participants were convinced that either the process of creation by God happened in six 24 hour days or it didn't happen at all, in which case God is fictional rather than historic (Doyle & Reed, 2013). This places the claims of Science in direct conflict with the students' Christian worldview and forces them to make a confronting choice. It would appear that most individuals who are presented with such an ultimatum would choose their well-established Christian worldview over Science

consistently, supported by the research of Miller et al. (2006). It is also worth mentioning that these 'young-earth creationist' perspectives were formed completely outside the Science classroom and the direct consequence of interactions with family, peers, church leaders and creationist literature. This strongly supports the notion that the students had already formed an opinion before they had entered the Science classroom and is in accordance with current literature (Woods & Scharmann, 2001).

A second point to be discussed regarding the 'young-earth creationist' perspective which was evident in several participants, was the lack of reference to the current scientific evidence supporting biological evolution. In relation to current religiously motivated anti-evolution literature, the vast majority contains some form of rebuttal to the evidence for biological evolution (Bergman, 2004; Doyle, 2014; Oard, 2014; Swenson, 2001; Walker, 2014; Walker, 2010; 2003). For this reason it was surprising that it was not mentioned by any of the participants during the interviews. One possible reason for this could be the participants' general lack of understanding of the evidence for biological evolution and therefore an inability to form a coherent counter-argument. Considering the poorly articulated responses in the evidence for evolution section of the interview it would not be unreasonable to assume that these participants had little interest in refuting the current evidence for biological evolution and were content to use their religious beliefs as the primary motive for their rejection of the theory.

A final point of interest in the discussion of the young-earth creationist participants was the idea that the completion of the unit of study of evolution did not necessarily diminish the participants' rejection of the theory but perhaps even reinforced it. This is consistent with a study conducted by David Jackson (2007), an Associate Professor of Science Education who was involved in training Middle school teachers in Georgia, USA. He described his interactions with religious pre-service teachers and their perspectives on biological evolution, explaining that many, who had initially had 'milder' misgivings about the theory when studying the unit on evolution, were provoked to engage in personal research and had their views strongly reinforced by 'Creation Science' and 'Intelligent Design' literature. He states, 'This literature is often more convincing to "inquiring minds" than are Science textbooks or teacher

lectures, because it makes more explicit, immediate and strategic links between its claims and the alleged evidence.' (2007, p. 164).

5.3.1.2 Evolutionary Theism

Several of the interviewed individuals could be described as adopting an 'evolutionary theist' perspective and this was made evident by their strong acceptance of biological evolution in addition to their strong acceptance of a Christian worldview. These individuals accepted all of the current evidence for biological evolution and were content to use the theory to explain the development and diversity of organic life. The motives for such acceptance appeared to be linked to the participants' genuine respect for the integrity of scientific research and those who study Science. Specific reference to the overwhelming evidence for evolution and its occurrence was also a key factor in their acceptance. These students appeared to view the controversy as a non-issue and it became evident that the participants were able to internalise the evidence presented in current scientific literature and form an opinion based on such evidence. It is noteworthy, however, that the content pertaining to biological evolution was delivered in exactly the same way to all students of this age group regardless of their acceptance or rejection of biological evolution. For this reason it could be interpreted that it was not necessarily the delivery of the content regarding the evidence for evolution which resulted in these students more readily accepting biological evolution but more likely their positive perspectives regarding the compatibility of the theory with their Christian worldview. An explanation of this positive relationship, between biological evolution and the Christian worldview, is likely linked to the previous experiences of the students. It is relevant to mention that one of participants who expressed these perspectives described himself as belonging a more conservative denomination of the Christian worldview, namely Catholic. In a study by Joseph Baker (2013) involving a survey of 1,648 American adults it was revealed that Evangelical Christians were more than twice as likely to reject biological evolution compared with Catholic Christians.

A point of distinction between these participants and the other students demonstrating strong acceptance of evolution but who claimed that they did not adopt a Christian worldview was their reference to the action of God in the process of biological evolution. It was a common theme for participants who adopted this perspective to

integrate their understanding of God as creator into their explanations of life's development. Their belief that God had used natural processes such as biological evolution, to create modern biological diversity was repeatedly stressed and clearly important to the participants. It is an essential feature of a Christian worldview to view God as the creator and in ultimate control (Smart, 2007). If these participants did not adopt this view it would dramatically compromise their acceptance of the mainstream Christian worldview and therefore it is no surprise that they were quick to mention these features of God. What makes these individuals unique was their ability to harmonise their understanding of biological evolution and their Christian worldview. Using Barbour's (1990) models of the relationship between Science and religious worldview, these participants reveal an underlying belief that Science is not in conflict with a religious worldview but can be comfortably integrated. The notion that both Science and a religious worldview may contribute to a comprehensive metaphysical worldview allowing the complete integration of scientific laws as well as the laws of God.

The participants who adopted this perspective did not mention the relationship between acceptance of biological evolution and how it could be perceived to undermine the authority of the Bible and the concept of original sin. This tension is a strong theme among those with a 'young-earth creationist' perspective as mentioned in the writings of Sarfati (1999), Cosner (2009) and Smith Jr, (2007). Regarding the absence of these elements in the discussions, a few possible interpretations could be made. It is completely possible that the students had not actually considered the implication and therefore did not feel the need to justify their position. Conversely it is possible that the participants had considered this point but had already personally resolved the issue and therefore did not feel it was worth mentioning. Another option could be that perhaps they had simply forgotten its relevance and therefore neglected to discuss it.

5.3.1.3 Alternate perspectives

The final group of participants who revealed several interesting themes throughout the interviews included those who demonstrated a strong Christian worldview but only partial acceptance of biological evolution. These individuals discussed diverse explanations of the development of organic life and included aspects of traditional

evolutionary theory as well as components of 'young-earth creationism'. A theme which was consistent across all of the individual participants who could be categorised as holding an alternate perspective was the deep personal conflict they appeared to be experiencing. In essence this conflict was between their confidence in the authority or the Bible and their Christian worldview compared with the authority of Science and those who practice it. It was clear that these students desired to consolidate both perspectives but found it difficult to do so. Meadows (2007, p. 150), a Science educator originally from a fundamentalist Christian background, comments on this tension stating, 'religious students who have been taught a literal interpretation of their scripture's accounts of origins will almost always see a deep conflict between their faith and evolution'

In specific, two areas of distinct conflict included: the age of the earth; and the process of life's development. The two alternative perspectives regarding the age of the earth included: approximately 6,000 years based on Ussher's chronology (Pierce, 1998) and 4.5 billion years based on current geology and cosmology (Prothero, 2007). The first perspective is founded on the interpretations of an Archbishop and propagated by religious leaders while the second, the evidence produced by Scientists and scientific research. The important decision for the student is based not only on the intellectual logic of the perspective but the perceived authority of the source of knowledge. The same principal can be applied to the second topic of conflict which is the process of life's development. The mainstream scientific community explains this development using the mechanism of biological evolution (Coyne, 2009; Dawkins, 2010) while a proportion of the Christian community professes that life has not dramatically changed over time but essentially exists today as it did when it was first created by God (Cosner; 2009; Sarfati, 1999). These two perspectives are in direct conflict and the student is presented with a confronting choice between two sources of knowledge; the evidence of Science or an interpretation of Biblical scripture. In a study conducted by Francis, Gibson, and Fulljames (1990, p.16) involving a group of sixteen Scottish adolescents it was concluded that, 'both scientism and the perception of Christianity as necessarily involving creationism… are important factors in helping to shape both attitudes towards Christianity and interest in Science. In particular, both factors contribute to making in more difficult for pupils to combine a positive attitude towards Christianity with a high level of interest in Science.'

