A review of research instruments assessing levels of student acceptance of evolution

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Abstract

Darwin's theory of evolution by means of natural selection, called evolution for short, is perceived as a unifying theme in biology, forming a major part of all biology syllabuses. It is reported that student acceptance of evolution associates with conceptual understandings of biological contents, nature of science, as well as motivations to learn. Studies on student acceptance of evolution have been carried out intensively, contributing to a large number of research instruments assessing different levels of student acceptance. This article therefore aims to review currently used research instruments which include quasi-continuous scales of acceptance, a binary classification scheme commonly used in quantitative studies, a ternary classification scheme commonly used in qualitative studies, and a multi-dimensional classification scheme based on the relationship between evolution and creation. It also provides discussion on advantages and drawbacks of these instruments. In addition, it suggests a preferred instrument which is believed to be able to elicit student levels of acceptance more effectively.

Introduction

The theory of evolution by means of natural selection, called evolution throughout this article, is stated to be a unifying theme underlying biological concepts (Dobzhansky, 1973). It naturalistically explains about biological processes related to the origin, diversification, and geographic distribution of living things on Earth (Mayr, 2001). Research has shown that student acceptance of evolution positively associated with understanding of the content of biological evolution measured in the form of final grades (Ingram and Nelson, 2006), as well as understanding of the nature of science (Lombrozo, Thanukos and Weisberg, 2008). However, the association between student acceptance and understanding of evolution is less clear-cut in some other qualitative studies such as Demastes-Southerland, Settlage, and Good (1996), perhaps because of the nature of qualitative research which is able to uncover variations of responses. Therefore, it remains uncertain whether student acceptance of evolution leads to understanding of evolution or the other way around.

In addition, a lack of acceptance of evolution may contribute to negative learning experiences about evolution. For example, McKeachie, Lin and Strayer (2002) show a correlation that students who did not accept evolution in their survey study tended to express lower intrinsic motivation, less interest, higher anxiety and more

emphasis on grades when learning about evolution. In other studies, students who did not accept evolution chose not to engage with the learning at all (Meadows, Doster and Jackson, 2000) or learned in order to falsify it (Yasri and Mancy, 2014).

Besides these educational implications, Brem et al. (2003) discuss the influence of student acceptance of evolution on personal and societal implications as they report that their US college student participants viewed undesirable consequences of accepting evolution, consisting of increase in selfishness and racism, and decrease in the sense of spirituality, purpose of life and self-determination. Therefore, these studies together suggest that it is important to study student acceptance of evolution in order to promote students' better understandings of evolution as well as the nature of science.

A number of studies have investigated the extent to which school and university students accept evolution (as summarised in Table 1). According to the review of literature, there are at least four methods used in previous studies to measure and classify levels of student acceptance of evolution: quasi-continuous scales of acceptance using the Measure of Acceptance of the Theory of Evolution (the MATE; Rutledge and Warden, 2000), a binary classification scheme commonly used in quantitative studies such as Donnelly et al. (2009), Downie and Barron (2000), Southcott and Downie (2012) and Özay Köse (2010), a ternary classification scheme commonly used in qualitative studies such as Hokayem and BouJaoude (2008) and Clores and Limjap (2006), and a categorical system based on the multi-dimensional relationship between evolution and creation used by McKeachie et al. (2002).

In sum, apart from the MATE, the other quantitative studies present similar pre-defined categories of student acceptance of evolution, although they differ in research participants, settings, numbers of categories, category names, and research approaches for data collection. Donnelly et al. (2009), Downie and Barron (2000), Southcott and Downie (2012) and Özay Köse (2010) classify student acceptance of evolution based on a binary classification scheme: those accepting evolution (often referred to as evolution acceptors or evolutionists) and those rejecting evolution (often referred to as evolution rejecters or creationists). A ternary classification scheme is adopted in some other qualitative studies such as Hokayem and BouJaoude (2008) and Clores and Limjap (2006), adding one middle position to capture individuals who are unsure (or doubtful or uncertain) about evolution. In addition, McKeachie et al. (2002) examine student acceptance of evolution in the

context where an explicit link between evolution and divine creation is made; thus an additional option is proposed such as "both evolution and creation accepted" (McKeachie et al., 2002).

