

Perceptions of the relationship between evolutionary theory and biblical explanations of the origins of life and their effects on the learning of evolution among high school students

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Abstract: This study explores the perceived relationship between evolution and the biblical account of creation amongst Thai high school students in Christian schools and the impact of these perceptions on learning. Evidence was found for the following perspectives: *creation only* and *compartmental (incompatible models)*; *NOMA*, *fusion*, and *complementary (compatible models)*. Each perspective is related to an approach to learning: *rejection* of one explanation, *switching* between explanations instrumentally according to the context, *differentiating* between areas of reality explained by each, *integration* of the explanations and *refinement* of one explanation through the other. Furthermore, students who held *compatible* perspectives had the potential to engage positively with learning about evolution, those adopting a *rejection* approach tended to engage with evolution in order to falsify it and the student who took a *switching* approach demonstrated detached learning. The study therefore provides an example situation in which learning within one discipline affects learning in another.

Introduction

Evolution is considered to be a unifying theme in biology; however, its development has relied on the combined effort of professionals in disciplines ranging from biology and medicine to physics and geology, engaged in observing, collection and experimentation to enrich and validate the theory. The area is also becoming ever more interdisciplinary as evolutionary models and frameworks are adopted by those working in domains as diverse as the social sciences and informatics. Research in the area therefore not only produces a body of knowledge that is central to the discipline of biology, it also stimulates scientific collaboration between professionals in different fields; teaching of evolution usually takes place in the context of biology, yet it is central to work in a broad range of discipline areas. Nonetheless, despite its inherent interdisciplinary importance as both a subject of study in its own right and a methodological tool, it has always been the subject of considerable debate, partially fuelled by its relationship with another disciplinary area, that of religion.

Specifically, evolutionary theory is perceived by some to directly contradict religious explanations of the origins of life. There has been a recent renewal of debates pertaining to the teaching of the origins of life and evolutionary theory in formal education (Berkman et al, 2008) with a majority of clashes occurring in relation to Christian groups (Padian 2009). We take the perspective that it is important to understand the ways learners perceive the relationship between religious and evolutionary accounts of the origins of life, as well as their impact on learning, in order to develop teaching approaches which simultaneously respect learners' beliefs and allow them to engage positively with evolution. A range of studies have gathered data on learner beliefs but have largely relied on quantitative approaches using pre-defined categories; we explore the relationships from the perspective of learners, allowing categories to arise from the data.

This paper uses a phenomenographic approach to analyze data collected via individual and in-depth interviews, providing evidence of different understandings of the relationship between evolution and creation as perceived by high school students attending Christian schools in Thailand. The findings reveal five different perspectives of the relationship among the students: *creation only*, *compartmental*, *NOMA*, *fusion* and *complementary* perspectives. Each perspective is related to an approach to learning: *rejection* of one explanation, *switching* between explanations instrumentally according to the context, *differentiating* between areas of reality explained by each, *integration* of the explanations and *refinement* of one explanation through the other. Furthermore, each approach reported here gives rise to different ways of engaging with evolution. Those who adopted *differentiating*, *integration* and *refining* approaches had the potential to engage positively with the lesson whereas those who adopted *rejection* approach tended to engage the lesson in order to falsify it. Finally, the student who took a *switching* approach demonstrated *detached learning* that appeared to take the form of cognitive understanding with little emotional engagement. A model is proposed that links these findings to perspectives from the literature. More generally, the study suggests that, at least in some contexts, learning of disciplinary material is strongly influenced by learning that takes place within other disciplines, with disciplinary epistemology playing a role in this.

This paper begins by presenting models of the relationship between science and religion, as applied to evolution and creation, drawn from the literature. It then explains the methodological approach implemented in this study, followed by findings, discussion and educational implications.