The results revealed that for most participants, it was not a simple case or acceptance or rejection but rather an attempt to reconcile both sources of truth. All students accepted the mechanism of natural selection and its effects on animal diversity while many rejected decent from a common ancestor. Many students accepted the age of the earth to be 4.5 billion years but very few accredited biological evolution as the major contributor of life's diversity. One point of consistency across all interviewed participants was the integration of their Christian worldview in their alternate explanations for life's diversity. This may have been in the form of specific reference to Biblical events, such as Noah's flood or the Garden of Eden, or perhaps Biblical figures such as Adam and Eve. This is consistent with the research of Shipman et al. (2002, p. 543) which detailed the process of religious students studying stellar evolution, 'Individual students have their own ways of approaching the topic… Each of the [key students studies] has attempted to integrate an understanding of Science and religion in their own way'.

In all cases of alternate explanations, there was some form of creation event consisting of God supernaturally forming an organic substance or organism. This organism ranged from bacteria or a primitive animal to complex organisms such as modern homo sapiens. The inclusion of this creation event in all alternate explanations strongly demonstrates the desire of the participants to integrate their Christian beliefs with their scientific explanations of life's development. These students consistently included some form of supernatural intervention in their explanations revealing their worldview that God is the creator and ultimately sovereign (Smart, 2007). It is no surprise that the participants integrated this concept into their perspectives as it is an essential component of the Christian worldview. A point of interest is the level of influence the participants described God as having during this process, varying from complete, constant control to more of an overall governance with little ongoing influence.

5.3.2 Summary for research question 2

The data collected throughout this study regarding Research question 2, revealed a significant negative association between acceptance of a Christian worldview and acceptance of biological evolution. This was indicated by the quantitative data and further supported by the qualitative data. The key emergent categories which were

identified throughout the interviews included: strong rejection; strong acceptance; and partial acceptance of biological evolution. An interpretation of these results included the notion that the participants experience a high degree of internal conflict and this was likely directly influenced by the notion of rejecting the authority of the Bible and therefore rejecting their Christian worldview. Furthermore, the results revealed that for most participants, it was not a simple case or acceptance or rejection but rather an attempt to reconcile both sources of truth. All interviewed students accepted the mechanism of natural selection and its effects on animal diversity while many rejected decent from a common ancestor. In all cases of participants who accepted a Christian worldview, there was clear mention of the role of God as the ultimate creator, whether the participant had adopted a young-earth creationist, theistic evolutionist or alternative perspective.

5.4 FINDINGS FOR RESEARCH QUESTION 3

The simple correlation between the Attitudes towards the Bible and Religious Faith scale and the Science-related Attitudes scale was not statistically significant. The standardised regression coefficient, using the individual as the unit of analysis was also not statistically significant.

Qualitative data demonstrated similar trends as quantitative data and complimented findings derived through different methods. The key emergent categories which were identified were subdivided into enjoyment of Science classes and importance of Science in society. Within the enjoyment of Science classes' category, several themes were identified. These included: personal relevance; expansion of knowledge; and factors hindering enjoyment of Science lessons. Within the importance of Science in society category, several themes were also identified including improvement of quality of life and improvement of current technology. There did not appear to be any significant relationship between students' Christian worldview and their Science-related Attitudes.

5.4.1 Associations between attitude and acceptance of a Christian worldview and students' attitudes to Science

According to the data collected throughout this study the relationship between a student's Christian worldview and their Science-related attitudes was non-significant. This was clearly revealed by the quantitative data but also supported by the qualitative data. The key emergent categories which were identified throughout the interviews were subdivided into enjoyment of Science classes and importance of Science in society where neither appeared to be significantly influenced by the students acceptance of a Christian worldview.

Perhaps the most significant information which emerged throughout the interviews was the generally positive attitudes of the participants towards Science and the role of Science in society. This positivity was evident in the participant responses regarding their enjoyment of Science lessons as a result of them identifying the personal relevance of Science in addition to the expansion of their own knowledge. Within the importance of Science in society category, participants described its ability to improve of quality of life as well as current technology. Throughout all of the interviews there was no mention of the participant's Christian worldview nor any reference to God or the Bible.

An interpretation of these emergent themes and in particular the lack of a mention of God or the Bible in this particular section of the discussion is the strong possibility that the participants did not recognise the relevance in making such correlations. The participants were completely content to discuss their enjoyment of Science and its applications without revealing a link with their Christian worldview. Although according to a small group of atheist scientist writers such as Dawkins (2006) and Coyne (2015), it may be expected that there would be a negative correlation between acceptance of a Christian worldview and Science-related attitudes this was not the case. In the same way there was no significant positive link, no negative link was apparent. It appeared that any relationship between the two variables was non-significant. The participants appeared to have generally positive attitudes despite their acceptance of a Christian worldview but their Science-related attitudes did not increase as a result of stronger acceptance of the Christian worldview either.

In contrast to the writings of Dawkins (2006) or Coyne (2015), many Christian theologians such as Walton (2009), McGrath (2007) and Collins (2006) have written extensively on the compatibility of a Christian worldview with the practice of Science. Not to mention publications, such as Bovey's (2008), 'God, the Big Bang and Bunsen-burning Issues' and Berry's (2009) 'Real Scientists Real Faith', which document over 30 prominent scientists' perspectives on the compatibility of their Christian beliefs and their scientific careers. These writers, whether intentionally or not, are promoting positive Science-related attitudes among their readership who are likely those practicing Science or at the very least interested in Science. An underlying theme in many of these publications is the intention to promote Science and demonstrate its non-conflict with a Christian worldview. Such writings tend to imply that although an individual with a Christian worldview may seek further answers to questions that Science simply cannot answer, the practice of Science is inherently materialistic and therefore should not be influenced by metaphysical or teleological explanations (Walton, 2009). It may be relevant at this point to mention 'young earth creationist' authors who, although basing their arguments on the Bible and the supernatural intervention of God, still attempt to justify their perspective using scientific practice. It is also important to highlight that a large portion of these individuals are practicing scientists and are convinced that they are using Science to provide legitimate evidence for their perspective. For these reasons it would seem appropriate that the Science-related attitudes of the participants were not significantly linked with their acceptance of a Christian worldview.