Table 1. A summary of existing findings on student acceptance of evolution based on different research instruments and methods

Authors	Sample/context	Research method	Categorical levels of acceptance of evolution
Donnelly et al. (2009)	29 high school students in USA	Mixed methods including MATE	1. Acceptors (37.9%) 2. Rejecters (62.1%)
Downie & Barron (2000)	2584 undergraduates in the UK	Questionnaire	1. Acceptors (no data provided) 2. Rejecters (6.7%)
Southcott & Downie (2012)	1403 undergraduates in the UK	Questionnaire	1. Acceptors (no data provided) 2. Rejecters (5.0%)
Özay Köse (2010)	250 high school students in Turkey	Questionnaire (using Downie & Barron's tool)	1. Acceptors (26.8%) 2. Rejecters (73.2%)
Hokayem & BouJaoude (2008)	11 undergraduates in Lebanon	Interviews using MATE questions	1. Accepting evolution (63.6%) 2. Uncertain about evolution (27.3%) 3. Rejecting evolution (9.1%)
Clores & Limjap (2006)	37 undergraduates in the Philippines	Interviews and journal entries	1. Acceptance of evolution (62.16%) 2. Doubtful about evolution (13.51%) 3. Rejection of evolution (24.32%)
McKeachie et al. (2002) – Pre test	60 undergraduates in USA	Questionnaire	1. Evolution accepted (18.3%) 2. Unsure (36.7%) 3. Evolution-Creation accepted (28.3%) 4. Evolution rejected (16.7%)
McKeachie et al. (2002) – Post test	28 undergraduates in USA	Questionnaire	1. Evolution accepted (10.7%) 2. Unsure (10.7%) 3. Evolution-Creation accepted (28.6%) 4. Evolution rejected (50.0%)

On the one hand, these categories can be understood as qualitatively distinct categories (i.e. accept, unsure or reject evolution). On the other hand, they can be viewed as levels of acceptance in which those who are unsure whether they accept evolution or not may sit somewhere between those accepting evolution and those rejecting it. This suggests that there might be other levels in the "continuum". For example, Smith (2010) suggests the additional levels "acceptance with some reservations" or "reject some parts". Existing studies are discussed in more detail in the next sections according to the number of categories used.

Quasi-continuous scales for classifying levels of student acceptance of evolution

The MATE is a 20-item evolution acceptance questionnaire based on a 5 Likert-scale method which is most widely used in evolution education research (Smith, 2010). The actual research tool is provided in Appendix A. Rutledge and Warden (2000) report a very high value of a reliability coefficient of 0.98 for the MATE. The 20 items measure five different aspects related to acceptance of evolution: the scientific validity of evolution, the acceptance of evolution within the scientific community, creationist perspectives on divine creation, human evolution and the age of the earth (Rutledge and Warden, 2000). Student acceptance is then scored from 20-100 possible points, with 20 being the lowest level of acceptance and 100 being the highest level of acceptance. The corresponding scores and categories for acceptance are 89-100, Very High Acceptance; 77-88, High Acceptance; 65-76 Moderate Acceptance; 53-64, Low Acceptance; and 20-52, Very Low Acceptance (Rutledge, 1996).

However, although wildly used, the MATE is not considered as the best tool for assessing student levels of acceptance for a number of reasons. First, the framework for classifying the five continuous levels of acceptance of evolution based on the corresponding scores fails to offer a clear boundary between those accepting evolution and those rejecting evolution, even though the labels “low” and “very low” acceptance may hint at the tendency of rejection of evolution. This critique is supported by the actual use of the MATE by Donnelly et al. (2009). Although they used the MATE as a tool to classify their student participants as “evolution acceptors” and “evolution rejecters”, they did not rely on the suggested framework of the five continuous levels, but adopted a statistical approach to convert the Likert rating scale data to interval data and designed the breaking point to distinguish the two groups of students by themselves. This statistical complication does not only discourage basic users of statistics, but it does also suggest that the classification into two groups is done in an arbitrary manner (i.e. depending on the breaking point decided by the researchers). Furthermore, the suggested approach does not weight items and there is no guarantee that all items provide the same amount of information in relation to the construct of interest, that is, acceptance.