Background

The word *evolution* is generally associated with Charles Darwin who described the theory of evolution in *On the Origin of Species* (Scott 2005), and more recent developments of this theory. Evolutionary theory explains changes in species of living organisms over time as due to variation amongst individuals and the processes of natural selection (Darwin 1859). In more recent versions of evolutionary theory, variation is claimed to arise randomly with respect to function, with natural selection acting as a directional force that increases the relative frequency of adaptive traits among the population (e.g. Dawkins 1986).

Another explanation of the origin of life is provided in the Bible and other religious texts. Specifically in the context of Christianity, the Bible explains that God created the Universe, the Earth and all living things (Alexander 2008). The explanation has been interpreted in a variety of ways, ranging from the literal to interpretations of the biblical creation story as a metaphor (Scott 2005). These interpretations have different implications for the relationship with the scientific theory of evolution. Although many Christians see no incompatibility between the biblical account and evolutionary theory (for example, those who see the biblical creation story as metaphorical), some interpretations lead to apparent incompatibilities between the scientific and religious claims regarding origins, with those subscribing solely to the religious viewpoint in its strong form often referred to as “creationists”.

Various understandings of the relationship between evolution and biblical accounts of the origins of life have been identified with Alexander (2007) describing four models relating science and religion (*conflict*, *complementary*, *fusion* and *NOMA* models). We now provide an overview of these models as a backdrop to our own study. Alexander’s work appears to be based on broader philosophical perspectives on the relationship between science and religion (e.g. Barbour 2002), but we concentrate on his work as the most recent source identified.

1. The conflict model

The first model identified by Alexander (2007) is the *conflict model*, according to which science and religion are considered to be in fundamental opposition. In this view, the two explanations provide incompatible answers to the same fundamental question. We note that this view can be divided into two: *evolution only* and *creation only* models.

The first subcategory maintains that evolution provides a sufficient and convincing explanation of the origins of life and that there is no place for God or supernatural powers in the scientific arena. This view has been shown to be widespread amongst science teachers and students in a number of settings. For instance, Ingram and Nelson (2006) found that over 60 percent of science students at the Midwestern University accepted the explanation of evolutionary biology, but did not accept biblical interpretations. In contrast, proponents of the *creation only* model reject the theory of evolution and accept that in the Bible (Scott 2005). This model is also found to be accepted by professionals in various domains. For example, Berkman *et al.* (2008) reported that 38 percent of American people stated that they would prefer that creation was taught in schools, not just in addition to, but in place of evolution.

2. The “NOMA” model

The second model is called *NOMA* after the *Non-Overlapping Magisteria* model proposed by Stephen Jay Gould in 2002 (Alexander 2007). In this view, science and religion deal with different domains of reality. Specifically, Gould (2002) suggests that science and religion focus on different fundamental questions: the magisterium of science relates to the facts of empirical data while the magisterium of religion covers questions concerning ultimate meaning and moral value. The two domains do not overlap by definition thus there is no conflict between the two.

This model corresponds to the viewpoint taken by a range of scientists and has been used by science teachers to support the teaching of evolution. For example, Ladine (2009) notes that separating biblical explanations from the theory of evolution enables him to teach evolution in Christian institutions comfortably and allows Christian students to be open to learning about evolution.

3. The complementary model

The *complementary model* provides another way in which evolution and creation can be considered as compatible. Alexander (2007, p.4) explains that “this model maintains that science and religion are addressing the same reality from different perspective, providing explanations that are not in any kind of rivalry to each other, but rather are complementary”. For example, one instantiation of this model would be that the belief that God directs the processes of evolution. Proponents of this perspective often argue that putting faith and scientific reason together enables us to better understand the whole range of reality (Berry 2007).

4. The fusion model

The final model identified by Alexander (2007) is called the *fusion model*. In this approach, there is no clear distinction between the kind of knowledge provided by evolutionary theory and religious explanations: both focus on the same reality and provide the same knowledge. Alexander (2007, p.3) explains that those who take this perspective “tend to blur the distinction between scientific and religious types of knowledge altogether, or attempt to utilize science in order to construct religious systems of thought, or vice versa”.