A review of the literature involving Science-related attitudes revealed some key factors of influence such as gender, classroom/teacher factors and curriculum variables (Osborne et al., 2010) however, there did not appear to be any available literature describing the relationship between acceptance of a Christian worldview and Science-related attitudes. The results of this study inferred that the relationship, if any, between these two variables was non-significant.

5.4.2 Summary for research question 3

The data collected throughout this study regarding Research question 3, revealed a non-significant relationship. This was indicated by the quantitative data and further supported by the qualitative data. The key emergent categories which were identified

throughout the interviews included the enjoyment of Science classes and importance of Science in society where neither appeared to be significantly influenced by the students acceptance of a Christian worldview. An interpretation of these results included the notion that the participants simply did not recognise the correlation between the two variables as being relevant or significant and this was likely a result of the well accepted notion that Science is the study of the natural world using materialistic explanations rather than metaphysical or teleological ones. Even among those individuals who attempt to invoke the supernatural to justify their perspective, such as 'young earth creationists', there was a strong sense that scientific evidence would support their propositions. As a result of these interpretations it is not surprising that the Science-related attitudes of the participants were not significantly linked with their acceptance of a Christian worldview.

5.5 SUMMARY OF CHAPTER

Following the introduction, Section 5.2 presented the findings of Research Question 1 and provided interpretations of these results. The quantitative data, including simple correlation and standardised regression coefficients were both positive but only the latter demonstrated strong significance. In general, this study did not identify any significant link between students' acceptance of a Christian worldview and their understanding of biological evolution. There was a distinct difference within conceptual areas of evolutionary theory and this indicated that a higher level of understanding of the mechanisms of evolution compared to the evidence for evolution may have been due to several factors. These included a general lack of interest or difficulty of the evidence for evolution; and the distinction made by 'young-earth creationist' literature that the mechanisms of evolution are compatible with their perspective but the evidence for evolution is not. The results demonstrated a weak positive association as most students, regardless of their acceptance of a Christian worldview, were motivated to deepen their understanding of biological evolution which may have been a result of their desire to be equipped to engage in a debate or alternatively the desire to better understand the concept.

Section 5.3 presented the findings of Research Question 2 and provided interpretations of these results. The data collected throughout this study revealed a significant

negative association between acceptance of a Christian worldview and acceptance of biological evolution and this was indicated by both the quantitative and qualitative data. The key emergent categories which were identified throughout the interviews included: strong rejection; strong acceptance; and partial acceptance of biological evolution. An interpretation of these results included the notion that the participants experience a high degree of internal conflict and this was likely directly influenced by the fear of rejecting the authority of the Bible and therefore rejecting their Christian worldview. The results also revealed that for most participants there was an attempt to consolidate both sources of truth. In all cases of participants who accepted a Christian worldview, there was clear mention of the role of God as the ultimate creator.

Section 5.4 presented the findings of Research Question 3 and provided interpretations of these results. The data collected throughout this study revealed a non-significant relationship and this was indicated by the quantitative and qualitative data. The key emergent categories which were identified throughout the interviews included the enjoyment of Science classes and importance of Science in society where neither appeared to be significantly influenced by the students acceptance of a Christian worldview. An interpretation of these results included the notion that the participants did not recognise the correlation between the two variables as being relevant and this was likely a result of the well accepted notion that Science is the study of the natural world using materialistic explanations rather than metaphysical ones. The next chapter provides a summary of the research and its findings, highlight the limitations and implications of the study, and offers suggestions for future research.

Chapter 6: Conclusion

6.1 INTRODUCTION

Chapter 6, the final chapter of this study, provides an overview of the research and its findings. After the introduction (Section 6.1) which provides an outline of the goals and context of the research, Section 6.2 presents a summary of the research findings, specifically addressing the three research questions and this is followed by Section 6.3 which details a description of the distinctive contributions made by this study. Proceeding this is Section 6.4 and 6.5 which describes the limitations of the study and provides a description of the practical implications of the findings. Finally Section 6.6 offers recommendations for future research followed by some concluding remarks in Section 6.7.

The purpose of this study was to explore the relationship between students' acceptance and understanding of the theory of biological evolution and its relationship to their own personal Christian worldview in the context of a Western Australian faith-based school. Building on Aikenhead's (1996) research, a developing theme in Science education literature is that Science and Science education are not necessarily pure disciplines, impervious to outside influence but may be significantly influenced by cultural forces. Contrary to the criticism of some scientists and Science educators, Aikenhead and Jegede (1999) argue that the acknowledgement of such cultural influence does not threaten scientific discipline but rather increases its accessibility to a greater range of students. An objective of this study was to acknowledge the influence of a Christian worldview on the understanding and acceptance of a particular scientific concept, biological evolution, and explore its extent. This study identified that such a relationship has not been adequately explored by the literature, particularly in an Australian context and therefore adds to the justification of the research.

A mixed methods approach to the research problem was adopted and involved collecting data from 101 secondary school students from a Western Australian faith-based school. The data included responses to a newly formed questionnaire containing four distinct scales: Understanding and attitudes towards the Bible and Religious Faith (Pope, 2014); Test of Science-related Attitudes (TOSRA) (Fraser, 1981);

Understanding of the theory of Evolution; and Measure of Acceptance of the Theory of Evolution (Rutledge & Warden, 1999). In conjunction with the questionnaire, follow-up interviews were conducted with 8 Year 10, 11 and 12 participants who were either enrolled in Human Biological Science or had completed a unit of study on biological evolution in their general Science class. Using both qualitative and quantitative data-analysis techniques, the researcher explored the role of a Christian worldview as a predictor of student understanding and acceptance of biological evolution in addition to Science-related attitudes. This study presented some of the first Western Australian data available concerning understanding and acceptance of biological evolution in relation to a Christian worldview, among high school students in a faith-based school.

6.2 SUMMARY OF RESEARCH FINDINGS

6.2.1 Research Question 1

Research question 1 was: What effect does attitude and acceptance of a Christian worldview have on students' understanding of the theory of biological evolution? The key findings of Research question 1 were:

1. This study did not identify any significant link between students' acceptance of a Christian worldview and their understanding of biological evolution which was consistent with other research.
2. Students demonstrated a higher level of understanding of the mechanisms of evolution compared to the evidence for evolution and this was likely due to two possible factors: a general lack of interest or greater conceptual difficulty of the topic and the distinction made by 'young-earth creationist' literature that the mechanisms of evolution are compatible with their perspective but the evidence for evolution is not.
3. A weak positive association between Christian worldview and understanding of biological evolution was identified. This was likely as most students, regardless of their acceptance of a Christian worldview, were motivated to deepen their understanding of biological evolution. This may have been as a result of their desire to be successful in a debate or alternatively the genuine desire to better understand the concept.