Similarly, although Hokayem and BouJaoude (2008) also used the MATE, they did not classify levels of student acceptance of evolution solely based on this research tool. In fact, they explained, “this questionnaire [MATE] was just used to gather preliminary information to initiate a discussion about the topic [the theory of evolution] and illustrate any changes in mind later on” (p. 401). They actually

classified levels of student acceptance based on interviews. It is true that the MATE has been widely used in educational research focusing on evolution education, but not in the way for which it was originally intended.

The second reason is provided by Smith (2010). From a philosophical perspective, Smith (2010) critiques the MATE for conflating knowledge with acceptance. From an empirical perspective, although the MATE has been shown to have a high Cronbach alpha coefficient value, suggesting that the items measure a single factor, Smith (2010) questions whether that factor is really acceptance. He points out: "what does it mean, for example, when a respondent asserts ("agree", "strongly agree", etc.) to the following statement: "Evolutionary theory generates testable predictions with respect to the characteristics of life"? Does the respondent accept the statement as true? Does s/he believe the statement is true? Does s/he accept/believe the statement as valid?" To address this issue, Smith (2010) suggests a possible way to measure acceptance of evolution as well as a classification of levels of acceptance of evolution in a way that is less ambiguous with respect to the distinctions between belief and acceptance, which will be discussed later.

A binary classification scheme for levels of student acceptance of evolution

A number of quantitative studies present the classification of levels of student acceptance into two: those accepting evolution or "acceptors" and those rejecting evolution or "rejecters". Using the MATE alongside additional analyses, Donnelly et al. (2009) classified 29 US high school biology students into 11 acceptors and 18 rejecters. All of the acceptors accepted human evolution as well as evolution as the explanation for modern life forms, and none accepted young-earth creationist statements. In contrast, among the rejecters, 12 accepted the statement that evolution is wrong because it contradicts the Bible and seven accepted the statement for young-earth creationism. Although the sample is small, and generalisation is therefore problematic, the ratio between acceptors and rejecters in this study does nonetheless reflect on the ratio reported in a larger survey study based on 1484 American adults which is almost 1:1 (Miller et al., 2006).

A similar classification scheme is found in the studies of Downie and Barron (2000) and Southcott and Downie (2012). Using the same research instrument, these two studies surveyed how undergraduate biology students attending a Scottish university perceived evolution and what reasons made them accept or reject it. The

former study was conducted during 1987 and 1999 with 2854 participants. The latter was carried out during 2008 and 2010 with 1403 participants. The student participants are simply classified to be either acceptors or rejecters depending on whether they accept or reject that "some kind of biological evolution, lasting many millions of years, has occurred on earth" (Downie and Barron, 2000, p. 140). Interestingly, unlike Donnelly et al. (2009)'s US based study, it is found that, within this context, the proportions of rejecters in both studies are much lower than the acceptors. In the former study, the average figure of the rejecters is 6.7%, whereas the figure in the latter work is about 5.0%. In contrast, using the research tool of Downie and Barron (2000) in a different context, Özay Köse (2010) showed that among 250 Turkish secondary school students, 73.2% were categorised as rejecters on the basis of their responses; whereas 26.8% as acceptors. These differences are probably explained by differences in the cultural context, as well as sample characteristics (e.g. Downie and Barron's samples had chosen to study biology).

Like the MATE, this binary classification scheme exhibits some limitations. This is due to the fact that although the use of two oppositional categories (i.e. rejecters versus acceptors) is predominant in research studies as well as in the public domain (Alexander 2009), it is not well accepted by a number of scholars. For example, Reich (2010) argues that these categories rely on a binary logic that fails to reflect the inter-woven and complex nature of knowledge systems such as those of science and religion. He also argues for a developmental sequence of positions of "epistemic cognition", according to which learners gradually become more competent at relating different ideas in religion and science. Therefore, it is reasonable to argue that these two radical categories fail to represent actual levels of acceptance of evolution. Ironically, this kind of classification scheme used in research may in fact contribute to students' perceived controversy of evolution as it seems to them that they have to take one side or can only either accept or reject evolution. This points to the importance of the development of a research measurement tool that includes a wider range of levels of acceptance of evolution and is explicit to the specific aspect of evolution that is being measured.