Aims of this study

The models identified by Alexander (2007) appear to have been identified from theoretical perspectives from the philosophy of science. Although a number of studies provide evidence for the existence of some of these perspectives, these mainly take the form of evaluations of particular curricula or courses. These studies generally rely on quantitative approaches that offer participants pre-defined categories based on the tutors' own experience or theoretical perspectives drawn from the literature. As a result, it may be that additional perspectives, or variants of these, exist amongst the student population. Furthermore, most empirical studies have been carried out in Western countries (USA, UK, EU countries), thus alternative perspectives may arise in other cultural contexts. Of particular importance to education, the ways in which these perceptions influence learning have not been investigated in detail.

The specific research questions addressed in the study were thus as follows: (1) How do Thai students at Christian schools perceive the relationship between evolution and creation? (2) How does their perception of the relationship relate to their account of the learning process in which they engaged while studying evolution?

The study reported here contributes to the broader literature on the educational implications of perceptions of the relationship between evolution and creation by investigating these viewpoints through discussions with students, without providing pre-defined categories. It focuses on developing a deeper understanding of students' perceptions of the relationship between the accounts of the origins of life, as well as on identifying the impacts of these perceptions on their learning of evolution. Because we expected to encounter less polarized responses in a context where the relationship between creation and evolution has been less politicized than in the Western world, we focus our study on students in Christian schools in Thailand where the Christian population generally adheres to Baptism, Presbyterianism and Pentecostalism. This new cultural context also extends our knowledge to beyond the Western world, potentially allowing additional perspectives to be identified.

Methodology and method

Since this study aims to identify the different ways that students perceive a specific phenomenon – that of the learning of evolution in their Christian school – phenomenography is chosen as a methodological framework for the study and associated data analysis (Marton 1981). A phenomenographic approach is appropriate for an empirical study such as this that aims to understand the ways in which people experience a particular phenomenon (Marton 1981), with particular emphasis on describing, analyzing and understanding the different ways in which people experience a situation from their personal viewpoint (Micari et al 2007). Researchers using phenomenography normally collect data from individual interviews which are transcribed and analyzed to identify common and contrasting perspectives relating to the phenomena of interest (Marton 1981).

Nine high school students, aged 17-18, currently enrolled in Christian schools in Bangkok took part in this study, alongside 2 teachers. In principle, all students should have encountered evolutionary and biblical explanations of the origins of life in the school context as evolution is a compulsory part of the science curriculum and Christian schools provide Bible Study classes that cover origins. To allow participants the freedom to describe freely the relationship between biblical and evolutionary perspectives on the origins of life, the 30-minute semi-structured interviews employed open-ended questions carried out in their schools. The interview consisted of two parts: firstly, the participants were asked to express their belief concerning the relationship between evolution and creation in a general sense; secondly, they were encouraged to talk about their experiences of learning about these in the classroom.

For data analysis, all interview records were transcribed in Thai. Based on the two sections of the interview, participant narratives were analyzed along three dimensions: their general perceptions of the relationship between the two explanations; the ways in which they approached the task of learning about the two explanations; and the types of their engagement with evolution. Similar and contrasting perspectives relating to each dimension were drawn from the narratives by grouping similar statements into categories to allow common themes to arise, whilst differences were also actively sought between descriptions in order to differentiate between participant perspectives.

Findings were also validated by using *data triangulation* and *investigator triangulation* (Marthison 1988). For data triangulation, we considered both the relationship between our findings and those from the philosophical literature and also interviewed teachers. Teachers and students were interviewed using a similar interview schedule; however, students reported on their own perceptions whilst teachers referred to their own position and to the learning of their students via questions relating to the issues they had encountered when teaching about evolution. For investigator triangulation, two researchers were involved in the data analysis that took place in two phases. The first author identified categories of relationship according to processes of phenomenography. Relevant sections were translated into English and the categories identified were compared to those considered in the literature. In the second phase, the categories were further refined in conjunction with the second author using a process of consensus, until both were comfortable. During the second stage, the categories were compared with Alexander's (2007) distinctions.