6.2.2 Research Question 2

Research Question 2 was: What effect does attitude and acceptance of a Christian worldview have on students' acceptance of the theory of biological evolution? The key findings of Research question 2 were:

1. This study identified a significant negative association between acceptance of a Christian worldview and acceptance of biological evolution which was consistent with other research.
2. The key emergent categories which were identified throughout the interviews included; strong rejection; strong acceptance; and partial acceptance of biological evolution.
3. All participants with a Christian worldview appeared to experience a degree of internal conflict and this was likely influenced by the notion of rejecting the authority of the Bible and therefore rejecting their Christian worldview.
4. For most participants, it was not a simple case or acceptance or rejection but rather an attempt to consolidate both sources of truth.
5. All interviewed students accepted the mechanism of natural selection and its effects on animal diversity while many rejected decent from a common ancestor.
6. In all cases of participants who accepted a Christian worldview, there was a clear mention of the role of God as the ultimate creator, whether the participant had adopted a young-earth creationist, theistic evolutionist or alternative perspective.

6.2.3 Research Question 3

Research Question 3 was: What effect does attitude and acceptance of a Christian worldview have on students' attitudes to science? The key findings of Research question 3 were:

1. This study did not identify any significant link between students' acceptance of a Christian worldview and their Science-related attitudes.
2. The key emergent categories which were identified throughout the interviews included the enjoyment of Science classes and importance of Science in society where neither appeared to be significantly influenced by the students acceptance of a Christian worldview.

3. The participants did not appear to recognise the correlation between the two variables as being relevant or significant and this was likely a result of the well accepted notion that Science is the study of the natural world using materialistic explanations rather than metaphysical or teleological ones.
4. Science-related attitudes were consistently positive among the participants and this was likely due to the belief that regardless of their worldview, scientific evidence would support their perspective.

6.3 DISTINCTIVE CONTRIBUTION OF THE STUDY

This study can comfortably be placed in the context of the literature on the relationship between religion and Science. As discussed in Section 2.6 of the literature review, according to the research of Barbour (1990) four main perspectives were identified, namely: conflict, independence, dialogue and integration. The 'conflict' model is typically promoted by two distinct groups of individuals; 'young-earth' creationists (Batten, 1999; Ham, 1987; Sarfati, 1999; Weiland, 1997) and a small group of atheist scientists and philosophers (Coyne, 2015; Dawkins, 2006; Dennet, 1995). In addition to this body of literature, this study can be placed in the more specific context of research pertaining to acceptance of biological evolution (Alters & Alters, 2001; Ferguson & Kameniar, 2014; Lawson & Worsnop, 1992; Meadows et al., 2000; Miller, Scoot, & Okamoto, 2006; Shipman et al., 2002; Wood & Scharmann, 2001). This area of scholarship includes a wealth of studies and this particular research has added to this field is several distinct ways.

The first and perhaps most relevant distinctive feature of this study was its Australian and specifically Western Australian context. Only one Australian study, conducted by Ferguson and Kameniar (2014) was found during a review of the literature, in relation to students' religious worldview and acceptance of biological evolution. The study was conducted in a Victorian public high school and involved interviews of four religious students. The students were selected based on their responses to a 'Religious Background and Behaviours' questionnaire and revealed a significant negative association between religious worldview and acceptance of biological evolution. Several distinctions can be made between the research of Ferguson and Kameniar (2014) and this study. The first distinction includes the location of the study. This

study was conducted in Western Australia rather than Victoria confirming that in this context, the two states are comparable. Furthermore, there is an abundance of literature available detailing the United States and United Kingdom (Alters & Alters, 2001; Lawson & Worsnop, 1992; Meadows et al., 2000; Miller, Scoot, & Okamoto, 2006; Shipman et al., 2002; Wood & Scharmann, 2001) while this study can in part fill the gap of an Australian context.

A second distinction is the type of school being researched. This study was conducted in a Christian faith-based school rather than a government school as in Ferguson and Kameniar's (2014) study. Both the independent nature of the school and the focus on Christian worldview is relevant. Although individuals who are religious but not of a Christian worldview may also demonstrate strong rejection of biological evolution, this study was conducted to specifically investigate those from a Christian perspective in a faith-based school.

One of the original purposes of this study was to identify the relationship between acceptance of a Christian worldview and Science-related attitudes, if any. Consequently the relationship between these two variables was non-significant and this finding is valuable as it has certain practical implication as well as being the first of its kind. There has been various studies conducted investigating Science-related attitudes (Cooper & McIntyre 1996; Fraser, 1978, 1981; Myers & Fouts 1992; Osborne et al., 2010; Weinburgh, 1995) but none were found which focused specifically on the influence of a Christian worldview. The overall trend among the participants' Science-related attitudes was consistently positive and did not appear to be influenced by the participants' Christian worldview.

Through the collection of quantitative and qualitative data in the form of questionaries and interviews, this study identified the arguments used by students to justify their perspectives regarding their degree of acceptance of biological evolution. With a focus on Christian worldview, this research has described the conflict that many individuals were facing and the extent to which they would go to consolidate their perspectives. Throughout this research three key positions were identified including: strong acceptance; strong rejection; and partial acceptance of biological evolution. This study

supported the findings of current literature revealing a significant negative association between acceptance of a Christian worldview and acceptance of biological evolution.

6.4 LIMITATIONS OF THE STUDY

For this research thesis an 'Instrumental Case Study' research method was adopted. Incidentally, the context of this study is narrow and very specific but it is these very features which act as a benefit rather than a limitation. The case itself is intrinsically interesting and therefore provides an opportunity for the researcher and readers to discover new meaning and insight. Although it may be possible to make generalisations and possibly transfer developed conclusions from this study to another, that was not its primary purpose. As suggested by Lincoln and Guba (1985) to aid in the transferability of this study, detailed descriptions of the school context, organisation of the study and methods of data collection and analysis have been presented, to assist the reader in assessing the transferability of the findings to other educational institutions.

This study adopted an explanatory mixed-methods approach to the research design in an effort to minimise any limitations to the study. The quantitative data provided broad generalisations and allowed the researcher to gain a general understanding of the trends and patterns among student responses to the research questions. This data was collected from student questionnaires. In reference to the quantitative data collection the major weakness of this study was the sample size and the source, namely the school from which the sample was drawn. While the number of participants in the qualitative component of the study was comparable to similar studies, the statistical rigours of a quantitative analysis call for a much larger sample size. The relatively small sample size for the quantitative component of this study represent a major limitation of the experimental design.

A second factor to be considered is in reference to the source of the data, namely the faith-based school. Considering that the school where all of the participants were enrolled was one which actively promoted a Christian worldview and included compulsory Biblical studies classes, the spectrum of students who accepted or rejected a Christian worldview was notably weighted towards those who hold a Christian

worldview. This does not imply that the majority of the spectrum was not represented but rather that a much smaller proportion of the student body held negative attitudes to the Christian worldview and this imbalance was another limitation of the study.

It was the qualitative data which allowed the researcher to gain specific understanding and interpret the meanings behind the responses provided by the participants in the quantitative data. This data was collected from student interviews. Some of the strengths of conducting interviews as a form of qualitative data collection include the supply of richly descriptive and in depth interpretations of data, the notion that the individual's sense of choice and individuality are upheld and the opportunity of the student to use their own words to describe personal experiences.