A ternary classification scheme for levels of student acceptance of evolution

Rather than classifying student acceptance of evolution into two oppositional groups, a number of studies, especially those by authors adopting a qualitative

approach, provide an optional level for those who are unsure or unable to decide whether or not they accept evolution. For example, Hokayem and BouJaoude (2008) examine student perceptions of evolution with regard to their epistemological beliefs about science and religion, focusing on 11 biology students who attended a course on evolution at university level in Lebanon, holding either Christian or Muslim beliefs. Using mixed research methods relying on semi-structured interviews initiated by MATE questions, the researchers deductively classified their student participants into three groups: seven who *completely accepted*, three who were unsure, and one who *rejected the theory*.

A similar classification is presented by Clores and Limjap (2006) who used a qualitative study to inductively examine how university students in the Philippines perceived evolution. The study involved 20 biology and 17 psychology students of Roman Catholic faith undertaking a 4-week general biology course, who voluntarily took part in this study. Based on interviews and written tasks after completing the course, the researchers present three categories of student acceptance. These comprised 23 students who *accepted*, nine who *rejected* and five who were *unsure* about whether they accepted the theory of evolution.

Apart from providing rich information regarding student opinions on acceptance of evolution, these qualitative and mixed-methods studies, adopting inductive and deductive approaches, suggest that there are a number of students who are unable to make a decision whether they should accept evolution or not. This strengthens the critique about the drawback of the binary logic and, of course, these students should not and cannot be labelled as either *acceptors* or *rejecters*. The qualitative nature of these studies thus makes it valuable to examine the proportion of participants who are unsure about evolution compared to those who accept and reject evolution in a larger group of sample using a new research instrument which includes this categorical level.

Nonetheless, researchers need to be careful when including a “neutral” or “unsure” option in a questionnaire. As suggested by Kulas et al. (2008), in quantitative work adopting a five or seven Likert-type statements, this “middle response” (i.e. unsure) may be selected for different reasons. For example, it may be an indication of uncertainty (i.e. no firm decision has been made), neutrality (i.e. genuinely having no partiality), or ambivalence (i.e. neither agree nor disagree), the non-applicability of other response categories (i.e. none of the categories capture the participant’s view), in addition to possibly the worst case in which a participant selects the

option because he or she does not want to consider the statement in any depth or does not really understand what they mean.

This "worst case" scenario is less likely to occur in qualitative interview studies because it is possible for researchers to ask participants further questions to clarify what is unclear. For example, those students who were classified in this category in Hokayem and BouJaoude (2008) and Clores and Limjap (2006) were able to explain *why* they were uncertain about evolution. Usually in questionnaire-based studies it is unclear what it means when the "unsure" option is selected. In a questionnaire, it is therefore valuable to ask participants directly why this box is ticked. However, the combination of two tasks - a selection of a level of acceptance of evolution based on a Likert item and a written explanation concerning reasons for selecting such level - should allow researchers to gain information regarding different levels of student acceptance of evolution and reasons for making a particular level of acceptance, while avoiding some of the ambiguities surrounding the selection of the "unsure" option in the absence of such information.

A multi-dimensional classification scheme for levels of student acceptance of evolution

In the situation where any alternatives explanations of the origins of life and biodiversity are known – for example in a Christian context – an alternative approach has been used that directly integrates these alternatives, leading to a multi-dimensional scheme for classifying qualitative different categories of student acceptance of evolution. McKeachie et al. (2002) explored acceptance of evolution by American college students taking a biology course using a questionnaire administered twice during the term (the first and the last weeks). Based on a single question with four qualitatively different choices representing different opinions on the acceptance of evolution in relation to interpretations of the biblical account of divine creation (the actual question is shown in Appendix B), the researchers report that among 60 volunteering participants at the start of the study, there were 11 who *accepted evolution as fact*, 22 were unsure about evolutionary theory, 17 *accepted both* the theory of evolution and the biblical account of divine creation, and 10 *rejected evolution*. However, by the end of the study when the second data collection was conducted, some of these perceptions had changed in the direction of greater acceptance of evolution over the period of the study. Although they did not collect evidence on causes, the researchers believe that these changes were the consequence of students' intrinsic motivation to learn about evolution related to