Findings

1. The relationship between evolution and creation

Analysis of the student narratives provided five perspectives on the relationship between evolutionary and biblical

accounts of the origins of life among participants in this group, summarized in Table 1. Four of the perspectives correspond roughly to categories identified by Alexander (2007), while the other has not been described in this context. The first two categories, *creation only* and *compartmental*, are both *incompatible* perspectives, while the remaining three, *NOMA*, *fusion* and *complementary* are *compatible* perspectives.

Expressing views in relation to the first of the *incompatible* perspectives, four students (Pavee, Prakhun, Nicha, and Thida) explained that they accepted the biblical explanation of God's creation and rejected evolutionary accounts, considering that it is impossible to reconcile the explanations. Three of these students (Pavee, Prakhun, and Nicha) gave their religious beliefs as the reason for their position, whereas Thida instead emphasized purpose, explaining that belief in God's creation gave her life purpose, whereas evolution did not and she was therefore more comfortable with the former. Their view is named *creation only* and corresponds to the subcategory of Alexander's (2007) *conflict model* where evolution is rejected.

Providing evidence for the second of the *incompatible* perspectives, Praporn explained that she viewed evolutionary and creation perspectives as different, but made no attempt to resolve this apparent contradiction, preferring to use the knowledge relating to each instrumentally in the relevant classes, using the different explanations as appropriate according to the context. This perspective, which we call *compartmental*, is not discussed by Alexander (2007) and we can find no evidence for it in the philosophy of science literature. This is perhaps unsurprising since the philosophy literature focuses explicitly on the relationship between science and religion, whereas the student holding this position actively avoids considering the connection.

In the first of the three *compatible* perspectives, Daungjai and Mothana expressed the view that evolution and creation address different kinds of fundamental question and realities: while evolution deals with the facts of scientific evidence, creation deals with religious concerns, such as belief, values and purpose of life. This perspective is named *NOMA* after Gould's (2002) model. Other *compatible* perspectives were held by Sadudee and Apai who believed that scientific and religious explanations pertain to the same reality, but are nonetheless compatible. Specifically, Sadudee appeared to hold a view most closely aligned with a *fusion* model whereby no clear distinction is made between scientific and religious knowledge, suggesting that evolution can be viewed as scientific creation and creation as scientific belief. Finally, Apai explained that he believed that in time, scientific and religious understandings of the world would become aligned, and that science would confirm his religious beliefs, in a way that is reminiscent of Alexander's (2007) *complementary* perspective.

Table 1: Perceptions of the relationship between evolution and creation

Category name	Representative statements
Conflict (Creation only)	Since evolution is different from the biblical explanation, I do not believe it. [...] Science is too small when compared to God. It cannot prove or disprove the existence of God. (Nicha)
	Creation is a purposeful plan of God. I am not purposeless any more in this sense. I know where I am from and where I will go after this. So, I am really happy that I am a beloved daughter of God. Although this idea is like children's thought, it can create my happiness. It is impossible that science can explain everything. (Thida)
Compartmental	These two theories seem different in various aspects, like time and process. However, I tried to ignore these differences when I studied. (Praporn)
NOMA	To me, evolution is a kind of scientific knowledge, but creation is a kind of religious belief. They are fundamentally different. [Science] deals with the matters and evidence. [Religion] deals with people's ethos and values. It explains what the purpose of life is. It teaches us how to be a good person. (Mothana)
Fusion	It is possible that God created small living things and let them evolve until they became billions of species as we can see at this moment. However, God is the origin of life, in my opinion. I do not reject evolution. [...] We should open our mind to receive a full range of knowledge. [A Christian biology teacher] can make evolution to be scientific creation and make creation to be scientific belief. (Sadudee)
Complementary	I believe in creation because I am a Christian. And also, I believe in evolution because it is reasonable. To me, science is about God and God is about science. [...] I treat science as a powerful tool to confirm that there is a God. (Apai)