Some of the distinct limitations of qualitative data collection include the researcher's strong bias and the possibility of the data being deceptive, as the information is interpreted by the researcher and the students could be providing the response the student perceives the researcher wants to hear and their very presence could possibly affect the students' response. The very nature of the interpretivist paradigm requires in depth description and interpretation of experiences and this includes that of the student participants as well as the researcher. The presence of a bias is inevitable although its identification is of great importance. In all cases the researcher had also been the student's classroom teacher and therefore had a rapport with the participating students. Ideally this created a degree of trust and increased the likeliness of the participants producing honest responses. It was also made clear that the student's responses would not be included in any form of assessment or reporting which would reduce the likeliness of a student responding untruthfully. It is worth noting that another limitation of interviews is the unclear, poorly articulated responses of certain student participants. This was a difficulty but satisfactorily overcome with requests of elaboration and further explanation. Another limitation of the qualitative data collection in this study was the exclusion of any interview questions regarding the participants' beliefs about the age of the earth. This particular topic was excluded as it was not directly related to biological evolution but following analysis and interpretation of the interviews, it became evident to the researcher that many participants purposefully raised the age of the Earth to be discussed to justify their beliefs. It may have been favourable to give all of the participants the opportunity to

discuss the topic rather than only those who initiated that component of the conversation to better represent the students' perspectives.

A general limitation of the 'Explanatory Mixed Methods' research design is it's labour intensive nature and the requirement of expertise and time in both qualitative and quantitative data collection. The collection and analysis of both qualitative and quantitative data was time consuming and the limited time restricted the amount of data collected and the depth of analysis. Fortunately the main limitations of using a performance / attitudinal questionnaire as a form of data collection, including the exclusion of notions of choice, freedom, individuality, were overcome as a result of the mixed methods research design which included the use of interviews and triangulation methods.

6.5 APPLICATIONS OF THE STUDY FOR EDUCATORS

Biological evolution has been identified as an essential concept in the study of biology and therefore a completely justified component of the secondary education syllabus (Cavallo & McCall, 2008; Rice & Kaya, 2010; Schilders et al., 2010). Blackwell et al.(2003) state that in the absence of evolutionary theory, biology is void of a unifying theme, coherence, understanding, and interpretation of relationships. With this sentiment established, it is certainly relevant to desire students of Science to understand and accept the concept. This study, and other research of a similar nature (Alters & Alters, 2001; Ferguson & Kameniar, 2014; Lawson & Worsnop, 1992; Meadows et al., 2000; Miller, Scoot, & Okamoto, 2006; Shipman et al., 2002; Wood & Scharmann, 2001), have confirmed that acceptance of a Christian worldview is negatively associated with acceptance of biological evolution. This finding has several implications in an educational context therefore educators would benefit from considering such applications.

6.5.1 Respect the students' religious worldview

As educators it is essential to show respect to students who are being taught. This concept is not unique among Science educators but is particularly relevant in this context. This study has clearly identified that the majority of the students who hold a Christian worldview were experiencing varying degrees of personal conflict while

discussing biological evolution. This is reason enough to prioritise creating a safe environment for students who are likely already experiencing a degree of discomfort and may be feeling threatened. Meadows (2007) suggests that Science educators must be especially careful when teaching about biological evolution to ensure that they are not attempting to compromise or undermine a student's religious beliefs and to instead respect that student's religious worldview. It is not necessary for an educator to agree with a student to respect his or her perspectives. Although the claims of young-earth creationist students may be difficult for many Science educators to take seriously, it is important that the educator acknowledge that the conflict which this student is experiencing is very real and personally significant. Meadows (2007) suggests that the simple action of acknowledging the difficulty or conflict the student is experiencing and demonstrating genuine concern for the them and their learning journey has the capacity to create a safe and secure environment. Being available to discuss the students' concerns and offering to listen, rather than debate, often creates a positive educational atmosphere. This strategy is also recommended by Jones (2007 p. 185) who states, 'My first instructional activity is to assure religious students that their personal belief systems are safe in my classroom. This is not simply a matter of making a blanket statement; it is a matter of developing trust and continually reinforcing that promise'.

Finally, it is consistently recommended in the literature (Cavallo & McCall, 2008; Jones, 2007; Meadows, 2007) that the students be made aware that acceptance of biological evolution is not an expectation of the educator while as understanding the theory is an expectation. Cavallo and McCall (2008, p. 529) state, 'The prevailing finding of this study and in the evolution literature indicates that the goal of teaching evolution should not be to change one's personal beliefs. The goal is to help students understand and be able to practice the processes of Science, to experience the tentative nature of Science, and to logically and thoughtfully analyse scientific evidence, gathered today or throughout history, to support and/or refute *any* scientific theory'. Such an attitude has the capacity to diffuse much conflict and allow the students to engage with the academic rigour of biological evolution without feeling pressured to reassess their own religious perspectives.

6.5.2 Discuss the nature of Science and the nature of religion

In the context of a faith-based school, it is expected that the students are regularly being exposed to some form of religious teaching or practice. Regarding Australian schools, it is also expected that students will study Science up until Year 10 and during that year will cover biological evolution. These two factors provide a unique opportunity to discuss the nature of Science and the nature of religion and how they may interact while still possessing different types of authority (Barbour, 1990). Meadows (2007) describes the topic of biological evolution as being an ideal occasion to explore the relationships between religion and Science and although this may not be appropriate in many educational settings, in a faith-based school it has the potential to create a genuine learning experience for many students. Highlighting the notion that Science looks for natural causes and accepts only materialistic evidence while religion relies on the supernatural and requires faith as a way of knowing, creates an important distinction which may alleviate some of the conflict experienced by many students. Meadows (2007, p. 155) states, 'Teachers should allow students the grace of being illogical, especially since the evidence for evolution may create deep cognitive conflicts for religious students… This focus on the nature of Science doesn't necessarily eliminate the conflict, but it can lower the stakes entailed.' Assuming that the goal of the educator is not to profess the superiority of either way of knowing, the context of biological evolution may provide a fruitful opportunity to discuss the distinction between religion and Science suggesting that the two are not incompatible but are simply founded on different assumptions. This study also revealed that those students who accepted a Christian worldview made a conscious effort to mention the role of God as the ultimate creator and if educators are to relieve some of the tension experienced by these students, there must be some form of space in their explanations for the supernatural. In this way, while scientific methods and evidence are materialistic, Science makes no claim to allocate the greater meaning or teleology of religion and in this manner they can coexist.

6.5.3 Present biological evolution as firmly established by scientific consensus

As a result of this study it has become evident that many students who hold a Christian worldview have a comparatively poor understanding of the evidence for evolution and in a more general sense, do not acknowledge the consensus among the scientific community that biological evolution has indeed occurred. This study has concluded

that this is likely linked to young earth creationist literature and its false implications that biological evolution is disputed among scientists. For this reason it is essential for Science educators to reaffirm students that although the details of the mechanisms of evolution and its frequently developing evidence are regularly in debate, its occurrence is not. Biological evolution as an explanation for the development of life is undisputed among the general scientific community and while Science educators must respect students' religious worldviews they must not soften this important reality (Meadows, 2007).