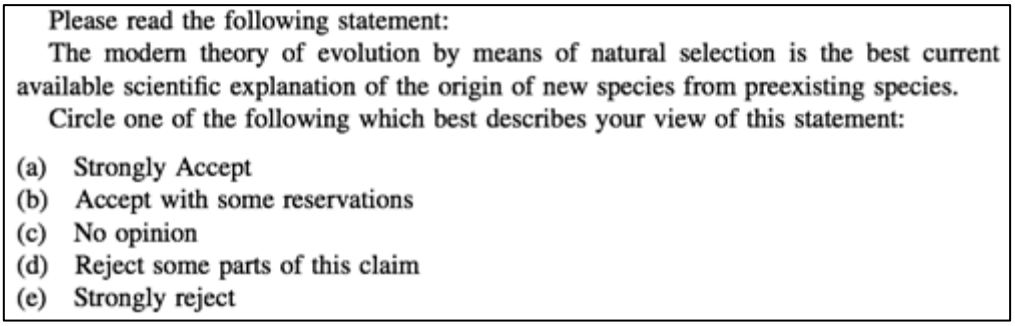
their acknowledgement of the importance of the theory of evolution in the scientific community. Nonetheless, among those students who claimed to accept both evolution and divine creation, it remains unclear in what particular ways they reconciled the two accounts.

The usefulness of this classification scheme is that each of the categories can be clearly distinguished by respondents. While *accepted evolution as fact*, *unsure* and *rejected evolution* are unidirectional, changing from the greatest degree of acceptance towards lesser degrees, *accepted both* provides another dimension which concerns a compatible relationship between evolution and creation. Although the idea of the clearly identified spaces between categories based on this classification scheme is useful, an issue is raised: whether it is necessary to explicitly make a reference to alternative explanations to evolution such as divine creation. Indeed, different research studies have different purposes. Student acceptance of evolution within the context of religious beliefs might be of interest of many researchers. However, some learners might not use religious lenses when considering the theory of evolution, and might use other rationalisations for accepting or rejecting evolution, or might provide justifications that rely on other forms of reasoning, whether or not their acceptance or rejection is religiously motivated. For example, the only student who rejected evolution in the study of Hokayem and BouJaoude (2008) did not express his opposition based on religious faith but on his scepticism about evolutionary evidence. The same is true with participants of Clores and Limjap (2006) who appeared to reject evolution based on their misconceptions about evolutionary theory and the nature of science.

In addition, in a context where the theistic belief regarding divine creation is little known, the inclusion of a specifically religious additional position (both evolution and creation accepted) might be awkward and rather less general. It is therefore useful to gain insight into how students perceive evolution on its own merits, only later focusing more specifically on its relationship with other explanations. In other words, rather than limiting student acceptance of evolution in religious contexts, the focus should be made on how students accept evolution as a scientifically valid explanation of the origin of life and emergence of the diversity of life forms. This allows religious rationales for particular levels of acceptance to emerge naturally. Claims about the roles of science and religion can be made more confidently if it is found that students still refer to religious perspectives even when the questionnaire question is explicitly limited to the scientific context.

A preferred instrument assessing student acceptance of evolution

Due to the drawbacks of the classification schemes presented above, I suggest here a newly developed scheme proposed by Smith (2010). This classification scheme embraces the advantage of the ternary classification scheme in terms of the inclusion of all possible ranges of levels of acceptance (i.e. acceptance, unsureness and rejection). In addition, it does not leave the usefulness of the multi-dimensional classification scheme which concerns qualitatively clear distinctions between categories (i.e. spaces between proposed categories can be clearly identified). However, this scheme avoids drawing an explicit link between biological evolution and biblical creation as done in the study of McKeachie et al. (2002), but emphasises merely accepting evolution as a scientifically valid explanation of the biodiversity in order that participants would not be misled. Figure 1 shows the original proposal suggested in Smith (2010, p. 534).



Please read the following statement:
The modern theory of evolution by means of natural selection is the best current available scientific explanation of the origin of new species from preexisting species.
Circle one of the following which best describes your view of this statement:

(a) Strongly Accept
(b) Accept with some reservations
(c) No opinion
(d) Reject some parts of this claim
(e) Strongly reject

Figure 1. A question assessing levels of student acceptance of evolution proposed by Smith (2010)

More specifically, Smith (2010) suggests a more explicit way to classify the levels of acceptance of evolution than the approaches used in earlier studies. Building on the idea of the ternary classification scheme, Smith (2010) extends the levels of acceptance to five categories. In fact, these five levels of acceptance are typical in the 5-point Likert type of question (i.e. strongly agree, agree, unsure, reject, strongly reject). However, instead of dividing acceptance into *strongly accept* and *accept* as is usually done, Smith (2010) divides it into *strongly accept* and *accept with reservation*. Likewise, instead of dividing rejection into *strongly reject* and *reject*, Smith (2010) divides it into *strongly reject* and *reject some parts*.

This way of classification, which is similar to the idea of the multi-dimensional classification scheme, provides a more clearly defined space between the categories which enable participants to be able to justify the qualitatively distinct space between *strongly accept* and *accept with reservation*, and between *strongly reject* and *reject some parts* more clearly. In addition, doing this would prompt respondents to think more carefully in terms of what the reservation is when they are going to select *accept with reservation* or what the rejected parts are when they are going to select *reject some parts*. On top of this, these modifications would help researchers ensure that respondents select one of these positions not because they only avoid choosing the "extreme" positions.

Summary and recommendation

This article reviews four categorisation schemes used to classify levels of student acceptance of evolution: quasi-continuous scales of acceptance using the MATE, a binary classification scheme (acceptors or rejecters) commonly used in quantitative studies, a ternary classification scheme (accept, unsure and reject) commonly used in qualitative studies, and a multi-dimensional classification system based on the relationship between evolution and creation. Each of these schemes has its own drawbacks and advantages. In order to measure levels of student acceptance of evolution more effectively, this article therefore suggests a classification and wording based on a single 5-scale item suggested by Smith (2010) in which the advantages of the four classification schemes are integrated. However, it is acknowledged here that there is no single perfect instrument. Nonetheless, this newly proposed instrument is worth considering. To make it more useful for data analysis, an additional question may be added in response to this 5-scale question such as reasons for being reserved from strong acceptance or which parts of the theory of evolution that respondents reject. This kind of question will provide qualitative data to strengthen findings from the proposed instrument alone. It is therefore suggested for researchers interested in investigating student acceptance of evolution to try this out empirically in order to explore its usefulness.

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References

Alexander, D. (2009). *Creation or evolution: Do we have to choose*?, Oxford, Monarch Books.

Brem, S. K., Ranney, M. & Schindel, J. (2003). Perceived consequences of evolution: College students perceive negative personal and social impact in evolutionary theory. *Science Education, 87*, 181-206.

Clores, M. & Limjap, A. (2006). Diversity of students' beliefs about biological evolution. *Asia Pacific Journal of Education, 26*, 65-77.

Demastes-Southerland, S., Settlage, J., & Good, R. G. (1996). Students' conceptions of natural selection and its role in evolution: Cases of replication and comparison. *Journal of Research in Science Teaching, 32*(5), 535-550.

Dobzhansky, T. (1973). Nothing in biology makes sense except in the light of evolution. *The American Biology Teacher, 35*(3), 125–129.

Donnelly, L., Kazempour, M. & Amirshokoohi, A. (2009). High school students' perceptions of evolution instruction: Acceptance and evolution learning experiences. *Research in Science Education, 39*, 643-660.

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

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

Ingram, E. L. & Nelson, C. E. (2006). Relationship between achievement and students' acceptance of evolution or creation in an upper-level evolution course. *Journal of Research in Science Teaching, 43*, 7-24.

Kulas, J. T., Stachowski, A. A. & Haynes, B. A. (2008). Middle response functioning in Likert-responses to personality items. *Journal of Business and Psychology, 22*, 251-259.

Lombrozo, T., Thanukos, A. & Weisberg, M. (2008). The Importance of Understanding the Nature of Science for Accepting Evolution. *Evolution: Education and Outreach, 1*, 290-298.

Mayr E. (2008). *What evolution is*. New York: Basic Books

Mckeachie, W., Lin, Y. & Strayer, J. (2002). Creation vs. evolution beliefs: effects on learning biology. *The American Biology Teacher, 64*, 189-192.

Meadows, L., Doster, E. & Jackson, D. (2000). Managing the conflict between evolution & religion. *The American Biology Teacher, 62*, 102-107.

Miller, J. D., Scott, E. C. & Okamoto, S. (2006). Public acceptance of evolution. *Science, 313*, 765-766.

Özay Köse, E. (2010). Biology students' and teachers' religious beliefs and attitudes towards theory of evolution. *Hacettepe Universitesi Journal of Education, 38*, 189-200.

Reich, K. H. (2010). *Developing the Horizons of the Mind: Relational and Contextual Reasoning and the Resolution of Cognitive Conflict*, Cambridge, Cambridge University Press.

Rutledge, M. & Warden, M. (2000). Evolutionary theory, the nature of science & high school biology teachers: Critical relationships. *The American Biology Teacher, 62*, 23-31.

Smith, M. (2010). Current Status of Research in Teaching and Learning Evolution: I. Philosophical/Epistemological Issues. *Science & Education, 19*, 523-538.

Smith, M. (2010b). Current Status of Research in Teaching and Learning Evolution: II. Pedagogical Issues. *Science & Education, 19*, 539-571.

Southcott, R. & Downie, J. R. (2012). Evolution and Religion: Attitudes of Scottish Bioscience Students to the Teaching of Evolutionary Biology. *Evolution: Education and Outreach, 5*, 301-311.

Yasri, P. & Mancy, R. (2014). Understanding student approaches to learning evolution in the context of their perceptions of the relationship between science and religion. *International Journal of Science Education, 36*(1), 24-45

Yasri, P., Arthur, S., Smith, M. U. & Mancy, R. (2013). Relating science and religion: An ontology of taxonomies and development of a research tool for identifying individual views. *Science & Education, 22*, 2679–2707.

Appendix A: The Measure of Acceptance of the Theory of Evolution (MATE) by Rutledge and Warden (2000)

For the following items, please indicate your agreement/disagreement with the given statements using the following scale:

- A = Strongly Agree
- B = Agree
- C = Undecided
- D = Disagree
- E = Strongly Disagree

1. Organisms existing today are the result of evolutionary processes that have occurred over millions of years.
2. The theory of evolution is incapable of being scientifically tested.
3. Modern humans are the product of evolutionary processes that have occurred over millions of years.
4. The theory of evolution is based on speculation and not valid scientific observation and testing.
5. Most scientists accept evolutionary theory to be a scientifically valid theory.
6. The available data are ambiguous (unclear) as to whether evolution actually occurs.
7. The age of the earth is less than 20,000 years.
8. There is a significant body of data that supports evolutionary theory.
9. Organisms exist today in essentially the same form in which they always have.
10. Evolution in not a scientifically valid theory.
11. The age of the earth is at least 4 billion years.
12. Current evolutionary theory is the result of sound scientific research and methodology.
13. Evolutionary theory generates testable predictions with respect to the characteristics of life.
14. The theory of evolution cannot be correct since it disagrees with the Biblical account of creation.
15. Humans exist today in essentially the same form in which they always have.
16. Evolutionary theory is supported by factual historical and laboratory data.
17. Much of the scientific community doubts if evolution occurs.

18. The theory of evolution brings meaning to the diverse characteristics and behaviors observed in living forms.
19. With few exceptions, organisms on earth came into existence at about the same time.
20. Evolution is a scientifically valid theory.

Appendix B: A multi-dimensional classification by McKeachie et al. (2002)

Which of these statements closely fits you?

a) I do not accept evolution as a proven fact. I believe in the literal interpretation of the Bible.
b) I do not know enough about evolution or the Bible to accept either as correct.
c) I accept evolution but I believe in the teachings of the Bible.
d) I accept evolution as a proven fact.