2. Learning approaches

Five approaches were found to be used to negotiate the relationship when learning about the scientific and religious accounts (see Table 2). Firstly, when Pavee, Prakhun and Nicha (*creation only*), learned about evolution in school, they took the Bible as their starting point, comparing new material to their knowledge of the biblical creation story and rejecting other explanations, in approach we name *rejection*. In addition to declining evolutionary theory, they actively engaged with learning about evolutionary theory with the explicit aim to critique the theory in order to reinforce their own religious perspective. Like these students, although Thida (*creation only*) did not learn about

evolution in her formal schooling, she consulted books, websites, and people in the church in order to reinforce her belief and argue against evolutionary theory.

Secondly, Praporn (*compartmental*) referred to having two modes of functioning, turning on “the switch of scientific mode” when learning about evolution, and turning it off again when in religious education classes. In relation to her approach when undergoing assessment, she answered questions about evolution as accurately as possible to gain good marks, despite not believing the explanations provided, or wishing to engage with them in a deep way. We name this approach *switching*.

Thirdly, Daungjai and Mothana (*NOMA*) used what we call a *differentiating* approach, attempting first to differentiate between the realms of applicability of the two accounts, and using the distinction to avoid internal conflict and confusion. Daungjai referred to metaphorical interpretations of the Bible in generating the distinction, whereas Mothana referred to the role of religion being to inform moral decisions and values.

Fourthly, Sadudee (*fusion*) was interested in finding the *integration* of evolution and creation and ways in which to coherently combine evolution and creation, suggesting that perhaps God had created life and that evolution explains the development of life forms into the broad range of species existing today.

Finally, Apai (*complementary*) was interested in learning about evolution and the complexities of life almost as *refinement* of the existence of God, claiming that when aspects of the two perspectives appeared not to correspond, that this was because of the current limitations of our scientific knowledge. For him, science is a powerful tool to allow human beings to see God more clearly.

Table 2: Approaches for negotiating the relationship in learning contexts

<i>Approach</i>	<i>Representative statements</i>
Rejection	I think it is better to know both explanations. It is because I can know how others think about evolution. I want to know more as I can find reasons to reject it. (Prakhun) God is the truth. What he says is an ultimate truth. Other explanations that oppose to the biblical account must be wrong. I have to deny them. (Thida)
Switching	In a science class, I tried to be a science person by answering all questions about evolution scientifically. When I studied about creation in a religion class, I turned the switch of scientific mode off and turned the religion one on. I tried to be a religious person. I answered everything according to religious beliefs. (Praporn)
Differentiating	They have different purposes. So, what I really did was I tried to differentiate both of them first. And then, I tried to understand which aspects that evolution wants to deal with and which aspects that creation tries to imply. (Mothana)
Integration	What I am looking for is the intersection between evolution and creation (Sadudee)
Refining	My stance is I will not immediately reject what I do not understand. I will think that it might be possible in some way. Although I cannot entirely understand how evolution and creation can be perfectly matched, I think it might be possible in the future. I treat science as a powerful tool to confirm that there is a God. I just think that there is a God and He is the truth. And then, other findings will verify His existence. (Apai)

3. Types of engagement with evolution

Data analysis demonstrated that the perspectives and approaches above can be linked to at least three different types of engagement with evolutionary theory and the understandings that arise from them: *engagement*, *learning to falsify* and *detached learning* (see Table 3).

Firstly, all students who held *compatible* perspectives (*NOMA*, *fusion* and *complementary*) appeared to be positively engaged with learning about evolution, claiming that their perspective helped them to avoid confusion and demonstrating enthusiasm and interest in the area. Whilst those with a *NOMA* perspective were interested in evolution principally for the scientific knowledge itself, those taking a *fusion* or *complementary* perspective also saw learning about evolution as a way of clarifying their understandings of religion. Secondly, those who hold a *conflict* view explained that they were actively engaged in their studies or studied outside of the classroom with the explicit aim of learning more about evolution in order to critique evolutionary explanations and thus strengthen arguments for their religious viewpoint, engaging with the primary purpose of *learning to falsify*. Finally, the student who took a *compartmental* view demonstrated *detached learning*, only acquiring knowledge about evolution because it was part of the school curriculum.