Considering the weakness of students with Christian worldviews in understanding of evidence for biological evolution this is also an area of interest for Science educators. Jones (2007) suggests initially focusing on plants as evidence for evolution rather than more complex organism such as humans. In particular she refers to ancestral relationships among photosynthetic organisms as they have little recent connection with humans and are less likely to be viewed as controversial. Furthermore there is the opportunity for plenty of practical activities and individual examination of data lending itself to a more balanced assessment of the evidence for evolution. A second benefit of Jones's (2007) approach is the link which can be draw to local organisms such as the Western Australian stromatolites adding a level of relevance for Australian students studying biological evolution.

6.6 RECOMMENDATIONS FOR FURTHER RESEARCH

This study has, to a certain extent, added to the understanding of the relationship between a Christian worldview and acceptance of biological evolution in Australian high school students and detailed a variety of perspectives on the issue. After reflecting on the findings of this study, several lines of inquiry have emerged which may be beneficial to address in the future. These include: Further investigation of the aspects of the Christian worldview which may be linked to rejection of biological evolution, further research into which aspects of biological evolutionary are perceived to be in direct conflict with a Christian worldview, the exploration of teaching practice which could more effectively encourage conflict management and inquiry into the influences on students to reject biological evolution such as parents, peers, church leaders or private research.

This study used a modified Christian orthodoxy scale developed by Pope (2014) as part of a questionnaire to indicate acceptance of a Christian worldview. This was an effective method of identifying a general spectrum of Christian worldview and this was explored in greater detail during the interviews. After analysis of the quantitative and qualitative data, it became evident that there were common themes throughout the Christian worldviews described by the students who rejected particular components of biological evolution. For this reason it would be valuable to investigate which particular aspects of the Christian worldview may be more strongly linked to rejection of biological evolution when compared with others. This research indicated a clear link between a literalistic interpretation of the book of Genesis and rejection of biological evolution therefore further research into various Christian perspectives, such as the nature of God or God's action in the natural world, could add valuable insight in this area of study.

Likewise, it may be beneficial to investigate which specific aspects of biological evolution are perceived to be in direct conflict with a Christian worldview. This research revealed that many students with Christian worldviews felt very little resistance to natural selection but a high level of conflict with common descent. Future research could examine the particular evolutionary concepts which cause the greatest conflict among students who hold Christian worldviews and such research would likely have direct practical applications for Science educators.

It would also be valuable to explore various methods of teaching practice with conflict management as a focus. Considering the degree of conflict which many religious students experience while studying biological evolution, further research on how this conflict could be minimised without sacrificing the rigour of the concept could prove valuable. There have been several recent studies carried out exploring such techniques with varying degrees of success and this study confirms the benefit of such research and perhaps encourages the necessity for more of its kind.

Finally, an inquiry into the influences on students to reject biological evolution would be an interesting point of inquiry. The extent by which these perspectives are formed independently by the students and their own private research and reflection in

comparison to the degree by which these students have been influenced by their parents, peers, church leaders or even teachers, would prove valuable.

6.7 CONCLUSION

The final chapter of this thesis provided a summary of the thesis in Section 6.1 and then Section 6.2 outlined the findings relevant to each of the research questions. Section 6.3 gave a description of the distinctive contributions made by this study to the literature and was followed by an identification of the limitations of the study in Section 6.4. Section 6.5 presented some practical applications of the study for Science educators and finally Section 6.6 described some suggestions for future research.

This study confirmed the current literature relating to the relationship between religion and Science, specifically acceptance of biological evolution. It demonstrated that within the context of an Australian faith-based school, a student's acceptance of a Christian worldview can be used as a predictor of their rejection of biological evolution. This study did not identify any significant link between students' acceptance of a Christian worldview and their understanding of biological evolution nor any significant link between students' acceptance of a Christian worldview and their Science-related attitudes. Finally, this research has identified and described several student perspectives and areas of conflict that have been experienced as a result of studying biological evolution.

After outlining and discussing the findings of this study throughout the preceding 5 Chapters, it is important to comment on the scope of this study and in what form its finding can be applied to a classroom setting. This study was conducted involving a specific group of students in a particular faith-based school in Western Australia. The research allows its readers to make predictions about the relationship between a Christian worldview and acceptance of biological evolution within the population but such a prediction is not to be used as a short cut for good pedagogy. It is the responsibility of the Science educator to assess each individual student based on their own interactions rather than approach any particular situation with overbearing assumptions. Good teaching practice involves a process of genuine discovery and the opportunity for a student to form new opinions without the predetermined expectations

of the Science educator framing their experience. That said, it is worthwhile acknowledging that many students who possess a Christian worldview will likely experience deep conflict while studying biological evolution and this must be considered by the Science educator before the onset of any particular lesson. Each student has the right to hold their own religious worldview and it is not the role of a Science educator to attempt to alter nor undermine such beliefs. It is, however, the role of the Science educator to create a safe learning environment where each student is respected and their views heard. As a consequence of such an environment, the students may learn to embrace the grandeur and intellectual satisfaction of the biological Sciences and perhaps even its foundational concept, biological evolution.

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Appendices

Appendix A: Student Questionnaire

Questionnaire Number _____ Age_____ Gender_____

Instructions: Put a cross (x) through the number in the scale which best reflects your response to each statement. Do not leave any statements blank.

1. Understanding and attitudes towards the Bible and Religious Faith.	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1. I am a Christian.	1	2	3	4	5
2. I consider attending church (or other religious meetings) on a regular basis important.	1	2	3	4	5
3. In general, religious beliefs are not important in my day-to-day life.	1	2	3	4	5
4. The Bible contains God's rules for living.	1	2	3	4	5
5. I feel guilty when I do something that is a sin.	1	2	3	4	5
6. The concept of God is an old superstition that is no longer needed to explain things in this modern time.	1	2	3	4	5
7. If a new scientific discovery were made that seemed to contradict the Bible I would assume the science was wrong.	1	2	3	4	5
8. When I pray to God He listens.	1	2	3	4	5
9. Through the life, death and resurrection of Jesus, God provided a way for forgiveness of man's sins.	1	2	3	4	5
10. Jesus Christ is the divine Son of God	1	2	3	4	5
11. God is not always aware of man's actions.	1	2	3	4	5
12. The Bible was written by men from men's imaginations. It was not inspired by God.	1	2	3	4	5
13. Even if they're not Christian, good people still go to heaven.	1	2	3	4	5
14. Jesus was crucified, died, and was buried, but on the third day He rose from the dead.	1	2	3	4	5
15. The Holy Trinity (God the Father, Jesus & the Holy Spirit) are all God.	1	2	3	4	5
16. What the Pastor/Church Leader/Priest says about the Bible is always true.	1	2	3	4	5
17. The majority of the events in the Bible are symbolic and didn't actually occur.	1	2	3	4	5
18. If God wanted to, He could perform supernatural miracles at any time.	1	2	3	4	5

19. God is ultimately good and desires good things for our lives.	1	2	3	4	5
20. The Devil/Satan is real and wants to stop people from doing the right thing.	1	2	3	4	5
21. The miracles reported in the Bible actually occurred.	1	2	3	4	5
22. One of God's primary purposes in creating life was so that He can love His creation and be loved by His creation.	1	2	3	4	5
23. Mary and Joseph, the parents of Jesus, conceived Jesus naturally and there was nothing supernatural about His birth.	1	2	3	4	5
24. When I have problems in my school, family or personal life I would rarely seek spiritual/religious comfort (pray, read the Bible etc.)	1	2	3	4	5
25. I believe that I was intentionally created by God and that He has a purpose for my life.	1	2	3	4	5
2. Attitudes to Scientific Inquiry	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1. I would prefer to find out why something happens by doing an experiment than by being told.	1	2	3	4	5
2. Doing experiments is not as good as finding out information from teachers.	1	2	3	4	5
3. I would prefer to do experiments than to read about them.	1	2	3	4	5
4. I would rather agree with other people than do an experiment to find out for myself.	1	2	3	4	5
5. I would prefer to do my own experiments than to find out information from a teacher.	1	2	3	4	5
6. I would rather find about things by asking an expert than by doing an experiment.	1	2	3	4	5
7. I would rather solve a problem by doing an experiment than be told the answer.	1	2	3	4	5
8. It is better to ask the teacher the answer than to find out by doing experiments.	1	2	3	4	5
9. I would prefer to do an experiment on a topic than to read about in science magazines.	1	2	3	4	5
10. It is better to be told scientific facts than to find them out from experiments.	1	2	3	4	5

3. Adoption of Scientific Attitudes	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1. I enjoy reading about things which disagree with my previous ideas.	1	2	3	4	5
2. I dislike repeating experiments to check that I get the same results.	1	2	3	4	5
3. I am curious about the world in which we live.	1	2	3	4	5
4. Finding out about new things is unimportant.	1	2	3	4	5
5. I like to listen to people whose opinions are different from mine.	1	2	3	4	5
6. I find it boring to hear about new ideas.	1	2	3	4	5
7. In science experiments, I like to use new methods which I have not used before.	1	2	3	4	5
8. I am unwilling to change my ideas when evidence shows that the ideas are poor.	1	2	3	4	5
9. In science experiments, I report unexpected results as well as expected ones.	1	2	3	4	5
10. I dislike listening to other people's opinions.	1	2	3	4	5
4. Enjoyment of Science Lessons	**Strongly Disagree**	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**
1. Science lessons are fun.	1	2	3	4	5
2. I dislike science lessons.	1	2	3	4	5
3. School should have more science lessons each week.	1	2	3	4	5
4. Science lessons bore me.	1	2	3	4	5
5. Science is one of the most interesting school subjects.	1	2	3	4	5
6. Science lessons are a waste of time.	1	2	3	4	5
7. I really enjoy going to science lessons.	1	2	3	4	5
8. The material covered in science lessons is uninteresting.	1	2	3	4	5
9. I look forward to science lessons.	1	2	3	4	5
10. I would enjoy more if there were no science lessons.	1	2	3	4	5

5. Understanding of the Theory of Evolution *(regarding understanding NOT acceptance)*	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1. Biological evolution is a process of gradual change, which is used by many scientists to explain the development of complex organisms from simple ones.	1	2	3	4	5
2. Biological evolution implies that all animals would have descended from some form of plant.	1	2	3	4	5
3. An 'adaptation' is a specific characteristic which an organism develops to aid in its survival.	1	2	3	4	5
4. Variation among a species is often the result of random genetic mutations.	1	2	3	4	5
5. Mutations are new, permanent, changes in DNA which were not present in the parents.	1	2	3	4	5
6. Biological evolution implies that *homo sapiens* (humans) are descendants of apes.	1	2	3	4	5
7. Natural selection states that organisms which survive due to a certain characteristic are likely to pass that favourable characteristic on to future offspring.	1	2	3	4	5
8. Biological evolution is a process of change, which explains how the universe began.	1	2	3	4	5
9. Natural selection states that organisms with favourable mutations are more likely to survive in certain environments.	1	2	3	4	5
10. Natural selection states that if there is a change in the environment, those organisms which have beneficial adaptations are more likely to survive.	1	2	3	4	5
11. Biological evolution is based on the idea that all life exists as a result of random, unguided, chance.	1	2	3	4	5
12. Biological evolution implies *homo sapiens* (humans) share a common ancestor with apes.	1	2	3	4	5
13. After many generations of evolution some members of a species may become so genetically different that they can no longer interbreed.	1	2	3	4	5
14. Biological evolution involves one organism randomly turning into another organism. (e.g fish into a bird)	1	2	3	4	5
15. Biological evolution requires millions of years to occur.	1	2	3	4	5
16. Biological evolution implies that all life descended from a single common ancestor.	1	2	3	4	5

17. Natural selection states that organisms change their physical characteristics to help survive in certain environments.	1	2	3	4	5
18. An 'adaptation' is a specific characteristic which and organism was born with, which aids in its survival.	1	2	3	4	5
19. Mutations are harmful changes in DNA which cause cancer and other diseases.	1	2	3	4	5
20. Biological evolution is when an environment changes, and therefore a species changes to survive in that environment.	1	2	3	4	5
6. Acceptance of the Theory of Evolution	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1. Organisms existing today are the result of evolutionary processes that have occurred over millions of years.	1	2	3	4	5
2. The theory of evolution is incapable of being scientifically tested	1	2	3	4	5
3. Modern humans are the product of evolutionary processes which have occurred over millions of years	1	2	3	4	5
4. The theory of evolution is based on speculation and not a valid scientific observation and testing.	1	2	3	4	5
5. Most scientists accept evolutionary theory to be a scientifically valid theory	1	2	3	4	5
6. The available data are ambiguous as to whether evolution actually occurs.	1	2	3	4	5
7. The age of the earth is less than 20,000 years.	1	2	3	4	5
8. There is a significant body of data which supports evolutionary theory	1	2	3	4	5
9. Organisms exist today in essentially the same form in which they always have.	1	2	3	4	5
10. Evolution is not a scientifically valid theory.	1	2	3	4	5
11. The age of the earth is at least 4 billion years.	1	2	3	4	5
12. Current evolutionary theory is the result of sound scientific research and methodology.	1	2	3	4	5
13. Evolutionary theory generates testable predictions with respect to the characters of life.	1	2	3	4	5
14. The theory of evolution cannot be correct since it disagrees with the Biblical account of creation.	1	2	3	4	5

15. Humans exist today in essentially the same format in which they always have.	1	2	3	4	5
16. Evolutionary theory is supported by factual, historical and laboratory data.	1	2	3	4	5
17. Much of the scientific community doubts if evolution occurs.	1	2	3	4	5
18. The theory of evolution brings meaning to the diverse characteristics and behaviours observed in living forms.	1	2	3	4	5
19. With few exceptions, organisms on earth came into existence at about the same time.	1	2	3	4	5
20. Evolution is a scientifically valid theory.	1	2	3	4	5

Appendix B: Interview Protocol

Curtin University

Introduction.
Read attached sheet.