Table 3: Types of engagement with evolutionary theory

<i>Type</i>	<i>Representative statements</i>
Engagement	I did not feel uncomfortable or want to reject it. In contrast, it was exciting to know how evolutionary processes work. The more I can see how science is complicated, the more I am sure that there is a

	God. As the Bible says, God is the source of wisdom. He gave the wisdom to us in order to let us see His works. (Apai)
Learning to falsify	There was no negative impact on my study at all. I even could get a good grade in that term. Basically, I am confident with God's creation. But I also wanted to know about evolution so that I can argue against it. (Pavee)
	At that time, I did nothing, as I did not want to create any controversial issue in the class. However, in my mind, I already rejected it. Then, I tried to ask my friend's father and other people in the church about this. They gave me a lot of information. [...] In addition, I read many books that support what I believe. I tried very hard to protect my belief. I stopped doing that when I felt that I did not wonder about the existence of God anymore. (Nicha)
Detached learning	In a science class, I tried to be a science person by answering all questions about evolution scientifically. When I studied about creation in a religion class, I turned the switch of scientific mode off and turned the religion one on. I tried to be a religious person. (Praporn)

Discussion and implications

In relation to earlier work, the study described here allows for the identification of additional perspectives not demonstrated in other empirical research. Based on the findings and in relation to the four models proposed by Alexander (2007), we claim that there are two primary ways of viewing the relationship between evolution and creation: *incompatible* and *compatible*. Figure 1 provides an overview of the findings, linking together perspectives on the relationship between evolution and creation, approaches to learning and engagement with evolution, as well as situating these within other perspectives in the literature.

In the *creation only* perspective, creation is accepted and evolution is not considered to provide an acceptable explanation; in the *evolution only* perspective, evolution is judged to be plausible and religious accounts are rejected; in the *compartmental* perspective, both explanations are considered to be internally consistent but are in conflict with one another, with no decision made as to the veracity of each. Although the first two models are discussed by Alexander (2007) and others, the *compartmental* model appears not to have arisen in earlier work and we suggest that it should be added as a subcategory of the *incompatible* perspectives. Furthermore, the data collected in this study therefore demonstrate the existence of incompatible amongst Christian students in Thailand, despite the background of Buddhist communities and the less politicized context.

The findings also reveal at least three categories of *compatible* perspectives, corresponding to those identified by Alexander (2007): *NOMA*, *fusion* and *complementary*. Students taking the *NOMA* perspective consider that evolution and creation are addressing different kinds of question and through seeking the different aspects of reality to which each explanation applies, avoid conflict. Students who hold a *fusion* view, do not seek distinctions, but rather attempt to integrate the two explanations through blending, perceiving no clear distinction between them. Finally, students taking a *complementary* viewpoint look for complementarities between the explanations and consider them to be mutually supportive. The data provide empirical evidence for the existence of all three compatible perspectives amongst Thai high school biology students.

The categories identified above were triangulated by interview data given by two biology teachers working at the Protestant school who had both been teaching biology for at least 5 years, and at least one of whom had taught evolution to the four students from the sample who were studying at this school. The teachers themselves appeared to hold a *NOMA* perspective. Moreover, they provided a third-person perspective on student learning describing examples of situations that correspond to *conflict*, *fusion* and *complementary* perspectives amongst their students. For example, one teacher stated that 'some of my students declined answering exam questions scientifically but they wrote their point of view instead, for example, God created all things (*conflict* perspective) and that 'some of them answered the questions according to scientific explanations discussed in the class but they concluded that all of those are controlled by God (*fusion* or *complementary*).

The different perspectives and associated learning approaches identified appear to give rise to a range of ways of engaging with evolutionary theory, which in turn support different educational outcomes for the students (see Figure 1). According to our proposed model, those students taking one of the *compatible* perspectives (*NOMA*, *fusion* and *complementary*) are able to learn about evolution without any conflict with their religious beliefs. These perspectives support either neutral or positive relationships between the learning that goes on in these two disciplines. However, students holding the *incompatible* viewpoints demonstrate different kinds of influences on their understanding and engagement. Not surprisingly, it was among students who interpreted the Bible literally that serious misconceptions (Scott 2005) were identified:

Evolution is about monkeys and humans. It claims that we are from monkeys. Natural selection is the reason why those monkeys could be humans. Those monkeys tried to adapt themselves to environments in which they lived. (Thida)

More subtly, despite rejecting evolution, some students who *learn to falsify* (and potentially also those using *switching*) may demonstrate convincing understanding of evolution:

There was no negative impact on my study at all. I even could get a good grade in that term. Basically, I am confident with God's creation. But I also wanted to know about evolution so that I can argue against it and answer questions related to the topic. [...] I actually should feel bored while I was studying. But it is not true. On the contrary, I was really keen to learn it. [...] It is weird, I know, that I wanted to know in order to reject it. (Pavee)

Although Pavee appears to have understood evolutionary theory sufficiently to do well on the course, his learning is qualitatively different from that of students who accept evolution as accurate.

In his introduction to the *Cambridge Handbook of the Learning Sciences*, Sawyer (2005, p.2) emphasizes the educational importance of “deeper conceptual understanding”, contrasting this with factual and procedural knowledge. However, the comments from students and teachers indicate that conceptual understanding does not necessarily lead to acceptance of evolutionary theory. As educators, we need to ask the question of the kind of learning – conceptual understanding or acceptance – we aspire to engender, as well as the moral implications of these intentions in a context where disciplinary knowledge may potentially threaten belief systems that are important to learners. There is evidence to suggest that some pedagogical approaches can support the acceptance of evolutionary theory without threatening religious beliefs. However, it is interesting to recognize that although accepting evolution as plausible may be a prerequisite to studying evolutionary biology, it may be possible to use evolutionary approaches as a methodology in other areas (such as the social sciences) whilst rejecting biological evolution. Indeed, approaching evolution from this perspective may even provide new pedagogical approaches.

At present, one of the most promising pedagogical approaches, as described in Ladine (2009), is the explicit exploration of the NOMA model with students. Ladine (2009) explains to students that he values religious studies as moral development and science as the discipline for naturalistic explanation, and provides evidence that this approach gives rise to positive engagement with evolution amongst his students. In an open-ended question that formed part of a course evaluation questionnaire, students of a private Christian college in the US explained that they had learnt that “evolution doesn't take God out of the picture,” “learning that evolution and religion can coexist,” and “that evolution may not really be as much of an evil lie as I have always been taught” (Ladine 2009, p.391).

Alternative pedagogies based on the other approaches associated with *compatible* perspectives – *integration* and *refining* – may also be developed. However, it is necessary tread carefully in this area. It was slightly surprising to us to realize that although three students (Pavee, Nicha and Sadudee) noted that evolutionary theory explains changes in species over time and is therefore not strictly concerned with origins of life (biogenesis), two of these students (Nicha and Sadudee) nonetheless rejected evolution. In other words, being explicit about this particular aspect of integration is not sufficient to allow students to accept evolutionary theory as they can nonetheless see conflicts in relation to other aspects, including timescale and purpose.

Even if we do not see the need for students to appropriate evolutionary theory, using an approach such as that described by Ladine (2009) may nonetheless be easier to justify on ethical grounds than leaving students to generate their own understandings of the relationship, as this can lead to a state of uncomfortable confusion:

To be honest, I am confused, as I don't know what is true. However, I try to ignore that. I try not to think about it too much. As I know, if I ask biology teachers, of course, they will use scientific evidence to explain it to me. If I ask religious teachers, they are going to let me read what the Bible says. There is no way to find their compatibility. So, it is better to keep quiet and forget it. (Praporn)

Finally, however, it is our hope that explicitly addressing the relationship between the two disciplines in order to encourage more sophisticated understandings of this may be to engender greater respect amongst learners in the classroom.

It is important to note some limitations of this study. The dataset was limited primarily due to political unrest in Thailand in 2009 at the time of data collection, making data collection from a larger sample, or indeed follow-up interviews, impossible. A single interview with each participant, is, however, reasonable in the context of this study since we intended to capture student positions at a single time point, rather than to establish how these changed over time. Since we were interested in their perceptions (a first-person account), the primary data source was student interviews, although two teachers were also interviewed. The nature of phenomenography, which aims primarily to develop well-defined categories of experience of a particular phenomenon, means that at least at early stages, these may constitute only a subset of categories that exist, and that furthermore, individuals included in the sample may be, in fact, unique. This does not detract from the validity of the study itself, but makes it difficult to generalize the results until further investigation has been carried out. Our claim is that the perspectives described have been uncovered; however, we make no claim as to their relative prevalence in the population either amongst the larger population from which they were drawn (high schools students at Christian schools in Thailand) or more generally.

More generally, the findings reported here reveal that at least in some areas, learning within one discipline can be strongly influenced by knowledge and learning within another: specifically, theology is shown to impact on scientific understandings. In line with Gould's (2002) claims about the different types of knowledge associated with religion and science, this impact may have its roots in the epistemology of science and religion more generally.

Indeed, Ladine (2009), while discussing perspectives of evolution and creation asserted that including God in the explanation of science indicates misunderstanding of the nature of science. It is therefore interesting to note a tendency amongst those students holding *compatible* perspectives to refer to science and religion more generally in their comments, despite being asked about evolution and creation.

For researchers, this study demonstrates the importance of an interdisciplinary approach to the study of learning in real world contexts. Specifically, it highlights the significance of disciplinary understandings of the nature of knowledge and reality, and informs theory in the learning sciences by exploring their effects on conceptual understanding of disciplinary material. In order to support student understanding and acceptance of disciplinary knowledge, we need to view our practice not as isolated within a discipline, but take account of its position in relation to knowledge and epistemologies appropriate to other disciplines. As educators, we need to be aware of the possible interactions between the epistemological paradigms underlying the disciplines in which we teach in order to address any conflicts sensitively and intelligently.

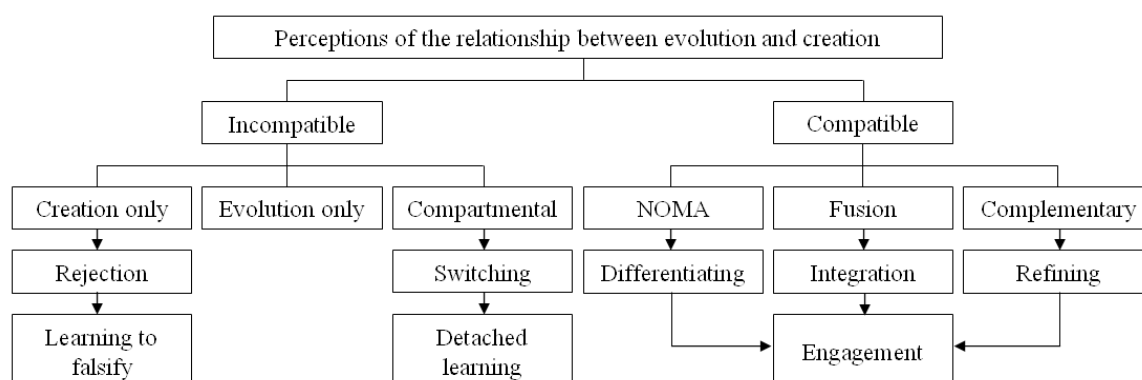


Figure 1: Proposed model relating the relationship between evolution and creation

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