Questions about attitudes to Science.

1. Do you generally enjoy science as a subject? What is it about science that you like/dislike?
2. Do you see the knowledge gained from science as useful to society? Why is this?

Questions about understanding biological evolution.

1. This picture [*referring to a photograph*] is of a polar bear in the snow. An adaptation of the polar bear is its white fur. According to biological evolution, could you explain the process which resulted in the polar bears fur being white? *(Mechanisms of evolution)*
2. Could you describe some of the reasons the general scientific community believes biological evolution has occurred? *(Evidence for evolution)*

Questions about acceptance of biological evolution.

1. Do you accept biological evolution as an acceptable explanation for the diversity of life on Earth? What reasons do you have for your acceptance/rejection?
2. Do you believe that biological evolution is compatible with a Christian faith? What reasons do you have for this belief?

Questions about Christian Faith.

1. Could you explain what being a Christian means to you?
2. Would you consider yourself a Christian? Why are/aren't you a Christian?

Conclusion

1. Do you have anything else that you would like to add relating to this topic?

Image from: http://www.hqwalls.com.ua/eng/animals_004.html

Appendix C: Information and Consent Form (Questionnaire)

Curtin University
School of Science and Mathematics Education

Participant Information Sheet (Questionnaire)

My name is Nicholas Chan. I am currently completing a piece of research for my Master of Philosophy (Science Education) at Curtin University.

Purpose of Research
I am investigating the idea that Christian Students in a faith based school are often presented with information which may contradict their religious beliefs, particularly in regard to evolutionary biology.

Your Role
I am interested in finding out the effect that belief in the Christian God may have on the acceptance and understanding of evolution in a faith-based school, in addition to understanding the nature of science and general attitudes to science. As part of this I am inviting you to complete a questionnaire about your personal beliefs regarding faith and the Christian God and what effect this has on your own attitudes and understanding in Science.

The questionnaire will take approximately 15 minutes.

Consent to Participate
Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. Your responses to this questionnaire are not part of any formal secondary school assessment. When you have signed the consent form I will assume that you have agreed to participate and allow me to use your data in this research.

Confidentiality
The information you provide will be kept separate from your personal details, and only myself and my supervisor will only have access to this. The questionnaire will not have your name or any other identifying information on it and in adherence to university policy and will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

Further Information
This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval Number SMEC-14-11). If you would like further information about the study, please feel free to contact me on 0400210429 or by email nchan@tcc.wa.edu.au. Alternatively, you can contact my supervisor Professor Vaille Dawson on 92667484 or v.dawson@curtin.edu.au

Thank you very much for your involvement in this research.
Your participation is greatly appreciated.

Curtin University

CONSENT FORM

- I understand the purpose and procedures of the study.
- I have been provided with the participation information sheet.
- I understand that the procedure itself may not benefit me.
- I understand that my involvement is voluntary and I can withdraw at any time without problem.
- I understand that no personal identifying information like my name and address will be used in any published materials.
- I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.
- I have been given the opportunity to ask questions about this research.
- I agree to participate in the study outlined to me.

Student Name: _____

Student Signature: _____

Date: _____

Parent/Guardian Name: _____

Parent/Guardian Signature: _____

Date: _____

Appendix D: Information and Consent Form (Interview)

Curtin University
School of Science and Mathematics Education

Participant Information Sheet (Interview)

My name is Nicholas Chan. I am currently completing a piece of research for my Master of Philosophy (Science Education) at Curtin University.

Purpose of Research
I am investigating the idea that Christian Students in a faith based school are often presented with information which may contradict their religious beliefs, particularly in regard to evolutionary biology.

Your Role
I am interested in finding out the effect that belief in the Christian God may have on the acceptance and understanding of evolution in a faith-based school, in addition to understanding the nature of science and general attitudes to science. As part of this I am inviting you to complete a questionnaire about your personal beliefs regarding faith and the Christian God and what effect this has on your own attitudes and understanding in Science.

The interview will take approximately 15 minutes.

Consent to Participate
Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. Your responses to this questionnaire are not part of any formal secondary school assessment. When you have signed the consent form I will assume that you have agreed to participate and allow me to use your data in this research.

Confidentiality
The information you provide will be kept separate from your personal details, and only myself and my supervisor will only have access to this. The interview transcript will not have your name or any other identifying information on it and in adherence to university policy, the interview tapes and transcribed information will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

Further Information
This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval Number SMEC-14-11). If you would like further information about the study, please feel free to contact me on 0400210429 or by email nchan@tcc.wa.edu.au. Alternatively, you can contact my supervisor Professor Vaille Dawson on 92667484 or v.dawson@curtin.edu.au

Thank you very much for your involvement in this research.
Your participation is greatly appreciated.

Curtin University

CONSENT FORM

- I understand the purpose and procedures of the study.
- I have been provided with the participation information sheet.
- I understand that the procedure itself may not benefit me.
- I understand that my involvement is voluntary and I can withdraw at any time without problem.
- I understand that no personal identifying information like my name and address will be used in any published materials.
- I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.
- I have been given the opportunity to ask questions about this research.
- I agree to participate in the study outlined to me.

Student Name: _____

Student Signature: _____

Date: _____

Parent/Guardian Name: _____

Parent/Guardian Signature: _____

Date: _____

Appendix E: Ethics Approval Letter

Curtin University

Memorandum

To	Nicholas Chan, SMEC
From	Pauline Howat, Administrator, Human Research Ethics Science and Mathematics Education Centre
Subject	Protocol Approval **SMEC-14-11**
Date	8 April 2011
Copy	Vaille Dawson, SMEC

Office of Research and Development

Human Research Ethics Committee

Telephone 9266 2784
Facsimile 9266 3793
Email hrec@curtin.edu.au

Thank you for your "Form C Application for Approval of Research with Low Risk (Ethical Requirements)" for the project titled *"A study on Christian students' acceptance and understanding of biological evolution in a West Australian faith based school"*. On behalf of the Human Research Ethics Committee, I am authorised to inform you that the project is approved.

Approval of this project is for a period of twelve months **5th April 2011** to **4th April 2012**.

A Consent Form must be provided to participants in your study. Details can be found on page 15 of *A Guide to Preparing Your Application for Ethics Approval at SMEC* which I have attached for you.

The approval number for your project is **SMEC-14-11**. *Please quote this number in any future correspondence*. If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.

Pauline

PAULINE HOWAT
Administrator
Human Research Ethics
Science and Mathematics Education Centre

Please Note: The following standard statement must be included in the information sheet to participants:
This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number SMEC-14-11). If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee,