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Students' Reasons for Accepting or Rejecting Evolution



A research project in partial fulfilment of a Master of Arts degree by
coursework and research report

Declaration

I, Jason Viviers, declare that this research project is my own, unaided work. It has not been submitted before for any other degree or examination at this or any other university.

X

Jason Viviers

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Aims

Reasons for acceptance or rejection of evolution (RARE 1.0) is a measure which assesses respondents most salient reasons for accepting or rejecting evolution. This research paper aims to further develop RARE 1.0 into RARE 2.0 in two phases. Phase 1 involves item generation, item review and a pilot study. Phase 2 involves conducting psychometric evaluations to assess reliability and validity of RARE 2.0.

Additionally, this research seeks to explore relationships between different variables, namely; epistemic cognitions involving science (ECS), scores achieved on RARE 2.0, religiosity/religious fundamentalism and acceptance of evolution. A further aim is to view how much variance is explained in predicting acceptance of evolution by the above variables.

This research aims to make comparisons between groups, specifically comparing ECS of those who score both high on acceptance of evolution and religiosity to those who score low on acceptance of evolution. Thereafter, scores of RARE will be compared by participants' year and field of study. Finally, this research aims to explore how scores achieved on RARE 2.0 are related to one's ECS and religiosity.

Rationale

Understanding evolution is necessary in the field of biology, medicine and psychology. Evolution has been said by Dobzhansky (1973) to be of such biological importance that “nothing in biology makes sense except in the light of evolution”. Evolution can be used to answer why the human brain has developed with its enormous complexity allowing for insights into human cognition and behaviour. Brem, Ranney and Schindel (2003) argue that evolution can be used to aid in explaining human behaviours such as violence. Dawkins (1979) uses evolutionary theory to explain altruistic and selfish behaviours. Thus, pre-rejecting evolution would make it unlikely for students to study human behaviour or neuroanatomy within an evolutionary paradigm. Heddy and Nadelson (2013) argue that evolution allows for the understanding of viruses and bacteria adapting to become anti-biotic resistant. Accepting evolution, therefore, is essential for students to competently engage within such fields of study. Lelliot (2016) has reported that South Africans have a relatively low acceptance rate of

evolution (59%). This low acceptance rate, if observed in students, will have educational implications within these fields of study. Therefore, understanding the reasons why one accepts or rejects evolution may be useful to an educator in appropriately teaching evolution or evolutionary theory in such a way that accounts for and responds to these reasons.

A member of the South African parliament, Dr. Mathole Motshekga, has dismissed evolution as pseudo-science and claims evolution is used to perpetuate perceptions of Africans as sub-human (Ackroyd, 2015). This rejection of evolution by an authority figure has the potential for anti-scientific claims to be spread to South Africans, thus further perpetuating rejection of evolution. Paz-y-Miño C. and Espinosa (2009) argue that community leaders influence what is taught in academic institutions, often weakening the science curriculum. Such a criticism of evolution can be explained by one's beliefs about science and, particularly, the science of evolution. Therefore, understanding one's epistemic cognitions involving science may potentially provide insights into such a perpetuation of rejection of evolution.

Additionally, research has shown religiosity to negatively correlate with acceptance of evolution (Heddy & Naddelson, 2012; Hill, 2014; Mazur, 2005; Paz-y-Miño-C, & Espinosa, 2015). However, one may adopt a position of a theistic evolutionist (one who is religious and accepts evolution). This would mean that religiosity alone cannot fully predict acceptance of evolution. Therefore, the relationships between religiosity and epistemic cognitions will provide useful insights into the complexities of accepting evolution.

Literature Review

Introduction

Evolution is a scientific theory explaining the origins of species through the gradual process of natural selection as the principal mechanism (Anderson, Fisher, & Norman, 2002). Evolution is non-controversial in the scientific community but it has not been well received by the public (Rutledge & Warden, 2000). A review of public acceptance of evolution conducted in 2006 has shown that countries such as Denmark, Sweden, France and Japan show at least 78% of adult acceptance of evolution (Miller, Scott & Okamoto, 2006). In contrast to these countries, South Africans have a 59% acceptance of evolution (Lelliot, 2016). It was found by Lelliot (2016) that South African citizens have a lower evolutionary acceptance rate as compared to their international counterparts also participating in the study.

Previous research has focused on understanding of evolution as a predictive variable in acceptance of evolution (Rutledge and Warden, 2000; Sinatra et al., 2003; Cavallo & McCall, 2008; Coleman, Dempster & Spears, 2015). The rationale being either that acceptance of a construct must accompany understanding thereof (Sinatra et al., 2003) or that rejection of evolution may be related to misunderstanding of evolution (Cavallo & McCall, 2008; Coleman et al., 2015). Results from such studies have produced mixed results. Some studies report a significant correlation between understanding and acceptance of evolution (Peker, Comert & Kence, 2009; Stanisavljević, Papadopoulou & Djuric, 2012), whereas other studies report a non-significant relationship (Coleman et al., 2015). Other studies report a lack of increase in acceptance of evolution after increasing understanding of evolution (Cavallo & McCall, 2008; Chinsamy & Plaganyi, 2008). This may be because understanding evolution simply does not cause one to believe it. Theoretically, it does not follow that understanding of any construct may lead to its acceptance (Davson-Galle, 2004). Lack of acceptance of a construct may hamper ones understanding of said construct, whereas, inversely, one's acceptance of a construct may facilitate understanding. However, one's understanding of evolution may, not fully explain one's acceptance of evolution. Therefore, due to the above mixed results within the literature, understanding of evolution will not be used as a variable within this study. This paper intends to explore one's reasons for accepting or rejecting evolution which may provide more useful insights into acceptance of evolution.

The paragraphs below explain how reasons can be measured using quantitative means while applying relevant theory. Additionally, it is argued that exploring reasons in conjunction

with epistemic cognitions involving science (ECS), religiosity, religious fundamentalism and the relationships thereof, can provide more explanatory power into why one either accepts or rejects evolution.

Acceptance of Evolution

Smith et al. (2016) argue that authors tend to treat the constructs ‘belief’ and ‘acceptance’ as opposing, partitionable constructs. Indeed, Paz-y-Miño-C et al. (2015) argue that belief in fact disrupts, distorts, delays, or stops acceptance of evolution (Paz-y-Miño-C et al., 2015). Here the authors have described belief as a potential barrier to accepting evolution. When speaking of evolution Sinatra et al. (2003) and Williams (2015) argue that one either accepts, rejects or is undecided about it. These authors attempt to draw a distinction between acceptance of a construct and belief in a construct (Sinatra et al., 2003; Williams, 2015). In their view, acceptance is the acknowledgement of fact along with understanding of the construct (Sinatra, 2003). Belief on the other hand, is argued to be the product of faith, or acknowledging a construct without evidence or in the face of contrary evidence, much like faith (Sinatra, 2003; Williams; 2015). This attempt by the authors to separate belief and acceptance effectively excludes one from being able to believe in evolution making evolution something which can only be accepted. However, this definitional partitioning of belief and acceptance may not be useful as a belief in a construct can be synonymous with its acceptance. This argument leads to difficulties in achieving a working definition of acceptance. However, a counter argument to Sinatra’s (2003) claim that acceptance of a construct is accompanied by understanding of said construct. The problem with this claim is that evidence of it may be lacking. Research shows that acceptance of evolution, while positively correlated, is not always significantly related to understanding of evolution (Coleman et al., 2015). One then, logically, can accept evolution without good understanding of it. One can have various degrees of acceptance of evolution as well as one’s understanding of it. The means with which researchers measure acceptance of evolution is by using a scale of acceptance. If one follows the definition of acceptance as argued by Sinatra (2003) and Williams (2015), there should be no need to measure acceptance of evolution. One would only need a one item questionnaire: “Do you accept evolution?” For this reason, this paper will adopt the position of Nehm and Schonfeld, (2007) who argue belief and acceptance can be used interchangeably. Acceptance of evolution will therefore be defined, for the purposes of this paper, as “the degree to which one holds evolution to be valid and true”.

The measure of acceptance of the theory of evolution (MATE) has been a popular choice in measuring samples acceptance of evolution (Coleman et al., 2015; Nadelson & Sinatra, 2009). However, Smith et al. (2016) have raised concerns over the construct validity of MATE. Smith et al. (2016) have argued that MATE conflates evolution acceptance with evolution knowledge. For this reason, Smith et al. (2016) argue that various studies found strong, moderate and weak correlations between evolution understanding and acceptance. The inconsistencies in the differing contexts may be explained by MATE being inconsistent in measuring actual acceptance.

Reasons for accepting or rejecting evolution

Persons may have multiple, interconnected and complex reasons for rejecting evolution. Common examples include; Evolution is just a theory (Sinatra, 2003) or there is a missing link to prove evolution (Lelliot, 2016). Research has shown examples of reasons that one may cite in rejection of evolution (Cavello & McCall, 2008; Lelliot, 2016; Nadelson & Southerland, 2012). Such examples include reasoning based on misunderstandings (Nadelson & Southerland, 2012), misconceptions such as humans having evolved from apes (Heddy & Sinatra, 2013), religious conflicts (Cavello & McCall, 2008; Lelliot, 2016; Nadelson & Southerland, 2012), agency and purposiveness (Heddy & Sinatra, 2003) and distinctiveness of species (Lelliot, 2016). Additionally, belief in evolution may also hold negative connotations and create a negative reaction (Brem et al., 2003; Heddy & Sinatra, 2013). However, these reasons are often based or sampled from qualitative data, whereas this research intends to gather participants reasoning in a standardised way through further developing an existing measure, RARE 1.0. Reasons for accepting or rejecting evolution (RARE 1.0) was developed by Viviers (2016), to measure reasons for accepting or rejecting evolution. To further develop RARE, this research will use Chinn, Reinhart and Buckland's (2014) AIR model of epistemic cognition to aid in item generation. Epistemic cognition as a construct will be defined in the paragraphs below as a separate variable from RARE 2.0. Further, the development of RARE 2.0 is discussed in detail in the below methods section. The following paragraphs discuss the AIR model and its relevance to RARE.

The AIR model was created to explain the ways in which persons evaluate both accurate and inaccurate information. AIR stands for Aims and values, epistemic Ideals and Reliable processes for achieving epistemic ends (schemas). These components of the AIR model will be used as potential subscales when developing RARE 2.0. Items will be generated to represent each component of the AIR model.

The Aims and value component of the AIR model explains that the way in which one processes information is influenced by their aims directed toward said information (Chinn et al., 2014). One's aims can be argued to be either epistemic, such as achieving knowledge, or non-epistemic, such as preserving one's world view (Chinn et al., 2014). When applied to evolution, one can either have the aim of critically processing information about evolution to determine whether one accepts or rejects the theory or, alternatively, simply to acquire knowledge about evolution. In contrast, one may have non-epistemic aims when engaging with evolutionary theory. Chinn et al. (2014) give examples of non-epistemic aims such as experiencing pleasure, adhering to group cohesiveness, avoiding effort or protecting one's positive self-image. If one engages with evolutionary theory with an aim to maintain in-group cohesiveness, one may reject evolution to adhere to a possible creationist in-group. Additionally, one may 'freeze' on an idea when engaging with a controversial topic such as evolution (Chinn et al., 2014). For example, when evaluating evolution, one may have the non-epistemic aim of avoiding uncertainty and not having a concrete position on evolution. In their research, Kienhues, Stadler and Bromme (2011), found that although their participants found knowledge in health sciences to be relative, they were still likely to come to a conclusion on the accuracy of information. It is possible that one will therefore 'freeze' on an idea "disproving" evolution such as citing missing links even if they find the theory to be complex and/or inconclusive. Such freezing on information or maintaining in-group harmony may offer a potential explanation as to why studies have found negative correlations between religiosity and acceptance of evolution (Paz-y-Miño-C & Espinosa, 2015). This may also be applicable when one is more conservative in acquiring new beliefs based on the epistemic aim of avoiding false beliefs (Chinn et al., 2014). More applicable to evolution, Chinn et al. (2014) argue that creationists may have the aim to know the truth of the bible and make sense of information with respect to religious teachings. These persons are more likely to freeze on inaccurate information when reading information on evolution. Therefore, understanding and measuring one's aims when evaluating evolution will be useful in predicting one's acceptance of evolution. Further, assessing the relationship between one's epistemic aims and one's religiosity may provide construct validity for this subscale of RARE 2.0.

One may have the epistemic aim of acquiring a minimally justified belief (Chinn et al., 2011). A minimally justified belief occurs when one adopts an a priori belief which is backed by minimal or evidence or argument. One merely needs some argument and evidence to support their belief as their belief may hold psychological utility (i.e. positive self- image/esteem, in-

group harmony etc.). One may be reluctant to or avoid evaluating rival hypotheses so as to avoid awareness of these conflicting with one's current world view. Instead, one may only need a minimally justified belief to support possible creationist world views. Minimally justified beliefs are therefore used to confirm one's beliefs as well as reject rival hypotheses. Belief in a missing link can then be used to reject evolution. One may latch onto misconceptions to further support one's world view such as 'evolution is only theory' (Moore et al., 2002). The aim here, may therefore be preservation of world view rather than careful truth seeking.

Epistemic ideals, put briefly, are the standards to which one may hold information to having good explanatory power (Chinn et al., 2014). Importantly, Chinn et al. (2014) note that ideals can operate tacitly and may vary across domains. In terms of evolution, Chinn et al. (2014) argue that the very idea of evolution conflicts with creationists epistemic ideals within the domain of explaining speciation. Creationists would therefore use their respective religion's account of creation as their epistemic ideal in this regard. Creationists would hold information in reputable regard only if it meets their epistemic ideal of correlating with biblical accounts. In contrast, scientists use the epistemic ideal of evidence and explanatory power when evaluating evolution. Therefore, it follows that evaluating one's epistemic ideals as per the origin of species will be predictive of one's acceptance of evolution. For example, one may hold religious beliefs but have reconciled their religious beliefs with evolution and thus accept evolution. However, this may be due to low religiosity or perhaps one may have come to accept evolution through studying it within university, arguably through a non-epistemic aim such as avoiding cognitive dissonance. Chinn et al. (2014) argue that non-epistemic aims, in certain instances, do aid in knowledge acquisition. For this reason, it would be important to assess one's epistemic ideals in conjunction with their epistemic aims.

Finally, Chinn et al. (2014) suggest investigating one's schemas for which they believe reliable knowledge to be produced which is labelled 'reliable processes'. Examples of such schemas include observation, experimentation, methodologies and argumentation (Chinn et al., 2014). It is suggested by the authors that these schemas can, again, vary across different domains of inquiry. Further, it is held by the authors that various schemas can be used to generate both accurate and inaccurate beliefs. It is argued that if one were to hold unreliable schemas as adequate for producing reliable knowledge, then one would be more likely to hold inaccurate information. An example given by Chinn et al. (2014) applicable to beliefs about evolution, is the process of personal evidence gathering. When one seeks information on evolution, one would have to observe the evidence for evolution from multiple sources.

However, a potential epistemic vice here is that persons who have non-epistemic aims or unhelpful epistemic ideals, may only expose themselves to evidence supporting their worldview (evolution is false). This creates a position for one to develop inaccurate beliefs. Therefore, it can be argued then to properly assess the reasons why one rejects evolution, their epistemic aims, ideals, and schemas must be evaluated.

Epistemic Cognition

Steup and Zalta (2005) define epistemology as the study of knowledge and belief. Epistemic Cognition (EC) is a field in psychology which focuses on topics such as knowledge and how one views knowledge. EC considers the ways in which individuals view knowledge either through evidence, understanding, truth, epistemic aims or sources of justification (Chinn et al., 2011). Growth of technology allows for large amounts of information to be easily accessible (Greene, 2016). Once one has already created a world view due to early experiences and influence from social authorities (Wilkins, 2011), one will then need minimally justifiable evidence to support said world view. Thus, for one to navigate through large quantities of information, one will need relatively advanced critical thinking skills (Green, 2016). One's views about knowledge and the processes of knowledge acquisition will therefore be influential in how one engages with information. Bishop & Trout (2004) argue that epistemic cognition does not relate only to the ways in which one may view knowledge, but also investigates one's reasoning abilities. The way one views knowledge may directly influence the decisions one makes based on how one evaluates the available evidence. It is argued boldly by Bishop & Trout (2004) that if one has improper reasoning abilities, that one's ability to make decisions in every aspect of life is severely hampered. This is supported by Chinn et al.'s (2014) theoretical model of epistemic cognition which proposes that one uses schemas in processing information. One using crude or non-critical processes (schemas) of evaluating evidence may be more likely to draw incorrect inferences from available information. Additionally, one's beliefs about knowledge has been shown to predict academic performance (Kuhn et al., 2001).

EC as a construct has been defined in numerous ways (Mason, 2016; Muis, Bendixen, & Haerle, 2006; Chinn et al., 2011; Greene, 2016). Researchers may be interested in measuring participants' beliefs about knowledge in general or their beliefs within a specific domain (psychology, science, politics etc.). Research has shown that participants differ in their perceptions of knowledge across various domains (Muis et al., 2006; Owen, 2011). Traditionally, this partitioning of epistemologies has been labelled as domain general or domain specific beliefs (Mason, 2016). Owen (2011) has raised concerns that domain specific

beliefs may affect one's domain general beliefs. Such an effect would then have implications for the validity of domain general measures of EC (Owen, 2011). This seems to be intuitively true as students who study more positivistic disciplines, such as those found within scientific fields of study, may use a positivistic paradigm to evaluate knowledge. In contrast, those studying disciplines found within a general bachelor of arts degree, may view knowledge as more constructed rather than positivistic (Muis et al., 2016). However, this does not exclude students from each respective discipline from viewing knowledge in more nuanced ways than strictly positive or constructed. Owen (2011) provides evidence that domain specific beliefs do in fact influence domain general beliefs.

Muis et al. (2006) explain that across different domains (fields of inquiry) there are variant ways of knowing. This would mean that respective domains may have different criteria for justified true belief. Domains within the humanities, for example, may utilize qualitative means of knowing. This is not to say that qualitative data is not useful, but certainly different to data collection in more positivistic domains. Put differently, the humanities may have more symbolic ways of knowing whereas 'hard science' domains emphasise a more rational or empirical way of knowing (Muis et al., 2006). In their meta-analysis, Muis et al. (2006) identified eight studies measuring students' epistemological beliefs using a between-subjects design. These studies partitioned participants either by field of study or by year of study (undergraduate or postgraduate). All examined studies found results supported some degree of domain specificity. Differences in various dimensions of knowledge were found between domains and by year of study. The general trend of the results indicated that examined students in the harder sciences were more likely to hold absolutists views of knowledge as compared to students within the soft sciences. Differences were also observed by year of study where postgraduate students held more evolved or sophisticated views of knowledge as compared to undergraduates (Muis et al., 2006).

Additionally, participants' beliefs about knowledge differ by year and field of study (Owen, 2011). Theoretically, students' perceptions of knowledge are expected to develop from naïve, simplistic beliefs – where there is a clear right and wrong answer (Dualism) - to more sophisticated beliefs about knowledge (Stahl & Bromme, 2007; Perry, 1999). Sophisticated

beliefs about knowledge see knowledge as more contextual and relative (Stahl & Bromme, 2007).

Sinatra et al. (2003) found that students who perceive knowledge in science as tentative (non-absolute) were more likely to accept evolution when compared to those who view knowledge as absolute (dichotomous/right or wrong). This may be due to one's epistemic ideals, as mentioned above. Those with more absolutist ideals may be less likely to accept evolution, especially when one has a religious worldview. Therefore, this research will define epistemic cognitions in science (ECS) as the degree to which one believes knowledge in science to be complex or certain. This definition allows for the partitioning of groups by epistemic cognitions. This then allows for comparisons to be made to one's acceptance of evolution as well as their epistemic ideals, aims and values and reliable processes as mentioned above. Specifically, reliable processes are said by Chinn et al. (2014) to vary across domains. Kienhues, Stadtler and Bromme (2011) found that epistemic beliefs become more complex when uncertainty or conflict is found within a certain field. Additionally, Kienhues, et al. (2011) found that when exposed to consistent information, participants are more likely to hold positivistic epistemic views. In contrast, when exposed to inconsistent/conflicting information, one's epistemic beliefs become more open and tentative. The implications towards accepting evolution may be explain by the AIR model. One may be approaching evolution, using their epistemic ideals within the domain of religiosity. Although evolution and religious accounts do conflict, one may view knowledge within religion as non-conflicting and therefore have a more positivistic view of knowledge within religion. Alternatively, one may view information regarding the theory of evolution to be complex and/or conflicting. However, to avoid uncertainty (Aims and Values) one may decide to reject evolution based on discrediting information. Therefore, ECS compared across fields of study, and with reference to one's perceived reliable processes and epistemic ideals relating to evolution, may provide insights into acceptance of evolution.

As is shown above, the literature seems to support some degree of domain specificity especially when knowledge levels increase. Since one's beliefs about knowledge vary between domains, it would be preferable to measure participant's beliefs about evolution. To achieve this, the present study will use Chinn, et al.'s (2014) AIR model of epistemic cognition to create an instrument measuring participant's belief about evolution with special focus on reasons for

rejection or acceptance. The AIR model, in conjunction with qualitative data collected in previous research, was used to create the measure ‘Reasons for Acceptance or Rejection of Evolution (RARE) 2.0. RARE 1.0 was initially developed using extant literature which cited potential reasons for acceptance or rejection of evolution. The development of RARE 2.0 will be discussed in more detail in the methods section below.

Complementary to the AIR model above, Wilkins (2011), has argued that sources of knowledge are presented by *social authorities* (parents, teachers, religious institutions). It is further argued that these sources of information become embedded with the individual (Wilkins, 2011). This may then create epistemic ideals within an individual. These ideals may, however, only be applicable to one within a certain domain. One with religious epistemic ideals may find science as questionable only within questions as to the origin of species. For this reason, it may be useful to assess the relationship between ECS and acceptance of evolution.

Information may not only be viewed coldly through empirical, rational or logical means. One may engage with controversial issues not only through their merits and rational argument, but also with emotions. Sinatra (2003) has argued that viewing students’ perceptions of information through only through reasoned lenses would paint a picture of students as overly rational. Instead, negative affective reactions, as argued above, need to be taken into account when students engage with new information. Evolution in particular has the potential to evoke negative reactions from students if evolution challenges their current ideological worldview. Negative affective reactions from engaging with evolutionary theory include: acceptance of evolution will lead to social and moral decline leaving ideas such as sin, moot (Brem et al., 2003; Blackwell et al., 2003; Sinatra et al., 2003). Additionally, evolution may undermine the notion that humans are special, unique creations with a divine right to govern over other ‘lower’ animals (Brem et al., 2003). More importantly, evolutionary theory has long been seen as an opposition to creationism and religion in general (Hill, 2004; Sinatra et al., 2003). This potential opposition to religious faith and negative affective reactions lead this research to examine religiosity and a variable in predicting acceptance of evolution.

Religiosity

Heddy and Nadelson (2012; 2013) argue that religiosity, regardless of denomination, can be influential in rejection of evolution which is supported by various empirical studies (Hill, 2014; Mazur, 2005; Paz-y-Miño-C, & Espinosa, 2015; Nadelson & Sinatra, 2009). Paz-y-Miño C. and Espinosa (2009) found higher evolutionary acceptance in a secular university

when compared to a religious (Christian) university. Yousuf, Daud and Nadeem, (2011) conducted research on Pakistani medical students' acceptance of evolution. Pakistan is argued to be a highly religious (Majority Islamic) country with a large support for creationism (Yousuf, et al., 2011). The majority of the sample tested low in evolutionary acceptance as well as believing that evolutionary theory cannot be true as it clashes with the Quran. However, it is suggested by the authors to include testing of religiosity in further research.

To explore the variables associated with acceptance of evolution, Heddy and Nadelson (2012) conducted a meta-analysis of data collected in 35 countries. From this data, it is reported that religiosity is negatively correlated with acceptance of evolution ($r = -0.81, p < .0005$). This extremely high and negative correlation provides evidence of a strong relationship between religiosity and acceptance of evolution. Heddy and Nadelson (2012) speculate that the reported relationship may be due to the influence of religious authority. In terms of EC, this can be described as Perry's (1999) intellectual position of dualism (absolutist) whereby religion positions knowledge as either right or wrong.

Additionally, Heddy and Nadelson (2012) had also found a significant, positive relationship between acceptance of evolution and school life expectancy (the number of predicted years of education). Heddy and Nadelson's 2013 meta-analysis found that acceptance of evolution was strongly, positively correlated with a degree in the sciences. The relationship here again suggests a link between education and acceptance of evolution. This provides evidence for education playing a role in predicting acceptance of evolution. However, mere education alone cannot account for one's acceptance of evolution. As has been mentioned above, there is a vast amount of information available to students and laypersons alike. Therefore, education alone may be less important than one's ability to engage critically with information. Education however, does make it more likely that one has developed a more nuanced way of interpreting information due to development in one's epistemological beliefs. This is supported by Paz-y-Miño-C, et al. (2015) whom provide evidence for the linear relationship between acceptance of evolution and formal education with specific emphasis of biology. More importantly, this relationship was higher within public, secular universities when compared to religious universities. This suggests again, that acceptance of evolution is related to religiosity and education/epistemological beliefs (Paz-y-Miño-C, et al., 2015).

Therefore, students' religiosity should be highly, negatively correlated with acceptance of evolution. However, merely measuring religiosity alone cannot fully predict acceptance of

evolution as one can be a theistic evolutionist. It may be helpful, to therefore measure religious fundamentalism in conjunction with religiosity. Chinsamy and Plaganyi (2008) found students rejecting evolution on religious grounds even after a university course in evolution. This shows how social authorities may influence epistemic ideals which then influences acceptance or rejection of evolution. Additionally, exploring the relationships between religiosity, acceptance of evolution and ECS may yield interesting results. Paz-y-Miño-C, & Espinosa, (2015) report that religiosity is also negatively correlated with scientific understanding in general. Contrasting the way in which one views science with their acceptance of evolution may reveal a compartmentalisation of evolution or a partitioning of science in general and evolutionary science. Yasri and Mancy (2014) conducted qualitative research exploring religious students' perceptions to learning about evolution. It was found that their participants may compartmentalise scientific knowledge and religious belief as different ways of knowing. Additionally, it was found that participants may be theistic evolutionists, arguing that religion and science are complementary. The remainder of participants found religion and science to be incompatible with specific reference to evolution. Finally, Duncan and Caruso (2014) found that religiosity was more predictive of acceptance of evolution when compared to level of education among university students. Additionally, it was found that religious students are still likely to reject evolution even if they are aware of scientific consensus of evolution and participated in a biology course, religiosity was still the best predictor of acceptance of evolution.

Within South Africa, there exists a rich multicultural environment. This creates a situation wherein many different religious contexts can be found with a reported 4 out of 5 South Africans self-identify as having at least some degree of religiosity (Rule, 2007). Therefore, measuring religiosity within the South African context can be difficult due to different religious affiliations of potential participants. It may therefore be more appropriate to measure participant's spirituality. In conducting research in religiosity in South Africa, Van der Walt and DeKlerk (2014) partition religion and spirituality, arguing that although religion may have spiritual qualities, religion should be restrictively refined to rituals, dogma and institutional practice. However, Hill and Pargament (2008) argue that polarizing religiosity and spirituality maybe not be a useful distinction. Hill and Pargament (2008) further elaborate that Spirituality manifests itself within religious contexts and attempting to partition these constructs may lead to rehashing old measures which in fact measure the same construct. Viewing these relationships in terms of religiosity and religious fundamentalism may be useful

in predicting acceptance of evolution. Additionally, the above proposed subscales of RARE 2.0 may be more informative when related to religiosity/religious fundamentalism.

Based on the above literature review and theoretical considerations, the following research questions, in order of importance, have been formulated:

Research questions

1. Does RARE 2.0 report good construct validity?
2. How much variance is explained in predicting acceptance of evolution by ECS and religiosity/religious fundamentalism?
3. How do theistic evolutionists compare to those who reject evolution in terms of epistemic cognitions?
4. What is the relationship between participants' religiosity/religious fundamentalism and epistemic cognitions?
5. How do scores achieved on RARE relate to participants' epistemic cognitions?
6. Do RARE 2.0 scores differ by year of study and by field of study?

Methods

Research Design

A non-experimental, cross-sectional design was used within this study. Correlations were used to assess relationships between variables and *ex-post facto*, between group comparisons are made. The design was non-experimental as there was no manipulation of any independent variable.

Sample

The research sampled from students attending the University of the Witwatersrand (Wits). The sample consisted of any student volunteer within the University regardless of demographic variables, current course of study or year of study. This was to achieve a representative sample of the student population to allow for greater generalizability to external student populations (O'Leary, 2004). A relatively large number of participants was sampled to allow for normality of data and for a representative sample (O'Leary, 2004). This allowed for comparisons to previous studies with smaller, narrower samples. A large sample additionally allows for a more robust factor analysis. Using students from a variety of academic backgrounds allowed for between-group comparisons. Participants were invited to participate in the study, therefore, the sampling strategy was a non-random, volunteer sampling strategy.

A total of 838 participants agreed to continue to complete the survey from a population of approximately 30 000 students. Inclusion criteria for these 838 participants were adequate completion of a certain number of items of each measure. For each measure respectively, participants were included if they completed at least 18 out of 22 items for RARE ($n = 476$), 14/17 for CAEB ($n = 473$), 2/3 for the test of religious fundamentalism ($n = 463$), 4/5 of the Religious orientation test ($n = 464$) and 11/13 for the GAENE ($n = 443$). These criteria yielded a sample of 476 [289 (61.8%) Female; 4 Other (0.9%)] participants.

The majority of participants identified as Christian (53%) with those with no religious affiliation constituting 25% of the sample. Further results show the sample consisted of Islam (3.6%), Hinduism (2%) and Judaism (3.8) and 4.5% identifying as 'other'. The majority of the sample listed English as their home language (61.5%) followed by isiZulu (7.9%), Afrikaans (6.8%), Xhosa (4.5%), Spedi (4%), Sesotho (2.3%), Venda (2.3%), Tswana (2.1%), Ndebele (.6%), Swati (.6%) and 'other' (6.2%). A small majority of the participants were registered in the Humanities (26.4%) followed by Health Sciences (26.2%), Engineering (16.4%), Sciences

(15.8%) and Commerce (15.1%). 67% of participants were undergraduate students with 33% constituting postgraduate. The average age of the participants was 24.40 (7.195) years with a range of 17-58.

Instruments

GAENE. To measure participants' acceptance of evolution, the Generalized Acceptance of Evolution Evaluation (GAENE) developed by Smith, Snyder and Devereaux. (2016) was used. GAENE is a 13 item (5 reverse scored), Likert-type scale with four anchors including: strongly disagree, disagree, agree and strongly agree. Raw scores range from 13 to 65. The mean was calculated by averaging the responses to each item creating a range of 1-4 with 1 being the lowest possible score and 4 being the highest possible score. Higher scores achieved on GAENE indicate higher acceptance of evolution. Smith et al., (2016) report a Cronbach's alpha (α) score for GAENE of 0.941 indicating high internal consistency. Principle component analysis of GAENE reveals that items on GAENE load on one factor indicating construct validity (Smith et al., 2016).

Sample items from GAENE include:

Everyone should understand evolution.

Simple organisms such as bacteria change over time.

Cronbach's alpha (α) was used to assess the internal consistency of the GAENE within the current sample. GAENE achieved a Cronbach's alpha score of .945 indicating very high internal consistency. Analysis of the item-total statistics table revealed that Cronbach's alpha was not increased by deleting any item. To assess the validity of the GAENE, an exploratory factor analysis was conducted. KMO was found to be significant ($p = .000$) and Bartlett's test of sphericity yielded a score of .949 indicating that the data were factorizable. The results indicated that a one factor solution best fits the data based on eigenvalues greater than one, analysis of the scree plot and total variance explained (60.948 for the first component). Additionally, each item loads onto the single component with a range of .685 - .881. The above statistics provide evidence for the reliability and validity of the GAENE.

RARE 2.0. RARE 2.0 was used to measure participant's reasons for accepting or rejecting evolution. RARE 2.0 is divided into three subscales; Epistemic aims and value, epistemic ideals and reliable processes for achieving epistemic ends. RARE was scored using a forced-choice Likert type scale. Items on RARE 2.0 have anchors (strongly disagree,

disagree, agree and strongly agree). High scores on RARE 2.0 represent evolutionary affirming reasoning. RARE consisted of 22 items with 13 reversed and a range of 22-88. The mean was calculated by averaging the responses to each item creating a range of 1-4 with 1 the lowest possible score and 4 being the highest possible score. Higher scores achieved on RARE 2.0 demonstrate higher agreement with evolutionary accepting statements. Reliability and validity of RARE 2.0 are reported in the results section below.

ROT. To measure participant's religiosity, the Religious Orientation Test (ROT) developed by Idehen (2001) was used. The ROT was developed to test religiosity on a Nigerian population. The ROT consists of six items each using a Likert-style response format. RAW scores range from 6-30 with item averages being used in the analysis. The range of scores achievable on the ROT is 1-5 with 1 being the lowest possible score and 5 being the highest possible score. Higher scores achieved on the ROT represent lower religiosity and lower scores indicating higher religiosity. Scores achieved on the ROT must therefore be read inversely.

Sample items from ROT include:

How religious, do you consider yourself to be?

How important is your religious belief in your daily life?

The ROT reports a Cronbach's alpha score of 0.8 indicating high internal consistency. The Religious Orientation Test (ROT) achieved a Cronbach's alpha of $\alpha = .937$ indicating high internal consistency. However, it must be noted that the ROT only consists of 6 items. The high Alpha coefficient may therefore indicate potential redundancy of the items. Inspection of the inter-item correlation matrix showed a range of correlations from .660-.843. The correlation matrix showed good clustering of items, however, these clusters do not yield extremely high correlations suggesting a fair amount variance between the items. Further, an exploratory, principal component factor analysis was conducted on the ROT to assess its validity. Results show a Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy score of .895. Additionally, Bartlett's test of sphericity was found to be significant ($p < .000$) suggesting that the data is factorizable. The ROT seeks to measure one's religiosity and therefore should only yield one component. From the conducted factor analysis, based on analysis of the scree plot and extraction based on eigen values greater than 1, it was found that the ROT only yielded one extractable factor. As the analysis only yielded one factor, a rotated factor solution could not be conducted. The unrotated factor solution showed each item loaded highly onto the single

component with a range of .845-.905. These results suggest that the ROT demonstrates good internal consistency and appears to be a valid measure of religiosity.

Test of Religious fundamentalism (TRF). To test religious fundamentalism, three items were presented to the participants from the Religious fundamentalism scale as developed by Altemeyer and Hunsberger (2004). Five anchors are used for these items and range from strongly disagree to strongly agree with the option of neutrality. RAW scores achievable on the test of religious fundamentalism range from (3-15). The mean was calculated by averaging the responses to each item creating a range of 1-5 with the lowest possible score being 1 and the highest possible score being 5. Higher scores achieved on the test of religious TRF indicate lower religious fundamentalism as with the ROT above. Lower scores achieved on the TRF fundamentalism indicate higher religious fundamentalism.

Sample items from the TRF include:

Whenever science and sacred scripture conflict, science is probably right.

All of the world's religions have flaws and wrong teachings. There is no perfectly true, right religion.

Cronbach's alpha was conducted on the TRF to assess its internal consistency. It was found that the TRF achieved a Cronbach's alpha score of $\alpha = .843$ indicating high internal consistency. Analysis of item-total statistics revealed that Cronbach's alpha will not be increased by deleting any item from the scale. Further, Pearson's moment correlation was conducted to assess the relationship between the ROT and the TRF. As both instruments measure an aspect of religiosity, a relatively high correlation should be expected between the instruments indicating convergent validity. Additionally, as the TRF only includes three items and may potentially not fulfil parametric assumptions, Spearman's Rho was conducted. Both Pearson's r and Spearman's ρ were conducted using a two-tailed test at the 0.01 level of significance. Both tests yielded significant correlations ($p < .000$ for both tests respectively). Pearson's $r = .756$ and Spearman's $\rho = .764$. These scores demonstrate moderate to high correlations. As mentioned in the above literature review, it would be expected for religiosity and religious fundamentalism to correlate as they are a similar construct. However, one can identify as religious without necessarily ascribing to religious fundamentalism. Therefore, the correlational results found make theoretical sense. An exploratory factor analysis was conducted to further explore the validity of the TRF. KMO was found to be significant ($p = .000$) and Bartlett's test of sphericity yielded a score of .722 indicating that the data is

factorizable based on the above criteria. Factors were extracted based on eigenvalues greater than 1 and yielded a one component solution with each item loading highly onto one component (Range = .855-.893). These results provide evidence for the reliability and validity of the TRF.

CAEB. Participants epistemic cognitions about science (ECS) were measured using the Connotative Aspects of Epistemic Belief (CAEB). CAEB was developed by Stahl and Bromme (2007) and is used to measure beliefs within certain domains of knowledge. The CAEB records scores on two subscales; texture (complexity) which consists of 10 items, and variability (certainty) of knowledge which consists of 7 items. The CAEB therefore has 17 items in total. The CAEB is scored on a scale from 1-7 with higher scores indicating higher texture and variability of knowledge in science respectively. Raw scores achievable on the CAEB ranging from 17-119. The mean was calculated by averaging the responses to each item creating a range of 1-7 with 1 being the highest possible score and 7 being the lowest possible score. Participants are asked to respond to CAEB on a continuum from 1-7 with one end representing greater agreement with a particular adjective and the other representing greater agreement with its opposing adjective.

Sample items from each subscale of CAEB include:

Texture. Knowledge in science is:

*Precise/Imprecise.*¹

Absolute/relative.

Variability. Knowledge in science is:

Stable/Unstable

Dynamic/Static.

The CAEB is argued to measure the connotative aspects of one's epistemic cognition using two subscales; texture and variability. Items 1-10 are theorized to measure texture while items 11-17 are theorized to measure variability. It is noted by the authors, that CAEB shows a stable two factor solution but does require further development to confirm its validity. To assess whether the results found in Stahl and Bromme (2007) are replicable, an exploratory

¹ For this item, scoring 1 on this item shows greater agreement that knowledge in science is precise while a score of 7 shows agreement that knowledge in science is imprecise. This scoring format is present throughout the CAEB.

factor analysis was conducted for confirmatory reasons to assess whether the CAEB shows a stable to factor solution. The EFA was conducted using a varimax rotation and was set to extract two factors from the data. Results revealed that the data was factorizable (KMO = .894; Bartlett's, X^2_{136} ; $p = 000$). Analysis of eigen values greater than one revealed that four factors could be extracted and the scree plot shows the point of inflexion at four extractable components. However, extraction was set at two factors. As shown in *table 2.1* below, a two-factor solution appears plausible. Component one shows loadings with a range of loadings from .526-799 save for item 9 (Negotiated/Discovered) which does not load on either factor. Component two demonstrates 6 loading items with item 17 loading on component one.

Reliability analysis was conducted on the overall scale as well as each component using Cronbach's alpha. The overall scale achieved a Cronbach's alpha score of .644 demonstrating moderate internal consistency (Field, 2009). Cronbach's alpha for component one was .828 demonstrating good internal consistency while component two achieved a score of .457 demonstrating a low internal consistency score. It was found that component one's internal consistency was increased to .860 by removing item 9. Item 9 was removed from the scale as this item did not load on any component, and reduced the internal consistency of the scale. Further, component two, variability, does not appear to be a reliable measure and was decided to be excluded from the below analysis. Items 1-8 and 10 were used to analyse the texture of one's epistemic beliefs (Only these items were used in calculating the above mean). The range of 1-7 is unaffected by these changes.

Table 2.1

<i>Factor analysis conducted on the CAEB using a two-factor solution</i>		
Item	Component	
	Texture	Variability
Precise/Imprecise	.724	-.061
Sorted/Unsorted	.744	.041
Exact/Vague	.799	-.065
Structured/Unstructured	.721	.090
Absolute/Relative	.576	-.324
Definite/Ambiguous	.729	-.191

Confirmable/Unconfirmable	.717	-.034
Objective/Subjective	.578	.016
Negotiated/Discovered	.140	-.241
RC10	.526	-.049
Open/Closed	.378	.387
Refutable/Irrefutable	-.050	.505
RC13	-.244	.420
Dynamic/Static	.423	.622
Temporary/Everlasting	-.275	.424
Flexible/inflexible	.143	.651
RC17	-.516	.256
Cronbach's Alpha	.828	.457

Note. Significant loadings presented in boldface

Procedure

RARE 2.0 was developed in 2 phases. Phase 1 of development included item generation. Items were generated using the AIR model of epistemic cognition. To aid in item generation, this research used qualitative data responding to the question “briefly give reasons as to why you either accept or reject evolution” collected by Viviers (2016). More examples of qualitative responses and item generation are included in appendix G. These data were analysed using a thematic analysis to explore the most salient reasons given for acceptance or rejection of evolution. These reasons were then mapped onto the AIR model of epistemic cognition to represent each of the model's components as illustrated by *table 2.2* below:

Table 2.2

<i>RARE 2.0 Item Generation</i>		
<u>Scale</u>	<u>Qualitative Response</u>	<u>Potential Item</u>
Reliable processes	No one has seen it happening, it is just a theory without firm facts	Evolution has not been observed by humans therefore no one knows if it occurred.
Epistemic aims and value	...for the fact that there are missing links we shouldn't conclude that it's true and some human body parts are far too complex to have evolved, like neurons, eyes and more...	There is not enough evidence to support evolution because there are too many missing links.
Epistemic Ideals	...It is a sound theory with no major logic flaws...however this is the theory that certainly makes the	Evolution is a sound theory with no major empirical or logical flaws.

most sense hence has never been disproved to date.

This table gives examples of qualitative responses collected by Viviers (2016) citing reasons for accepting or rejecting evolution.

Thereafter, generated items were sent to expert reviewers (including Prof. Clark Chinn, co-author of the AIR model) to assess the face and content validity of the items. The items of RARE 2.0 were reviewed and assessed in terms of their usefulness and essentialness. Recommendations on the wording and item-to-scale assignment were given and noted.

The version of RARE 2.0 presented to participants for piloting is presented as *table 3.2* in the below results section. Piloting was conducted on 6 post-graduate students attending the University of the Witwatersrand. The pilot consisted of completing RARE 2.0 and answering two questions; “Please point out any ambiguous items or any items which you feel might be problematic to someone taking the survey” and “If the scale did not capture your personal reasons for accepting or rejecting evolution, please add any suggestions for items you feel should have been added to the scale”. Only Descriptive statistics and reliability analysis could be conducted during the pilot as the sample size was small. Results of the pilot reveal a mean of 2.76. Reliability analysis showed a Cronbach’s alpha of .988 revealing extremely high reliability.

Phase 2 of developing RARE 2.0 included inviting participants to complete RARE 2.0 along with the above measures and conducting psychometric analyses on RARE 2.0. Potential participants were contacted via email and invited to participate in the research. Participants were told that the research is based on exploring reasons for acceptance or rejection of evolution. Once participants agreed to participate, they were directed to follow a link to an online survey platform (SurveyMonkey.com) where the data was collected. After following the link, participants acknowledged that they are participating voluntarily by choosing to follow the provided link and were informed that they could withdraw at any time up to the point of completion. Participants were each randomly assigned a unique code upon accessing the survey to identify them. There is no way of linking the code to the identity of the participant.

Participants were asked to complete a demographic questionnaire reporting on home language, age, gender, religious affiliation, course and year of study. Participants were presented with the instruments in the order; CAEB, RARE 2.0, ROT, the TRF and the GAENE. The items in RARE 2.0 were randomly presented to participants to control for any ordering

affects. Upon completion of the questionnaires, Participants were thanked for their participation and were again assured they would remain anonymous.

Ethical considerations

Ethical Clearance was received by the University of the Witwaterstrand Human Research Ethics Committee (non-medical) for a project entitled “evolution is for the birds: Students’ reasons for accepting or rejecting evolution”. This project operated under the clearance achieved for the above-mentioned project as the current project is exploring an unchanged area of research. Proposed changes to the study were submitted for approval by the committee.

In the phase 1 of developing RARE 2.0, participants were approached by the researcher and asked to complete RARE 2.0 and provide feedback on face and content validity. Those who piloted RARE 2.0 were told that RARE 2.0 attempts to measure reasons for accepting or rejecting evolution. Participation in piloting was completely voluntary and participants were told that they may withdraw at any point until completion.

In phase 2, Potential participants were informed that they are participating in a study on beliefs about evolution. Participants were told participation would take approximately 25 minutes. Participants were given the researcher’s contact number and email address to seek more information about the research if required. To additionally meet the requirement of informed consent, participants were alerted to the possibility of positive evolutionary statements encountered in the study potentially conflicting with their religious beliefs. Participants were therefore told that they could withdraw from participation at any time up to the point of completion (O’Leary, 2004). Further, the potential participants were told the potential benefits of their participation to knowledge acquisition (Homon, 1991). This fulfils the requirement of informed consent as participants were contacted via email and had the opportunity to refuse to participate (Homon, 1991).

Participants were directed to complete the survey via a provided link. Participants were not asked for their name or any identifying information. Participants were asked demographic questions which are necessary for data analyses but still assured anonymity. Participants were not in contact with the researcher unless the participant contacted the researcher for more information. If a participant had contacted the researcher, said participants would be assured that their name, number or any identifying characteristics would be kept confidential. Participants were informed that the data collected was kept secure on a password protected

laptop and raw data would only be viewed by the researchers (O’Leary, 2004). Further, the data will be kept for the duration of the ongoing research within this field.

Finally, participants were provided with contact details for the Wits Career counselling and development unit (CCDU) and Wits Emthonjeni centre in case of any distress caused by participating in the research so that they may be able to seek counselling.

Data Analysis

In phase 2, an exploratory and confirmatory factor analysis were conducted. Additionally, internal consistency was evaluated by using Cronbach’s alpha scores on each subscale of RARE 2.0 and the overall measure in both phase 1 and phase 2.

The research conducted Pearson’s correlations to assess relationships between the above variables. Specifically, the relationship between participants’ religiosity/religious fundamentalism and ECS was assessed. Relationships between religiosity and acceptance of evolution were also explored using Pearson’s correlations. Pearson’s correlations are appropriate as they allow for the summarising linear relationships between variables. (Knoke, Bohrnstedt & Potter Mee, 2002).

Analyses of variance (ANOVA) was used to test for differences in demographic variables (Linneman, 2011), specifically year and field of study. Additional ANOVA’s were conducted as participants were categorized by degree of religiosity/religious fundamentalism and ECS to test for differences between groups with acceptance of evolution being the dependent variable.

Further, RARE 2.0 is expected to correlate positively with GAENE as both instruments measured acceptance of evolution to some degree. Correlations between RARE and the above variables allowed for assessment of convergent and discriminant validity.

Results

Descriptives

Descriptive statistics were analysed for each instrument respectively to assess averages and standard deviations. Item averages are reported. The mean is reported by the participants' average score achieved within the range of possible scores on each item (see Methods section above). Acceptance of evolution (GAENE) appears to be relatively high within the sample with the data appearing to be slightly negatively skewed. A log transformation was applied to the GAENE data, which did not correct the negatively skewed distribution. However, the skewness coefficient of each variable falls between -1 and 1 suggesting a normal distribution of the data. Higher scores achieved on the CAEB represent more open/subjective views of knowledge in science with lower scores showing more closed/ objective views. By analysing the CAEB's mean, it can be seen that the participants held a more objective view of knowledge within science as the mean is more positively skewed. This suggests the majority of the participants believe the nature of knowledge within science to be static rather than dynamic.

The means of both tests pertaining to religiosity suggests low religiosity and/or religious fundamentalism within the sample. The standard deviation for the Test of Religious Fundamentalism is 1.24 and read in conjunction with the mean (3.26) show low religiosity. As stated in the methods section above, high scores on the ROT and test of religious fundamentalism represent lower religiosity. *Table 3.1* below provides a summary of the means, standard deviations, range and skewness coefficients found for each instrument.

Table 3.1

<i>Summary descriptive statistics for RARE 2.0, GAENE, CAEB, TRF and ROT</i>								
	N	Range	Mean	Std. Deviation	Skewness		Kurtosis	
		Lowest and highest possible scores	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
RARE 2.0	476	1-4	2.7976	.79386	-.247	.112	-1.077	.223
GAENE	443	1-4	2.9279	.70043	-.374	.116	-.496	.231
CAEB	473	1-7	3.0350	.81817	.792	.112	.823	.224
TRF	463	1-5	3.2613	1.24010	-.394	.113	-1.012	.226
ROT	464	1-5	3.3038	1.17932	-.059	.113	-1.283	.226

RARE 2.0

RARE 2.0 scores yielded an average of 2.79 with a standard deviation of .79 with a range of 1-4. This indicates that the distribution of the sampled data is negatively skewed. A log transformation was conducted on the data in an attempt to create a more normal distribution. However, the data remained negatively skewed post-transformation. The implications will be discussed in the discussion section below.

In order to assess RARE's internal consistency, Cronbach's alpha coefficient was conducted on all 22 items. Results from the analysis revealed an alpha coefficient of $\alpha = .966$. The item total statistics revealed that removing item 1 increased Cronbach's alpha to .971. Additionally, item 1 and item 2 use similar wording with the items opposing each other. (See *table 3.2* below). Including both items 1 and 2 in the scale may therefore be redundant. Additionally, many of the participants omitted a response to item 1 ($n = 183$). It is noteworthy that items within RARE 2.0 were presented to participants in a random order so as to rule out any ordering effects. For these reasons, item 1 was removed from subsequent analysis. Removing any other item, aside from item 1, did not increase the alpha value for RARE. Analysis of the inter-item correlation matrix revealed, interestingly, that items 15 and 16 perfectly correlated with each other ($r = 1.0$). *table 3.2* below are items 15 and 16 respectively:

I reject evolution because it stands contrary to my religious beliefs.

Religious accounts of the origin of species are more credible because they are more complete than evolutionary accounts.

Due to this correlation, the determinant of the co-variation matrix could not be calculated. Further, a perfect correlation will not allow for KMO or Bartlett's test of sphericity in an exploratory factor analysis. Both items 15 and 16 have religious connotations. However, item 15 appears to be a more direct question assessing epistemic ideals whereas item 16 appears to be more indirect. Item 15 explicitly presents one's epistemic ideal for religious beliefs whereas item 16 makes the assumption of one having religious beliefs including asking questions of the completeness of religious accounts of the origin of species. As has been shown above, items 15 and 16 correlate perfectly with each other which suggests that including both items is redundant. While both items have religious connotations, item 16 has both a religious connotation and more subtle/specific way of assessing one's epistemic ideals. Therefore, due

to the above reasons, item 15 was removed from analysis as it may be redundant with respect to item 16. Item 16 was included within the analysis as it may implicitly measure what is assessed in item 15 and better assess one's epistemic ideals.

Once these items were removed, Cronbach's alpha was conducted on the remaining 20 items. The new alpha coefficient for RARE was found to be .969 indicating extremely high internal consistency (Field, 2009). Further, Cronbach's alpha did not significantly increase by removing any item/s. The inter-item correlation matrix (See appendix F) revealed that no items correlated less than .3 indicating that each item correlated well with the overall score of the scale (Field, 2009). Split-half reliability was conducted to further assess the reliability of RARE. The first 10 items were found to be highly correlated ($r = .932$) with the last 10 items again indicating high reliability of the measure.

As RARE and GAENE both assess acceptance of evolution to varying degrees, a high correlation between these measures may demonstrate convergent validity. Correlations between these measures was conducted using Pearson's r and it was found that these two measures correlate highly with each other ($r = .887$) thus demonstrating convergent validity.

To further test the validity of RARE, an exploratory, principal component, factor analysis (EFA) was conducted. Initially, an EFA was conducted for exploratory reasons. KMO was found to be .98 and Bartlett's test of sphericity was found to be significant ($\chi^2_{190}; p = .000$). Factors were extracted based on eigen values greater than 1. Only 1 component demonstrated an eigen value greater than 1 which explained 63.7% of the variance. By examining the scree plot, the point of inflexion appears to be after 1 component. Therefore, it was found that a one factor solution best fit the data, contrary to the design of RARE which was based on three components. A parallel analysis or Velicer's map can be conducted for a more objective measure of the number of components to extract. However, based on the design of RARE, a one component solution makes sense as RARE assesses evolutionary accepting or rejecting statements and, as shown above, correlates highly with GAENE demonstrating that RARE may be sharing covariance with acceptance of evolution. Each item loaded onto the extracted factor ranging from moderate to high loadings. *Table 3.2* below demonstrates the loadings. As is shown in *table 3.2*, item 20, had the lowest loading value of .5 which is higher than the deemed acceptable loading value of .298 for a sample of over 300 participants (Field, 2009). From this table, it appears a one factor solution may be appropriate for the data.

An additional EFA was conducted on RARE for confirmatory reasons, fixing the number of components to be extracted at 3. As each theorized component within RARE measures aspects of one's epistemic cognitions, each component should theoretically be highly correlated. For this reason, an oblique rotation method was conducted using a Promax rotation. A promax rotation is used when the components are expected to be highly correlated (Field, 2009) and thus is an appropriate rotation to be used for RARE. The values for KMO, Bartlett's, eigen values and the scree plot remained the same for this analysis. Factors and factor loadings are presented in *table 3.3* below.

Items 2 - 7 were theorized to measure one's reliable processes. As can be seen below, these items demonstrate one instance of cross loading (item 5). However, the primary loadings of this is in component 2. Items 3 and 6 show primary loadings on component 1. Items 2, 4, 5 and 7 high primary loadings on component 2. None of the items in Reliable Processes Cross loaded onto component 3. Items 8-14 (Aims and Values) show all primary loadings on component 1 except for item 13. No items from this component loaded onto component 3. Items 16-21, Epistemic Ideals, show poor loadings onto component 3. Item 20, however, shows strong primary loading onto this item. No other item loaded onto component 3.

As items 3 and 6 primarily load into component 1, these items were added to the Aims and Values subscale (see below discussion for rationale). Component 1 is therefore theorized to measure Aims and Values. Component 2 is theorized to measure one's Reliable Processes. Although there are cross loadings, the primary loading of these items is on the relative theoretical components. Items 16-21 do not load onto component 3 except for item 20.

Table 3.2

EFA for RARE 2.1 using components extracted by eigen values great than 1	
Item	Component 1
2. Experts have presented evidence for and against evolution. The evidence seems to suggest that evolution has occurred.	.795
3. Evolution has not been observed and/or is not observable by humans. Therefore, no one knows if it occurred	.799
4. Because the theory of evolution has been through many peer reviewed processed and scientist accept it, I believe in evolution.	.856
5. I believe in evolution because scientific evidence provides a reliable and valid guide to the facts about the history of life.	.882
6. I have been told by my parents/church that evolution is false and I believe their testimony to be true.	.768
7. Evolution is supported by numerous and varied empirical evidence such as the fossil record.	.761
8. There is no good reason to study evolution as it cannot fully explain the origin of species.	.816
9. There is not enough evidence to support evolution as there are too many missing links	.845
10. Living organisms are far too complex to be explained by evolutionary theory.	.860
11. If the theory of evolution were true, there would be no objective morality. There is an objective morality. Therefore, evolution is false.	.824
12. Evolution is a controversial, complex topic and knowledge is not certain on either side of the debate. Therefore, I cannot fully accept evolution.	.769
13. I have learned about evolution through my studies (or personal research) and learning about evolution has led me to accept it.	.862

14. I reject the theory of evolution because humans cannot have evolved from apes.	.844
16. Religious accounts of the origin of species are more credible because they are more complete than evolutionary accounts.	.837
17. Evolution is a sound theory with no major empirical or logical flaws	.651
18. Evolution is yet to be disproven and I therefore accept it.	.680
19. Most scientists disagree whether evolution is true. If evolution were true, there would be a clear academic consensus on the topic. Therefore, evolution is false.	.815
20. I have no religious affiliation and therefore have no reason to reject evolution.	.597
21. Evolution may have occurred for plant and other animal species, but humans cannot have been the product of evolution.	.772
22. I accept evolution because it is the theory which makes most sense in accounting for the origin of species.	.872
Cronbach's Alpha (α)	.966

Note. Significant factor loadings presented in boldface

Table 3.3

<i>Factors analysis for RARE 2.1 using three components</i>			
Item	<u>Component</u>		
	Aims and Values	Reliable Processes	Epistemic Ideals
2. Experts have presented evidence for and against evolution. The evidence seems to suggest that evolution has occurred.	.272	.609	-.037
4. Because the theory of evolution has been through many peer-reviewed processed and scientist accept it, I believe in evolution.	.252	.627	.076
5. I believe in evolution because scientific evidence provides a reliable and valid guide to the facts about the history of life.	.432	.522	-.018
7. Evolution is supported by numerous and varied empirical evidence such as the fossil record.	.145	.767	-.137
3. Evolution has not been observed and/or is not observable by humans. Therefore, no one knows if it occurred	.739	.217	-.203

6. I have been told by my parents/church that evolution is false and I believe their testimony to be true.	.749	-.027	.121
8. There is no good reason to study evolution as it cannot fully explain the origin of species.	.733	.209	-.149
9. There is not enough evidence to support evolution as there are too many missing links	.605	.292	-.010
10. Living organisms are far too complex to be explained by evolutionary theory.	.691	.215	-.006
11. If the theory of evolution were true, there would be no objective morality. There is an objective morality. Therefore, evolution is false.	.869	.026	-.072
12. Evolution is a controversial, complex topic and knowledge is not certain on either side of the debate. Therefore, I cannot fully accept evolution.	.638	.043	.202
13. I have learned about evolution through my studies (or personal research) and learning about evolution has led me to accept it.	.359	.514	.085
14. I reject the theory of evolution because humans cannot have evolved from apes.	.820	.011	.073
16. Religious accounts of the origin of species are more credible because they are more complete than evolutionary accounts.	.790	-.052	.216
17. Evolution is a sound theory with no major empirical or logical flaws	-.279	.899	.188
18. Evolution is yet to be disproven and I therefore accept it.	-.095	.838	.020
19. Most scientists disagree whether evolution is true. If evolution were true, there would be a clear academic consensus on the topic. Therefore, evolution is false.	.855	.041	-.090
20. I have no religious affiliation and therefore have no reason to reject evolution.	.017	.100	.879
21. Evolution may have occurred for plant and other animal species, but humans cannot have been the product of evolution.	.994	-.262	.087
22. I accept evolution because it is the theory which makes most sense in accounting for the origin of species.	.356	.510	.116
Cronbach's Alpha (α)	.946	.901	.936

Note. Significant factor loadings are represented in boldface

The above EFA (*table 3.3*) appears to hold relatively encouraging results. However, due to cross-loadings and component 3, a confirmatory factor analysis was conducted on the newly formulated RARE 2.0. The CFA on RARE 2.1² was conducted using only participants who had not omitted any responses to control for missing data. Analyses were conducted using 476 participants. Figure 3.2 demonstrates the theorized model as well as correlations. Epistemic Ideals, Aims and Values and Reliable processes were added as manifest variables with the corresponding items. Covariance paths were added between each latent variable as RARE 2.1's subscales are theorized to measure a similar latent variable.

CFA results

To test multiple theoretical models, four separate CFAs were conducted using maximum likelihood methods. The first CFA was conducted using a one factor solution with each item corresponding to one variable. For each model, the chi-square fit statistic was found to be significant. Although a significant result demonstrates poor fit, Klein (1994) argues that chi-squared results should be interpreted cautiously and with reference to degrees of freedom. Fit indices for model 1 were as follows: *CMIN/DF*: 2.75, *RMSEA*: .061, *HI*: .067, *LO*: .054, *P-Close* .004; *CFI*: .965, *TLI*: .960.

CFA 2. The second CFA was conducted using a three-factor solution which produced relatively good fit indices. (*CMIN/DF*: 2.992, *RMSEA*: .065, *HI*: .071, *LO*: .058, *P-Close* .000; *CFI*: .961, *TLI*: .954). *Table 3.4* below shows factor loadings, all of which are significant. Correlations between each factor were extremely high with Epistemic ideals correlating .988 with Aims and Values, and .968 with Reliable Processes. Reliable processes correlated .959 with Aims and Values.

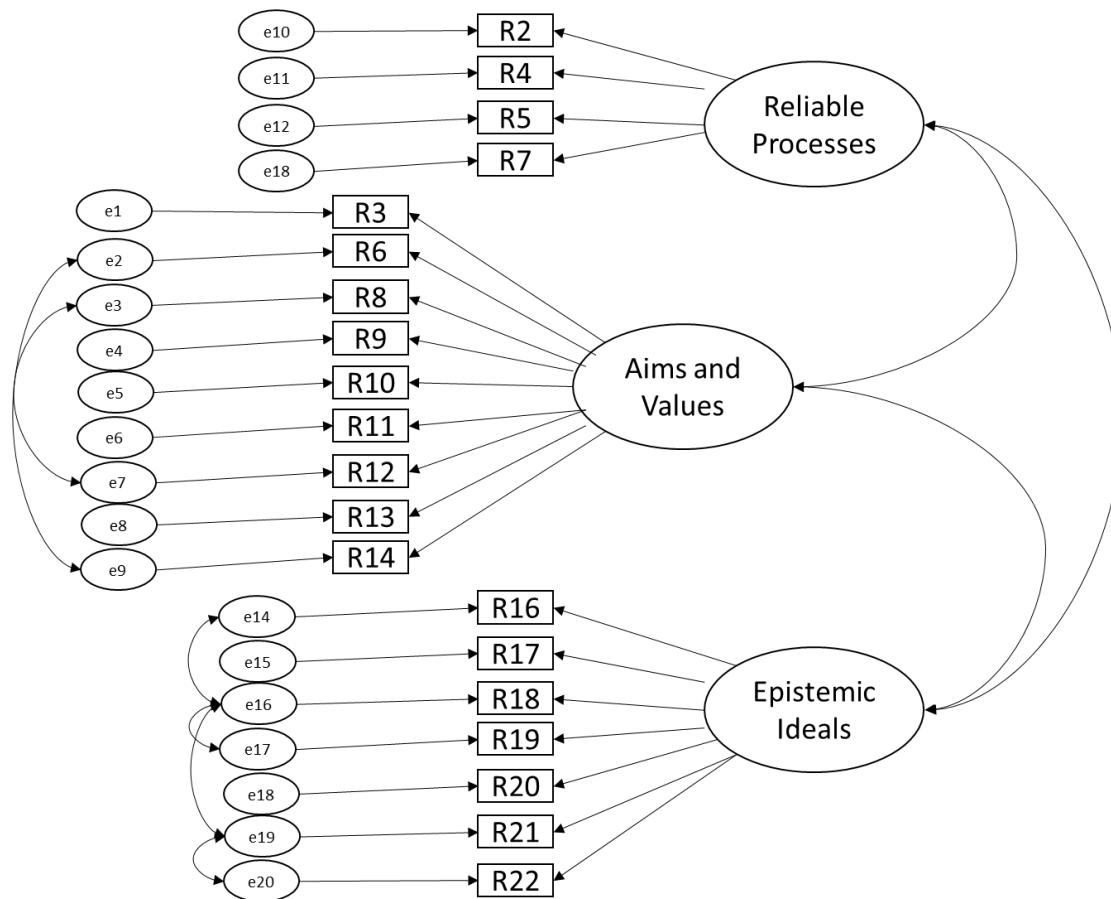
CFA 3. As only one item loaded onto component 3, and additional CFA was conducted only using components 1 and 2. (*CMIN/DF*: 2.04, *RMSEA*: .047, *HI*: .058, *LO*: .035, *P-Close* .659; *CFI*: .988, *TLI*: .985). Items demonstrated good loadings onto each respective variable with a range loading of .75 - .898.

CFA 4. Although items 17 and 18 are shown in the above EFA to load highly onto component 2 (aims and values), addition of these items into the third CFA produce poorer fit indices (*CMIN/DF*: 8.07, *RMSEA*: .122, *P-close*; .000, *CFI*: .89, *TLI*: .874)

² Items 3 and 6 were moved to a new component. This change allowed for the Renaming of RARE 2.0 to RARE 2.1

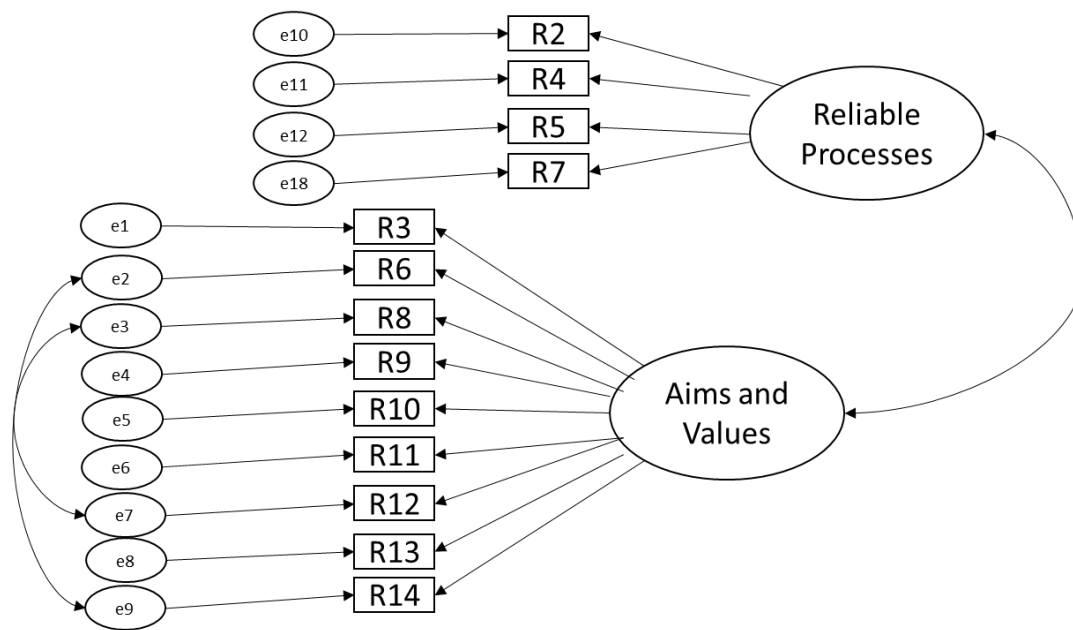
From the above results, it can be seen that a two-factor solution, excluding epistemic ideals best fits the data. However, although CFA 3 demonstrated the best fit indices, CFA, the theorized three-component model does demonstrate good model fit. Therefore, in the below analyses, where results indicate ‘RARE 2.1’ the analysis was conducted using the three-component solution as per figure 3.2.

Figure 3.2: RARE 2.1 using a three-component solution.



The above figure shows a potential three factor solution for RARE 2.1. The components are represented by ovals (latent variables) while the items allocated to each item are represented by rectangles (manifest variables).

Figure 3.3: RARE 2.1 using a two-factor solution



The above model shows a potential two-component solution to RARE 2.1. All items representing epistemic ideals have been excluded from this model to make comparisons of the fit indices between models.

Table 3.4:

Factor loadings of each item onto their respective components as per figure 3.2			
Item loading			Estimate
R2	<---	Reliable Process	,796
R4	<---	Reliable Process	,863
R5	<---	Reliable Process	,900
R7	<---	Reliable Process	,767
R8	<---	Aims Values	,814
R9	<---	Aims Values	,839
R10	<---	Aims Values	,858
R11	<---	Aims Values	,821
R12	<---	Aims Values	,759
R13	<---	Aims Values	,852
R14	<---	Aims Values	,837
R16	<---	E Ideals	,833
R17	<---	E Ideals	,627
R18	<---	E Ideals	,679
R19	<---	E Ideals	,812
R20	<---	E Ideals	,578
R21	<---	E Ideals	,772
R22	<---	E Ideals	,875
R6	<---	Aims Values	,752
R3	<---	Aims Values	,792

Because the CFA revealed extremely high correlations between manifest variables, a multiple regression analysis (multiple regression 1) was conducted to check for

multicollinearity. Multicollinearity is present when each variable entered into a model measures the same construct and is thus redundant. If multicollinearity is present using each subscale as a variable to predict acceptance of evolution, then it can be assumed that each subscale of RARE 2.1 is measuring the same construct. Further, running a stepwise multiple regression analysis, using each subscale in separate steps, can show whether each subscale is uniquely contributing to the model. Results from the multiple regression reveal a significant overall model ($p = .000$). Aims and Values was first entered into the model followed by Epistemic Ideals and Reliable Processes respectively. The R^2 change at each step was found to be significant ($p = .000$ at each step). This suggests that each subscale uniquely contributes to predicting acceptance of evolution. To check for multicollinearity, VIF and tolerance values were observed. No VIF values were found to be greater than 10 while no tolerance values were found to be smaller than .10. The condition index revealed a value of 29.61 which is smaller than 30. These results suggest that there is no multicollinearity among the variables.

Do RARE 2.0 scores differ by year of study and by field of study?

In order to determine whether scores achieved on RARE differed by field of study and by undergraduates or post-graduates, a one-way ANOVA and an independent samples t-test were conducted respectively. Field of study was operationalised as the faculty in which participants were registered (see above methods sections and above sample description for faculty composition). A one-way ANOVA was conducted using RARE scores as the dependent variable and faculty as the independent variable. Levene's statistic was found to be non-significant ($p = .708$) suggesting homogeneity of variance for field of study. The overall ANOVA model was found to be significant ($F_{3,992} = 4$; $p = .003$) showing a significant difference in RARE scores by faculty. LSD Post-hoc tests were conducted to compare scores by faculty. Participants registered in the Sciences were found to be significantly different from each faculty in terms of RARE 2.1 scores and achieved the highest average of 3.097. Engineering students were found to have the lowest average on RARE 2.1 (2.589) and were found to be significantly different from Health sciences ($p = 0.016$) and Science students only ($p = .000$). Humanities students were found to only be significantly different from Science students ($p = 0.017$) with an average of 2.813. These results show that Science students achieved the highest scores on RARE suggesting greater agreement with evolutionary accepting statements than any other faculty. *Table 3.5* below shows the number of participants in each faculty as well as mean RARE scores.

Table 3.5

Mean RARE 2.1 score by faculty		
	N	Mean
Commerce Law and Management	68	2.7566
Engineering and Built Environment	72	2.5896
Health Sciences	116	2.8737
Humanities	116	2.8138
Sciences	69	3.0971
Total	441	2.8285

An independent samples t-test was conducted to assess whether Undergraduates and Postgraduates were significantly different in terms of RARE scores. Results indicated homogeneity of variance was not achieved as Levene's statistic was found to be significant ($p = .032$). P was therefore interpreted using equal variances not assumed. Results revealed that participants did not significantly differ by post-graduate or undergraduate studies ($t_{319}=439$; $p = 0.75$). These results suggest that faculty appears to have a greater impact on predicting evolutionary accepting reasoning than does undergraduate or postgraduate studies.

Table 3.6

RARE 2.1 Scores for Undergraduates and Postgraduates		
Undergrad/Postgrad	N	Mean
Undergraduate	294	2.8379
Postgraduate	147	2.8116

The next step in analyses was to compare each subscale of RARE 2.1 by field of study. Three separate one-way ANOVA's were conducted using faculty as the dependant variable with each subscale of RARE 2.1 as an independent variable. All three overall models were found to be significant (Reliable Processes: $F = 3.792$; $p = .005$. Epistemic Ideals: $F = 3.345$; $p = .010$. Aims and Values: $F = 4.177$; $p = .002$). The Levene's test statistic for all three one-way ANOVA's conducted were found to be not significant thus suggesting homogeneity of variance for each analysis. Table 3.7 below shows the p-values for each analysis.

LSD post-hoc tests were conducted to compare means between faculties. *Table 3.7* below shows means and significant group differences for each component. As can be seen in *table 3.7*, between group differences remain fairly consistent between components. However, for Aims and Values, EBE students do not significantly differ from humanities students. Interestingly, humanities students are different from sciences students in Aims and Processes but not in Ideals. Health Sciences and science students only differ significantly in terms of epistemic ideals. This pattern of results seems to suggest that each component of RARE 2.1 is eliciting different reactions across domains of study.

Table 3.7

<i>Significant between group differences by component</i>			
Component	Levene's test	Group Mean	Significant Between Group Differences
<i>Reliable Processes</i>	$p = .421$	Sci (3.13) EBE (2.61) Hum (2.86) Hsc (2.91) CLM (2.78)	CLM - Sci ($p = .013$) EBE - HSc ($p = .017$) EBE - Sci ($p = .000$) EBE - Hum ($p = .044$) Hum - Sci - ($p = .030$)
<i>Aims and Values</i>	$p = .597$	Sci (3.19) EBE (2.66) Hum (2.85) Hsc (2.98) CLM (2.81)	CLM - Sci ($p = .008$) EBE - HSc ($p = .011$) EBE - Sci ($p = .000$) Hum - Sci ($p = .008$)
<i>Epistemic Ideals</i>	$p = .862$	Sci (2.94) EBE (2.48) Hum (2.71) Hsc (2.71) CLM (2.65)	CLM - Sci ($p = .028$) EBE - HSc ($p = .045$) EBE - Sci ($p = .000$) EBE - Hum ($p = .032$) Hsc - Sci ($p = .044$)

Note. Significant group differences column shows significant group difference as per post-hoc tests. Groups are compared as: group 1 - group 2.

Reasons for accepting or rejecting evolution

Acceptance Items. Science students had the highest average on item 7 which cites evidence as their reason for accepting evolution (3.43). 91.3% of science students agreed with this item. In contrast only 70.8% of engineering students agreed with this item. Further, science

students scored highest on items citing expert authority³ (3.16) and evolution being true as science is reliable and valid⁴ (3.1). Theistic Evolutionists and those with closed ECS too scored highest on these items. These items fall under the *Reliable processes* subscale of RARE. Those who reject evolution score low on items measuring reliable processes (R2 = 1.76; R4 = 1.36; R5 = 1.31 and R7 = 1.83)

Rejection Items. Engineering students scored highest on items 3, 9, 10 and 12. Humanities student's most salient reasons for rejecting evolution are items 9, 10, 12 and 14. The low acceptance group, as coded above, score highest on items 8, 9, 10 and 14. All these items fall under the *Aims and Values subscale*. Those scoring high on religiosity scored highest on items 9, 10, 12 and 16. Those coded as having high religious fundamentalism scored highest on items scored highest on items 9, 10, 14 and 16. Those with open ECS scored highest on items 9, 10, 12 and 16. Items 9 - 14 score within the *Aims and Values* subscale with item 16 falling with the *Epistemic Ideals* subscale.

What is the relationship between participants' religiosity/religious fundamentalism and epistemic cognitions?

In order to assess whether epistemic cognitions about science (ECS) differed among those with high and low religiosity as well as religious fundamentalism, participants were split into a binary group of high religiosity or low religiosity. This was done by coding those scoring 2.49/5 or lower on the ROT as "high religiosity" and those scoring 2.5/5 or higher as "low religiosity" (higher scores on ROT represent lower religiosity). An independent samples t-test was then conducted using ECS as the dependant variable and high/low religiosity as the grouping variable. Results revealed Levene's statistic to be significant ($p = .000$) suggesting no homogeneity of variance. Therefore, bootstrapping was conducted using 1000 samples. Results showed a significant difference in ECS by Religiosity ($t_{4.25} = 194$; $p = .000$). Interestingly, those with low religiosity ($n = 326$) were found to have a lower CAEB mean (2.919) than the high religiosity group ($n = 135$; CAEB mean = 3.304). Higher scores achieved on CAEB demonstrate a more open view of the variability on knowledge in science. These results show that those with lower religiosity had a more closed/definite view of knowledge in

³ Item 2

⁴ Item 5

science than did the high religiosity group. Cohen's d was calculated using the same formula as above and yielded a score of .46 which can be described as a small to moderate effect size.

Pearson's r correlations as well as Spearman's ρ correlations were conducted to assess the relationship between ECS and Religiosity. Results revealed a significant ($p = .000$) weak to moderate, negative correlation at the 0.01 level of significance ($r = -.353$; $\rho = -.336$). These results show a negative relationship between religiosity and ECS suggesting ECS becomes more open with lower religiosity.

Additionally, participants were coded into a group of high and low religious fundamentalism in the same manner as was done for religiosity. An independent samples t-test was conducted to assess differences in ECS by high/low religious fundamentalism. Bootstrapping was performed using 1000 samples as Levene's statistic was found to be significant ($p = .000$). Results revealed a significant difference in ECS among the groups ($t_{6,226} = 183$; $p = .001$). Those with high religious fundamentalism ($n = 130$) revealed a higher CAEB score of 3.439 than did the low fundamentalism group ($n = 330$; CAEB = 2.875) suggesting the same pattern of results as above. Additionally, both Pearson's and Spearman's correlations were conducted. Results showed a significant ($p = .000$), weak to moderate, negative correlation between religious fundamentalism and ECS ($r = -.388$; $\rho = -.386$) which, again, suggests the same pattern of results as above. Cohen's d for this analysis gave a score of .688 which can be described as moderate to high.

An additional analysis was conducted to assess group differences in acceptance of evolution between those with more open (scoring between 4-7) and those with closed (Between 1-3) ECS within the entire sample. An independent samples t-test revealed a significant difference between the groups ($p = .000$). Results showed that those with more closed ECS scored higher on acceptance (GAENE mean = 3.14) than those with more open ECS (2.32).

How do theistic evolutionists compare to those who reject evolution in terms of epistemic cognitions?

Theistic evolutionists were operationalised by grouping together those who scored highly on religiosity (1.5/5 or lower on the ROT) and highly on acceptance of evolution (2.8/4 on GAENE). Participants were coded in this way to include the bottom 30% of participants in

terms of religiosity⁵ and the top 30% of participants in terms of acceptance of evolution. The partitioning was done this way to both separate high/low religiosity/acceptance, but to also include a higher number of participants in each group.

Participants who reject evolution were coded as those having low acceptance. Initially, participants were coded as having low acceptance by scoring 1.2/4 or lower on GAENE (to represent the bottom 30%). However, this coding strategy only yielded 14 participants who met this criterion. Therefore, Low acceptance was operationalised as those scoring 1.95 or lower on GAENE. The implication of this change will be discussed in the limitations section below.

All above participants were coded together to create a group of 77 with 35 theistic evolutionists and 42 participants who reject evolution. Kolmogorov-Smirnov and Shapiro-Wilk tests of normality was conducted on ECS for the created group. Both tests were found to be non-significant ($p = .20$ and $.655$ respectively) suggesting the data is normally distributed. Levene's statistic was found to be non-significant ($p = .232$) suggesting homogeneity of variance.

An independent samples t-test was conducted in order to assess how these participants differ in terms of ECS. Results revealed a significant difference between groups ($p = .004$). Theistic evolutionist scored lower on ECS (3.029) than did those who reject evolution (3.619). These results are similar to the above findings that those with higher religiosity have more open ECS. Cohen's d was calculated using the formula $(M1 - M2 / SD_{pooled})^6$ which yielded an effect size of .683. This demonstrates a moderate effect size.

Correlations

Table 3.8 below demonstrates correlations between each variable. Religiosity was found to significantly ($p = .000$), positively correlate with acceptance of evolution demonstrating a moderate to strong relationship ($r = .664$). However, this correlation should be read inversely as higher scores achieved on ROT demonstrates lower religiosity. Therefore, the less religious one is, the higher one's acceptance correlation will be. The same is true of

⁵ Note that because higher scores on the ROT represent lower religiosity, the bottom scoring 30% have higher religiosity than that top 70%

⁶ M1 represents theistic evolutionist's mean and M2 represents those who reject evolution's mean. SD_{pooled} is the pooled standard deviations of the two groups.

religious fundamentalism which demonstrated a moderate to strong, significant ($p = .000$) correlation with acceptance ($r = .791$). Higher scores achieved on the test of religious fundamentalism demonstrates lower religious fundamentalism (See above instruments section). This means that lower fundamentalism correlates highly with acceptance. Religiosity and religious fundamentalism demonstrated a moderate to strong, positive, significant ($p = .000$) relationship ($r = .771$).

Table 3.8:

<i>Pearson's Correlations Between Observed Variables</i>				
Variable	Acceptance	Religiosity	Religious Fundamentalism	ECS
Acceptance (GAENE)	1.000	-	-	-
Religiosity (ROT)	.664**	1.000	-	-
Religious Fundamentalism (TRF)	.791**	.771**	1.000	-
ECS (CAEB)	-.426**	-.354**	-.383**	1.000

Significant correlations are marked by **

How much variance is explained in predicting acceptance of evolution by ECS and religiosity/religious fundamentalism?

To predict acceptance of evolution, a stepwise multiple regression (Multiple Regression 2) was conducted using ECS, religiosity and religious fundamentalism as predictor variables. Step 1, religiosity was entered. In steps 2 and 3 religious fundamentalism and ECS were entered respectively. As is shown above, post-graduates and undergraduates do not differ in terms of RARE 2.1 scores and therefore, should theoretically not differ in terms of acceptance scores. Therefore, this was not entered into the model as a variable. Field of study was not entered into the equation as it was not the focus of this research question. Additionally, field of study is explored using ANOVA's as above. An independent samples t-test was conducted to assess if there were any group differences in acceptance scores using gender as a grouping variable. A non-significant group difference was found ($t = 1.796$; $p = .073$). Therefore, gender was not included into the model as a variable.

To check for linearity, part and partial plots were assessed using a linear line and a loess line. Each straight line and loess line for each plot were found to not significantly deviate from each other suggesting a linear relationship.

To check for multivariate outliers, Mahalanobis distance was observed. As three IV's are present, no value should be greater than 16.27. Based on this criterium, 3 multivariate outliers were observed and removed. Cook's and leverage values were assessed to check for homoscedacity. For Cook's distance, no values higher than 1 were found. Leverage average for the data is $3[(3+1)/439]^7 = 0.0273$. To meet the requirements of homoscedacity, no leverage values should be higher than the leverage average. However, 3 values were found to be higher than the leverage average and were subsequently removed from analysis. 3 univariate outliers were identified and removed using studentized residuals smaller than -3 or greater than 3. Residuals were found to be normally distributed by checking the residuals histogram. The multiple regression was conducted again once outliers had been removed to meet all assumptions of a multiple regression analysis. Missing cases were excluded list wise leaving the remaining sample size at 431. To check for multicollinearity, VIF and tolerance values were observed. No VIF values were found to be greater than 10 while no tolerance values were found to be smaller than .10. The condition index revealed a value of 15.109 which is smaller than 30. These results suggest that there is no multicollinearity among the variables.

The overall model was found to be significant at each step ($p = .000$). All three variables entered into the equation were found to be significant predictors of acceptance of evolution. Step 1 included only religiosity in the model which yielded an R^2 value of .440 thus explaining 44% of the variance. The unstandardized beta coefficient was .391 at this step with a confidence interval of .349 - .433. These values show a relatively high prediction value of the acceptance of evolution. At step 2, religious fundamentalism was entered into the model. R^2 at step 2 was .633 with a significant increase in R^2 ($p = .000$). At this step, 63,3% of the variance could be explained. However, part correlations at this step for religiosity only shows a value of .084 which now only contributes .007% of the variance. Religious fundamentalism had a part correlation of .439 which contributes to 19% of the variance. Squared part correlations explain the unique contribution to the model. When religious fundamentalism is added, religiosity contributes very little additionally to the model. At step 3, ECS was added which yielded an R^2 value of .649 which also showed a significant increase ($p = .000$). At this step, religiosity contributed less to the model with a part correlation of .07. Religious fundamentalism also slightly decreased which a part correlation of .409 while ECS showed a correlation of -.126.

⁷ Formula for leverage average = $3[(k+1)/n]$ where k = no. of IVs; n = sample size

ECS therefore contributed .015% to the model. Religious fundamentalism provided the largest contribution to the model.

As religious fundamentalism is shown to be the most important predictor of acceptance of evolution, two further multiple regression analyses were conducted. A multiple regression using the same variables was conducted on participants that tested high (Multiple Regression 3), and low (Multiple Regression 4) in religious fundamentalism respectively. These analyses were conducted to view the predictive value of ECS between these two groups. Variables were again entered in three steps. However, for this analysis, ECS was entered first followed by religiosity and religious fundamentalism respectively. For those testing high in fundamentalism, the overall model at each step was found to be significant. ECS was shown to be a significant predictor of acceptance of evolution at step 1 ($p = .048$; $R^2 = .033$). At step 2, ECS ceased to be significant ($p = .56$) with only religiosity shown to be significant ($p = .012$). The R^2 at this step was .086. At step 3, both ECS ($p = .058$) and religiosity ($p = .100$) were no longer significant with only religious fundamentalism being statistically significant ($p = .001$; $R^2 = .168$). In contrast, those testing low in religious fundamentalism, showed a significant predictive value of ECS at each step ($p = .000$ at each step). The R^2 values at each step were .147, .306 and .492 respectively. Religiosity was found to be significant at step 2 ($p = .000$) but not at step 3 ($p = .106$) once religious fundamentalism was added to the model.

An additional, bivariate correlation was conducted between religiosity and ECS for theistic evolutionists to assess the relationship between these variables for this group. Results showed no significant correlation ($p = .227$, $r = -.189$). It would appear that neither religiosity ($p = .347$; $r = -.164$) nor ECS correlate significantly with acceptance for theistic evolutionists and therefore cannot be a good predictor of acceptance of evolution for this group. Indeed, a multiple regression (multiple regression 5) analysis using ECS and religiosity to predict acceptance revealed a non-significant overall model ($F = 1.053$; $p = .361$).

A further multiple regression (multiple regression 6) was conducted to assess which variables are significant in predicting acceptance of evolution when the components of RARE 2.1 are added to the model. In a single model, Epistemic Ideals, Reliable Processes, Aims and Values, ECS, Religiosity, and religious fundamentalism were added in one step. As is shown above, each of the above variables, in isolation, is a significant predictors of acceptance of evolution. However, when added together, Epistemic Ideals and Religiosity are not significant predictors ($p = .424$ and $p = .70$ respectively).

Table 3.9

Multiple Regression 2 at each step

Variables	Step 1			Step 2			Step 3		
	B	SE	β	B	SE	β	B	SE	β
Religiosity	.391	.021	.664***	.077	.027	.131**	.066	.027	.111**
Religious Fundamentalism				.391	.026	.690**	.370	.026	.635***
ECS						***	-.128	.029	-.137**
(Constant)	1.634	.075		1.389	.063		1.880	.128	
F	337.437***			369.506***			263.325***		
R ²	.440			.633			.647		
Change in R ²				.193***			.016***		

Note. The above show the results of the first multiple regression conducted (multiple regression 2) at each step in the analysis. Significant beta coefficients are represented by ***

Discussion

Descriptives

Lelliot (2016) has reported that South Africans have a relatively low acceptance rate of evolution (59%). However, this figure is not strictly generalisable to the population as the study sampled from visitors to the Cradle of Humankind, a world heritage site in South Africa. The study by Lelliot (2016), although useful, was conducted using simple quantitative data sampling (i.e. response to one item) to measure acceptance of evolution. As discussed in the above literature review, acceptance can be measured on a spectrum rather than as a binary. Comparatively, Coleman et al. (2015) found an average acceptance score using MATE of 72.76 out of a possible 100 i.e. 72.76%. The current study found an average of 2.92/4 (73%). An average of 73% represents a relatively high acceptance of evolution. However, this figure should not be read comparatively to the Miller et al. (2006) statistics as above, but should be read as a high average degree of acceptance within the sample. Coleman et al.'s (2015) sample appear to have a similar acceptance rate to the current study. However, MATE has been argued to be a problematic instrument in measuring acceptance of evolution (Smith et al., 2016).

The sample appeared to have a positively skewed distribution in terms of ECS with an average CAEB score of 3.03/7. This suggests a more authoritarian connotative response to knowledge in science within university students. As mentioned in the methods section above, the component used within the CAEB assesses complexity of knowledge in science. Higher scores achieved on complexity can be argued to show more non-absolutists views of knowledge in science.

Religiosity and religious fundamentalism can be argued to be relatively low amongst the sample as participants achieved relatively low mean scores on these measures. The mean score for ROT was 3.26 out of a possible 5. A score of 1 would mean extremely high religiosity with a score of 5 being not religious at all. The mean score is higher than the achievable midpoint (2.5) thus suggesting lower religiosity on average throughout the sample.

Development of RARE 2.0

As mentioned in the results section above, the sampled data within RARE 2.1 appears to be negatively skewed. This may be due to the sample having a high average acceptance of evolution as shown by the GAENE. Further, the sample appeared to have both low religiosity and low religious fundamentalism. However, the statistical analyses used above are quite robust and a skewed distribution should not affect the validity of the results.

One of the explicit aims of this research was to develop RARE 2.0. RARE demonstrates excellent reliability in its entirety as well as for each of its subscales. This is however, not surprising as one will complete the scale with a pre-existing stance towards evolution and answer the scale congruent to this stance. This high reliability does show that the items included in the analysis are void of ambiguity and no item significantly decreased the internal consistency of the scale. As can be seen from the above results, RARE 2.1 seems to best fit a one factor solution based on an EFA. This suggests it may measure only one construct which is highly correlated to acceptance of evolution. However, from the above CFA, it can be seen that using a one factor model produces only moderately better fit when compared to a three-factor model with a two-factor solution demonstrating the best fit.

Upon moving items 3 and 6 from *Reliable Processes* to *Aims and Values*, RARE 2.1 demonstrated relatively good model fit indices. The changing of these items makes theoretical sense. Item 3: ‘Evolution has not been observed and/or is not observable by humans. Therefore, no one knows if it occurred’ may appear, logically, to assess *Reliable Processes* as observability is one of the criteria for good science. However, the idea or misconception that evolution is not observable may be an example of freezing and would therefore fall under the category of *Aims and Values*. The Theory of evolution is often claimed by creationists to not fulfil the criteria of observability, claiming that because evolution, specifically ‘macro-evolution’ cannot be *directly* observed, it cannot be good science. This is indeed a fallacy as evolution is observed *ex-post facto*. This misconception may therefore be frozen upon to achieve the epistemic aim of holding ideologically congruent beliefs.

Item 6; “I have been told by my parents/church that evolution is false, and I believe their testimony to be true” may present parental or clerical testimony to be a reliable process. However, an argument can be made that accepting the above parties’ testimony can fall under the aim of maintaining in-group cohesiveness. Accepting claims made by one’s parents or by

one's church, rather than questioning or critically evaluating them, can create in-group cohesiveness. Alternatively, questioning anti-evolution claims may potentially lead to scorn or judgment from these authority figures thus preventing further argument. These theoretical arguments, as well as empirical data gathered from the EFA and CFA suggests that items 3 and 6 are best suited as measuring one's Aims and Values. It must be noted that factor three (Epistemic Ideals) in the EFA shows low loadings as well as multiple cross loadings.

However, items theoretically placed in components 1 and 2 do not significantly load onto component 3 thus lending some support for a three-factor solution. Comparatively, acceptance of evolution measures such as the GAENE (Smith et al., 2016) and MATE (Ruteledge and Warden, 1999) demonstrate a one factor solution. Because RARE 2.1 and GAENE demonstrate high correlations, it would make sense that RARE 2.1 too would have a one factor solution. However, based on the above CFA, a two-factor solution demonstrates better fit indices than a one component solution. Based on these considerations, a three-factor solution appears more plausible than a one factor solution. Interestingly, items 17 and 18 originally designed to measure *Epistemic ideals* load highly onto *reliable processes* as per the EFA. However, addition of these items to the Aims and Values reduced the fit indices as per the CFA. These items therefore do not appear to be measuring Aims and Values as is suggested by the EFA.

Additional support for a three-factor solution comes from the above multiple regression (multiple regression 1) analysis. Each component of RARE uniquely and significantly contributes to predicting acceptance of evolution. Additionally, a significant change in R^2 was observed in each step of the model as well as no observed multicollinearity, again, suggesting a unique contribution of each subscale. Acceptance of evolution was chosen as a predictor value as RARE 2.1 and acceptance of evolution are shown to highly correlate with each other. As RARE 2.1 is used to measure evolutionary accepting reasoning, it would make sense to use acceptance of evolution to assess whether each subscale provided a unique contribution. However, items within Epistemic ideals may need to be reformulated for future research to properly confirm a three-factor solution. Item 20, in particular was the only item to significantly load onto component 3. However, all theorized items as per figure 3.2 above were included in the *Epistemic Ideals* subscale. Reformulating these items using similar language as in item 20 may better measure Epistemic ideals.

Salient Reasons

Items 2, 5 and 7, under the *Reliable Processes* scale demonstrate the highest means by groups with higher acceptance of evolution scores. Science students, those with closed ECS, and theistic evolutionists scored highest on these items. These items are worded as follows:

2. Experts have presented evidence for and against evolution. The evidence seems to suggest that evolution has occurred

5. I believe in evolution because scientific evidence provides a reliable and valid guide to the facts about the history of life.

7. Evolution is supported by numerous and varied empirical evidence such as the fossil record

Item 2 and 7 are based on evidence. Item 5 cites science as being reliable and valid. This would suggest that those who accept evolution do so based on the authority or upon the trust of science. Additionally, contrary to the results of Coleman et al. (2015), the results of this study suggest that those with more closed views of ECS are more likely to accept evolution. This may be due to the way in which ECS was operationalised. Previous research was conducted using views about the nature of science as opposed to ECS. However, these constructs should theoretically have a large degree of overlap. The CAEB uses connotation to measure ones ECS as opposed to other Nature Of Science (NOS) measures which use more direct questioning on a Likert-type scale. Past research, using more traditional ECS measures, points to those with static views about NOS to be less likely to accept evolution (Cavallo & McCall, 2008; Sinatra, 2003). However, reading the results of the present usage of CAEB in conjunction with RARE scores suggest that the participants do view science as somewhat of an authority. This is especially true of item 5 which sees science as a valid and reliable guide.

However, those who were more likely to reject evolution scored highest on items 9, 10 and 12 and 14. This pattern of results seems to suggest that when one accepts evolution, one does so using reliable processes. In contrast, one seems to reject evolution using aims and values. The only exceptions come from engineering students who cite item 3 to reject evolution and the religious fundamentalism and open ECS group citing one Epistemic ideal item to reject evolution. These items are worded as follows:

9. There is not enough evidence to support evolution as there are too many missing links

10. Living organisms are far too complex to be explained by evolutionary theory.

12. *Evolution is a controversial, complex topic and knowledge is not certain on either side of the debate. Therefore, I cannot fully accept evolution.*

14. *I reject the theory of evolution because humans cannot have evolved from apes.*

The highest scoring rejection items appear to vary by groups. All above mentioned groups score highly on items 9 and 10. These items refer to a lack of evidence and complexity of life respectively. Chinsamy and Plaganyi (2008), found that after a semester long evolution course, students understanding of evolution increased but their views on evolution remained relatively consistent. This was particularly seen in those who found human life to be too complex to be explained by evolution. The results found here with respect to item 10 seem to support these findings. Those who score high in religiosity and religious fundamentalism, score highly on item 16 which promotes the credibility of religious accounts of the origin of species (“Religious accounts of the origin of species are more credible because they are more complete than evolutionary accounts”). It would make sense that only this group scored highest on this item as fundamentalists regard their religious doctrine to have *a priori* knowledge or as the starting point for scientific inquiry. Item 14 is based on the popular misconception that accuses evolutionary theory of suggesting humans evolved from modern apes. This, again, may be a clear example of freezing. Further, this finding supports previous literature that misunderstanding are prominent reasons for rejecting evolution (Nadelson & Southerland, 2012). Interestingly, Engineering students scored highly on item 3: “Evolution has not been observed and/or is not observable by humans. Therefore, no one knows if it occurred”. Item 3, as explained above, was initially coded as a reliable process. As this item cross loaded on both the Reliable Processes and Aims and Values components, it would make sense that this item is measuring both constructs. However, it is important to note that in the above literature review, one’s ECS may vary across domains (Muis et al., 2006; Owen, 2011). It can be hypothesised, that engineering students are more likely to engage with the scientific method than are humanities students. Therefore, the engineering students may have frozen on the idea that evolution is not observable. As explained in the above literature review, ‘freezing’ is the focusing on one argument or detail which supports your position. The idea which is frozen on is often not subject to critical evaluation and is taken at face value (Chinn et al., 2014). Humanities students may too have frozen on certain ideas or arguments, but may be less likely to freeze on an argument such as in item 3. This is because, within the humanities, using the scientific method (i.e. observability makes for good science), is not the primary method of acquiring knowledge. However, Science students did not score as highly on this item as did the

engineering students. Science students intuitively have more or at least equal exposure to the scientific method than do engineering students. Additionally, engineering students had a significantly lower RARE 2.1 mean when compared to science students suggesting they are less likely to endorse the evolutionary accepting statements in general. Therefore, engineering students may have scored higher on item 3 than science students as engineering students are less likely to endorse evolution is general.⁸ Item 14 is based on the popular misconception that evolutionary theory suggests that humans have evolved from modern day apes. This misconception has been observed as a common reason for rejection of evolution (Heddy & Sinatra, 2013) and these results appear to confirm those findings.

Chinn et al., (2014) suggest that one's epistemic Aims, Ideals and Reliable processes may be different across different fields of inquiry (e.g. gossip vs. global warming). As is seen above, RARE demonstrated multiple instances of cross loadings. Therefore, it is highly plausible from the data and theory, that different items may act as Aims and Values across the participants epistemic cognitions. Item 3 and 6 were both moved to this component, however, no items from Aims and Values primary loadings were present on *Epistemic Ideals* or onto *Reliable Processes*. It can be hypothesised that Reliable Processes may be a more fluid component, whereas Aims and Values as well as Epistemic Ideals, appear to be more static. This is to say that an item theorized as a *Reliable Process* may also act as an *Aim or Value* depending on the participant. However, an *Aims and Values* item does not appear to act as a *Reliable Process* or an *Epistemic Ideal*. Items from Reliable Processes can load onto Aims and Values, but Aims and Values does not load onto Reliable Processes. Rather than demonstrating covariance, the relationship between these components seems to be unidirectional.

Multiple Regression

Each variable entered into the multiple regression (Multiple Regression 2) produced a unique contribution to predicting acceptance of evolution. The overall model explains 64.9% of the variance in accepting evolution. Although the addition of ECS into the model produced a statistically significant R^2 change, the actual change only accounted for 1.6% of the variance. Initially, religiosity accounted for a large part of the variance at step 1. However, with the addition of religious fundamentalism into the model, it can be seen that religiosity only

⁸ Item 3 is a rejection item. As engineering students have the lowest RARE 2.1 mean across domains on study, it would make sense that they score higher on this item than science students who have the highest RARE 2.1 scores.

contributed less than 1% to the model. This demonstrates a considerably low effect size for ECS and religiosity with religious fundamentalism appearing to be the most important predictor. The correlations between religiosity and acceptance of evolution was found to be $-.664$, which is lower than the findings from Heddy and Nadelson's (2012) meta-analysis ($r = -.81$). The correlation can still be described as moderate and does support previous findings which show a negative relationship. Importantly, religious fundamentalism showed a higher correlation with acceptance ($r = .791$) suggesting that fundamentalism is a better predictor of religiosity. This research may help to confirm global trends in the decline of religious fundamentalism as only 42 participants met the criteria for high religious fundamentalism. However, this may be subject to critical review and is discussed in the limitations section below.

It is important to note that although ECS and religiosity have been shown to be a significant predictor of acceptance of evolution, this is not true of theistic evolutionists. Multiple regression 5 as per above show that ECS and Religiosity do not predict acceptance of evolution for this group. Although religiosity and ECS are theoretically assumed, and have been shown empirically to significantly predict acceptance of evolution, this is not true for this subsample. Additionally, previous research has varied and been inconclusive as to the relationship between understanding and acceptance of evolution. Why then, does this group accept evolution? Based on their RARE scores, it would appear that it is due to the presence and acceptance of scientific evidence which is most salient for this group.

Alternatively, by examining the most salient reasons for rejecting evolution, items based on an absence of evidence appear to be the most commonly endorsed rejection item within the entire sample. Item 9 in particular, is present among all the above rejecting groups. Item 9 states that there is not enough evidence to prove evolution. Item 10 refers to the complexity of living organisms while item 12 states that there is debate in the scientific community over the validity of evolution. Item 14 states that humans cannot have evolved from apes. These items are based on misconceptions and a clear argument can be made that these participants are freezing on these misconceptions and using these to support their non-epistemic aim of avoiding cognitive dissonance. Items which contain ideas upon which participants may freeze may then be the most important subscale of RARE for predicting rejection of evolution. As religious fundamentalism has been shown to be the most important predictor in acceptance of evolution, it would make sense that item 20; *"I have no religious affiliation and therefore have no reason to reject evolution."* loads highly onto component 3:

Epistemic Ideals. If one is a fundamentalist, their ideals of what constitutes good knowledge should be directly influenced by their religious beliefs. Item 20 can therefore be said to be a good item in measuring Epistemic Ideals.

In terms of RARE 2.1, multiple regression 3, conducted in this research has shown that when each component of RARE 2.1 is entered into an equation predicting acceptance of evolution, the role of religiosity becomes non-significant. Interestingly, the addition of the components of RARE 2.1 does not reduce ECS to a non-significant predictor as with theistic evolutionists. Instead, Epistemic ideals and religiosity were found to be non-significant predictors. Epistemic Ideals are theorized to be the ideals to which one holds an explanation to be good. As is explained in the above literature review, those with creationists beliefs see religious accounts to have good explanatory power and are held to be ideal. Using only the components of RARE 2.1 shows that each component is indeed a significant predictor as per multiple regression 2. However, multiple regression 3 includes all RARE 2.1 components along with ECS, religiosity and religious fundamentalism. Although religiosity is non-significant, religious fundamentalism remains significant in this model. With the addition of religious fundamentalism, Epistemic ideals may be measuring a similar construct. *Epistemic ideals* can carry a religious component. Indeed, bivariate correlations show a high correlation between religious fundamentalism and epistemic ideals $r = .808$. However, this is only a marginally higher correlation than with Aims and Values $r = .768$ and reliable processes ($r = .729$). The fact remains that Epistemic Ideals is only non-significant when religiosity and religious fundamentalism are present in the model⁹ while Reliable Processes and Aims and Values remain significant in either model. These results further provide evidence as to the validity of RARE 2.1. As Epistemic ideals are theorized to differ based on one's religious affiliation (in particular for evolution), it would make sense that religiosity and epistemic ideals placed into the same model becomes redundant.

Between Groups Comparisons

Although there exists a correlation between ECS and Acceptance of evolution for the overall population, subsequent multiple regressions conducted only on those testing high in religious fundamentalism shows that ECS is only significant when religiosity and religious fundamentalism were included into the model. In contrast ECS was a significant predictor for those testing low on religious fundamentalism at each step. Religiosity, ceased to reach

⁹ This was checked conducting a multiple regression using RARE 2.1 components and ECS. Epistemic ideals were found to be significant in this model ($p = .01$)

significance when fundamentalism was entered into the model for both groups. Research has shown that perceptions of knowledge varies across domains (Muis et al., 2006; Owen, 2011), however, testing between different levels of ECS by field of study may not have supplied sufficient information in predicting acceptance of evolution.

ECS scores differ between groups of high/low religiosity and high/low religious fundamentalism which produced an interesting result. However, the effect size of ECS as per the multiple regression diminishes the importance of this result. Instead, RARE 2.1 scores, compared by field of study, might provide more useful information. As is seen in the above results section, Humanities and Science students do not score significantly different in terms of Reliable Processes and Aims and Values, but do score differently in terms of Epistemic Ideals. It could be that humanities students hold different ideals of what constitutes knowledge in evolution compared to science students. Further, Health sciences students and science students only significantly differ in terms of epistemic ideals. Humanities students and Engineering students differ only by aims and values. The implications of these differences can, for now, only be speculated. However, these results are encouraging in that it shows the different subscales of RARE 2.1 are answered differently across domains, suggesting again that knowledge is perceived differently across domains. These results seem to demonstrate that participants use different epistemic practices to evaluate knowledge. RARE 2.1 may, therefore be not only evaluating aspects of acceptance of evolution, but also one's Epistemic cognitions about evolution. Interestingly, no group differences were found between post-graduate and undergraduate students in terms of RARE scores.

When comparing Theistic evolutionists to those who reject evolution, it was found that theistic evolutionists have more closed ECS. Closed ECS would mean a more objective/authoritarian view of knowledge within science compared to open ECS which sees knowledge in science as more subjective/arbitrary. This makes sense when combined with Theistic Evolutionists salient reasons which cite evidence as their reasons for accepting evolution. These results suggest, that theistic evolutionists, when compared to religious rejecters of evolution, see scientific evidence as absolute. This, however, is an inaccurate view of knowledge within science. Evidence can be tenuous, misinterpreted or invalidated based on new data. Alternatively, it may be that these students see the current evidence for evolution to be overwhelming or scientifically sound. Based on theistic evolutionists, and the current sample in general, it does seem to suggest that more closed ECS seem predictive in assessing acceptance of evolution. The same pattern of results is observed for religiosity in general.

Those with high religiosity tend to have more open ECS and see science as less absolute or see science as subjective. This view of science, however should not be conflated with a sophisticated view of science as described in the literature above. Instead, this viewing of science as subjective is likely to demonstrate a lack of trust in the scientific method or way of knowing. Alternatively, it may be that those with high religious fundamentalism in fact do have a more sophisticated view of the nature of science. However, coupled with the above rejection reasons (lack of evidence/misconceptions of evolutionary theory) this explanation seems less likely. It must be noted that effect sizes for these analyses can only be describe as moderate at best. This is in accordance with ECS being a poor predictor of acceptance of evolution when religious fundamentalism is entered into the equation.

Bivariate correlations have shown that ECS negatively correlates with Acceptance of evolution and negatively correlates with both religiosity and religious fundamentalism. Higher (more open) scores on ECS correlate with lower scores on acceptance of evolution. Higher scores on ECS correlate with higher scores of religiosities. This is contrary to the results reported by Sinatra et al. (2003) which showed those with more static views on science as less likely to accept evolution. Cavallo and McCall (2008) found that students who view science as static are reported to be less likely to accept evolution as opposed to students who view science as tentative. Additionally, Coleman et al. (2015) found no significant correlation between NOS views and Acceptance of evolution for South African students. The current results seem contrary to these studies as ECS has been shown to be a predictor of acceptance of evolution. The current study found that those with more static views are more likely to accept evolution, the opposite of what was found in Cavallo & McCall (2008). Stahl and Bromme (2007) have argued that seeing science as open and dynamic represent a more sophisticated view of knowledge. The results of this study, indicate, contrary to what is hypothesised in the above literature review, that those with less sophisticated views about knowledge are more likely to accept evolution. However, as is suggested by Sinatra (2003) and Kienhues, et al. (2011), those who see conflicting evidence within a field may use these conflicts to reject a construct. Seeing science as more open may lead one to easier believe there to be conflicts within evolutionary theory. The difference in the finding may be in the way in which ECS was operationalized. NOS measures traditionally test more or less correct views as to the nature of science, whereas the CAEB tests connotative responses. As has been shown in the literature, understanding of evolution is an insufficient predictor of acceptance. Further, correct NOS understandings have been found to positively correlate with understanding and not acceptance (Coleman et al.,

2015). Therefore, NOS understandings may be akin to testing understanding of evolution. The CAEB may therefore be a more valid measure and may explain the difference in results.

Implications of the study

Contributions. This study provides support for Coleman et al.'s (2015) baseline figure for acceptance of evolution. This study has also provided conflicting evidence for the role of ECS in predicting acceptance of evolution. Future research should perhaps be conducted using different ECS measures. Alternatively, the CAEB could be used using 'knowledge in evolutionary theory' rather than 'knowledge in science'.

The psychometrics conducted for GAENE, ROT and religious fundamentalism show good evidence of high reliability and construct validity. The soundness of these measures provides good internal validity for the conclusions reached as to the role of religious fundamentalism.

Further, this research has demonstrated potential evidence for the validity of the AIR model. Encouraging results for the AIR model of epistemic cognition have been found in this study. RARE 2.1 was designed using the AIR model and subsequent CFAs have shown the model to fit relatively well within the current sample. Further instruments could be developed using the AIR model to assess epistemic cognitions more generally. However, the current instrument shows that designing evolutionary accepting or rejecting statements based on the AIR model demonstrate unique and varied effects in predicting acceptance of evolution. This model does not correlate highly with the CAEB which is encouraging as the CAEB theorizes a two-factor solution. Previous models of epistemic cognition offer a variety of theorized components which have been shown to be problematic (DeBacker et al., 2008).

This study has demonstrated the role of religious fundamentalism in predicting acceptance of evolution. In terms of the non-experimental design of this research, this study can make tenuous causality claims at best. Religious fundamentalism cannot be easily or perhaps at all manipulated. However, it does allow for comparisons between groups with religious fundamentalism being either present or absent. Contrast groups can be found in comparing low to high religious fundamentalism groups. In terms of temporal precedence, theoretically, religious fundamentalism probably precedes an opinion of evolution as religion is often taught to children from a young age (Wilkins, 2014), whereas evolution is only taught once children enter formal schooling. However, it may still be a tenuous assumption which

cannot be strictly shown. Covariation, however, is certainly present as religious fundamentalism and acceptance of evolution have been shown above to be significantly correlated.

Religious fundamentalism has been shown to be a better predictor of acceptance of evolution than religiosity. Future research should therefore focus on religious fundamentalism rather than only religiosity. Further, it has been found that those with high religious fundamentalism have misconceptions as to the origin of modern humans. This study has therefore shown the role of freezing in rejecting evolution. Educators should perhaps focus on addressing popular misconceptions when teaching evolution. Those that accept evolution have been shown to do so mainly on the grounds of evidence. Educators should therefore stress the evidence of evolution, while addressing possible misconceptions as to a ‘missing link’.

Limitations. Due to the design of this research, causal claims cannot be made. An unfortunate limitation of the study is that field of study could not be added into the multiple regression 2 as a predictor variable. However, the between groups comparisons by field of study remains informative.

As per compliance with the principle of informed consent, the key topic of the study (i.e. belief in evolution) was conveyed overtly to potential participants. An adverse reaction to answering questions about evolution may have precluded potential participants with higher religiosity from completing the survey. This may be evidenced by the low religiosity and religious fundamentalism means within the sample. Further, as mentioned in the above literature review, evolution may create a negative, affective emotional reaction from participants which may have influenced those with high religiosity to answer the instruments in a disingenuous manner. However, because univariate and multivariate outliers were removed from the multiple regression analyses, this effect may have been slightly controlled for. These participants’ potential negative reactions may still have influenced the results on some level.

The response rate for this study was very low. An email invitation was sent to the entire student body of the University of the Witwatersrand. The initial sample consisted of 838 students which was reduced to 476 participants based on the above selection criteria. The above considerations may have negative implications as to the internal validity of the study. The low response rate could potentially be explained by the order of the instruments’ presentation. CAEB was presented as the first scale within the study. CAEB may be a counter intuitive instrument to answer as it places knowledge in science on a spectrum rather than presenting on

a traditional Likert-type scale. Additionally, the study was presented to participants to be involving evolution. However, the first instrument they encountered involved knowledge within science, and this may have dissuaded participants from completing the study.

The CAEB was presented as the first measure to participants to prevent any priming affects from the evolution questionnaires in an attempt to prevent participants from deducing the above research questions. However, within the invitation to participate, potential participants were made aware of the fact that the study revolves around beliefs about evolution. This may have prompted religious students/those who reject evolution to answer the CAEB in such a way that sees science as more tentative or questionable. Those who accept evolution, in contrast, may have wanted to attest to the soundness of science. This may explain the negative correlation between ECS and acceptance of evolution. Further, the CAEB could only be analysed with one subscale (texture), as the subscale, variability, demonstrated poor reliability. The results of the study, especially in terms of the multiple regression, may have shown a more important role of ECS had the measure had been used as intended by its creators.

The current research was conducted on a student sample and these results may not be transferable to the general South African population. This is especially true of the mean acceptance of evolution and ECS. However, the role of religious fundamentalism and freezing should theoretically not differ between students and non-students. Further research should be conducted on the general population to compare these results.

Answering the research question comparing theistic evolutionists and those who reject evolution by ECS presented some challenges. Operationalising participants into theistic evolutionists was done by grouping together the lower 30th percentile of ROT (bottom 30 = higher religiosity) and the higher 30th percentile of GAENE. However, when operationalising those who reject evolution, the bottom 30th percentile of GAENE could not be used due to sample size constraints. Only 14 participants fell within the bottom 30% of GAENE, which again, suggests the data is negatively skewed. Additionally, the difficulty in creating groups based on the above criteria may lead to non-homogenous groups and be a threat to internal validity.

Recommendations for future research.

RARE 2.1 would benefit from a careful re-evaluation of the *Epistemic Ideals* component. This component is arguably useful in assessing acceptance of evolution or beliefs

about knowledge in general¹⁰. Based on the factor analyses above, it can be suggested that this component does require items similar to item 20.

Future research may want to specifically target theistic evolutionists and this group has been shown in this study to yield complex results. Additionally, a similar research design could be conducted on a more religious sample.

This research has shown the potential validity of the AIR model of epistemic cognition. Future research should be conducted using the AIR model as a more direct measure of epistemic cognitions either within domain general, or within domain specific epistemic cognitions.

Conclusion

Accepting or rejecting evolution remains to be a complex, multi-layered construct. The above research has found some interesting but not unexpected results. As is shown in the literature, religiosity, and in particular, religious fundamentalism are strong predictors of acceptance of evolution. However, ECS, although weak when added to a multiple regression model, still demonstrates moderate effect sizes when compared across groups. This study has shown the potential for the AIR model of epistemic cognition. RARE 2.1 appears to be a psychometrically sound instrument and can be used to assess one's reasons for accepting or rejecting evolution with relative accuracy. Epistemic ideals appear to be the least predictive component as it may require further development. Answering the above research questions; RARE 2.1 does appear to report reasonably good construct validity however more development of epistemic aims is required. 64,9% of variance is explained in predicting acceptance of evolution through the above variables. It has been shown that although each variable is a significant predictor, religious fundamentalism explains the most variance. Theistic evolutionists demonstrate a more authoritarian ECS compared to those who reject evolution. Religiosity and Religious fundamentalism present a negative relationship with ECS meaning that lower religiosity correlates with a more closed/authoritarian ECS and vice-versa. Finally, RARE 2.0 scores differ by field of study with science students achieving the highest RARE 2.0 mean and engineering students the lowest. No significant differences were found by comparing undergraduates and postgraduates.

¹⁰ As is evidenced by this component's correlation with religiosity. See above results section.

In conclusion, it appears one accepts evolution when one has low religious fundamentalism, closed/authoritarian ECS and understands the evidence for evolution. One rejects evolution when one has high religious fundamentalism, open/subjective ECS and has misconceptions about evolution. However, these variables may vary depending on one's field of study.

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Appendices

Appendix A: Religious Orientation Scale (ROT)

	1	2	3	4	5
How religious, do you consider yourself to be?	Very Religious	Quite religious	Fairly religious	Not very religious	Not at all religious
How often do you attend religious services?	Frequently	Often	Sometimes	Seldom	Never
How often do you pray?	5+ times a day	More than twice a day	Once a day	Only when necessary	Never
How often do you read Holy Scriptures?	Daily	Often	Occasionally	Seldom	Never
How often do you watch or listen to religious programmes	Always	Frequently	Sometimes	Rarely	Never
How important is your religious belief in your daily life?	Of utmost importance	Of great importance	Of some importance	Of little importance	Of no importance
Whenever science and sacred scripture conflict, science is probably right	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Scriptures contain general truths, but they should NOT be considered completely, literally true from beginning to end	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
All of the world's religions have flaws and wrong teachings. There is <i>no</i> perfectly true, right religion	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree

Appendix B: Generalized Acceptance of Evolution Evaluation (GAENE)

Everyone should understand evolution.	Strongly Disagree	Disagree	Agree	Strongly Agree
It is important to let people know about how strong the evidence that supports evolution is.	Strongly Disagree	Disagree	Agree	Strongly Agree
Some parts of evolutionary theory could be true.	Strongly Disagree	Disagree	Agree	Strongly Agree
Evolutionary theory applies to all plants and animals, including humans	Strongly Disagree	Disagree	Agree	Strongly Agree
People who plan to become biologists need to understand evolution	Strongly Disagree	Disagree	Agree	Strongly Agree
I would be willing to argue in favor of evolutionary in a public forum such as a school club, church group, or meeting of public school parents.	Strongly Disagree	Disagree	Agree	Strongly Agree
Simple organisms such as bacteria change over time.	Strongly Disagree	Disagree	Agree	Strongly Agree
Nothing in biology makes sense without evolution	Strongly Disagree	Disagree	Agree	Strongly Agree
Understanding evolution helps me understand the other parts of biology.	Strongly Disagree	Disagree	Agree	Strongly Agree
I would be willing to argue in favour of evolution in a small group of friends.	Strongly Disagree	Disagree	Agree	Strongly Agree
Evolution is a good explanation of how humans first emerged on the earth.	Strongly Disagree	Disagree	Agree	Strongly Agree
Evolution is a scientific fact.	Strongly Disagree	Disagree	Agree	Strongly Agree
Evolution is a good explanation of how new species arise.	Strongly Disagree	Disagree	Agree	Strongly Agree

Appendix C: The Connotative Aspects of Epistemic Belief (CAEB)

Knowledge in Science is:						
Precise (1)	2	3	4	5	6	Imprecise (7)
Sorted (1)	2	3	4	5	6	Unsorted (7)
Exact (1)	2	3	4	5	6	Vague (7)
Structured (1)	2	3	4	5	6	Unstructured (7)
Definite (1)	2	3	4	5	6	Ambiguous (7)
Absolute (1)	2	3	4	5	6	Relative (7)
Confirmable (1)	2	3	4	5	6	Unconfirmable (7)
Objective (1)	2	3	4	5	6	Subjective (7)
Negotiated (1)	2	3	4	5	6	Discovered (7)
Superficial (1)	2	3	4	5	6	Profound (7)
Open (1)	2	3	4	5	6	Closed (7)
Completed (1)	2	3	4	5	6	Uncompleted (7)
Refutable (1)	2	3	4	5	6	Irrefutable (7)
Dynamic (1)	2	3	4	5	6	Static (7)
Temporary (1)	2	3	4	5	6	Everlasting (7)
Flexible (1)	2	3	4	5	6	Inflexible (7)
Stable (1)	2	3	4	5	6	Unstable (7)

Appendix D: Participant Information Sheet



Psychology
School of Human & Community
Development
University of the Witwatersrand
Private Bag 3, Wits, 2050
Tel: 011 717 4503 Fax 011 717 4559



Dear Sir / Madam

Good day

My name is Jason Viviers and I am currently completing my masters degree in psychology and am being supervised by Dr. Michael Pitman. I am inviting you to participate in my research on evolutionary acceptance and rejection within students attending the University of the Witwatersrand (Wits). If you choose to participate, please follow the provided link to complete provided surveys. Participation will consist of completing a demographic questionnaire, questionnaires addressing evolutionary acceptance, beliefs about the nature of science, reasons for evolutionary acceptance or rejection and religiosity. Participation is completely voluntary and will take up to 25 minutes to complete. You may withdraw from participation at any time during completion of the questionnaires without any penalty. All participants will remain anonymous.

Choosing to begin and/or complete the above-mentioned questionnaires will serve as voluntary consent.

To further ensure your anonymity, IP addresses will not be recorded. Only myself and Dr. Pitman will have access to the raw data which will be stored on a password protected computer. While feedback of specific, personal results is not possible due to anonymity, my email address and cell phone number are provided below if you have any further interest in the general results of the study. If participation in this research causes you any distress, I will be available for consultation and numbers for the Wits career counselling and development unit (CCDU) as well as for the Emthonjeni centre are provided below to allow for you to seek counselling.

Thank you for taking time to

consider this invitation and your participation would be greatly appreciated and add to current understanding of evolutionary acceptance or rejection in South Africa.

Researcher contact details: Jason Viviers: Tel: 079 880 1025. Email: Jason.Viviers@students.wits.ac.za

Wits CCDU contact details: 011 717 9140 / 32

Wits Emthonjeni centre contact details: Director: Prof Karen Milner. Email: karen.milner@wits.ac.za. Tel: 011 717-8663

Appendix E: Ethical Clearance certificate



Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

R14/49 Viviers

CLEARANCE CERTIFICATE**PROTOCOL NUMBER: H16/05/24****PROJECT TITLE**

Evolution is for the birds: Reasons for students' acceptance or rejection of evolution

INVESTIGATOR(S)

Mr J Viviers

SCHOOL/DEPARTMENT

Human and Community Development/

DATE CONSIDERED

20 May 2016

DECISION OF THE COMMITTEE

Approved unconditionally

EXPIRY DATE

20 June 2019

DATE

21 June 2016

CHAIRPERSON

(Professor J Knight)

cc: Supervisor : Dr L Buckland

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

 Signature

 Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix F: Inter-Item Correlation Matrix

Inter-Item Correlation Matrix	R22									
		.686	.624	.759	.802	.661	.646	.682	.716	.734
	R21		.548	.656	.656	.584	.502	.588	.634	.644
	R20		.441	.373	.510	.477	.450	.426	.428	.468
	R19		.658	.640	.654	.693	.602	.554	.722	.707
	R18		.531	.521	.614	.612	.483	.542	.525	.530
	R17		.557	.473	.618	.571	.405	.528	.455	.549
	R16		.609	.636	.670	.709	.679	.584	.655	.731
	R14		.633	.667	.678	.701	.680	.594	.690	.709
	R13		.679	.659	.771	.786	.604	.636	.674	.698
	R12		.579	.608	.645	.655	.549	.507	.568	.661
Inter-Item Correlation Matrix	R11		.601	.671	.668	.700	.647	.596	.685	.691
	R10		.646	.686	.691	.761	.642	.619	.721	.726
	R9		.642	.695	.689	.721	.627	.631	.698	1.000
	R8		.595	.678	.646	.689	.620	.624	1.000	.698
	R7		.644	.599	.659	.708	.529	1.000	.624	.619
	R6		.599	.580	.629	.643	1.000	.529	.620	.642
	R5		.697	.656	.766	1.000	.643	.708	.689	.721
	R4		.701	.656	.766	.629	.659	.646	.689	.691
	R3		.606	1.000	.656	.580	.599	.678	.695	.686
	R2		1.000	.606	.697	.599	.644	.595	.642	.646

	.682	.635	.780	.715	.704	.587	.625	.685	.533	.605	1.000
	.653	.647	.622	.722	.682	.414	.438	.653	.419	1.000	.605
	.425	.453	.521	.473	.530	.423	.427	.419	1.000	.419	.533
	.703	.591	.659	.685	.684	.450	.466	1.000	.419	.653	.685
	.506	.446	.620	.520	.499	.446	1.000	.466	.427	.438	.625
	.431	.520	.560	.480	.484	1.000	.446	.450	.423	.414	.587
	.703	.653	.695	.722	1.000	.484	.499	.684	.530	.682	.704
	.688	.637	.710	1.000	.722	.480	.520	.685	.473	.722	.715
	.671	.627	1.000	.710	.695	.560	.620	.659	.521	.622	.780
	.621	1.000	.627	.637	.653	.520	.446	.591	.453	.647	.635
	1.000	.621	.671	.688	.703	.431	.506	.703	.425	.653	.682
	.723	.661	.698	.709	.731	.549	.530	.707	.468	.644	.734
	.691	.642	.714	.684	.671	.528	.545	.684	.480	.634	.716
	.685	.568	.674	.690	.655	.455	.525	.722	.428	.588	.682
	.596	.507	.636	.594	.584	.528	.542	.554	.426	.502	.646
	.647	.549	.604	.680	.679	.405	.483	.602	.450	.584	.661
	.700	.655	.786	.701	.709	.571	.612	.693	.477	.656	.802
	.668	.645	.771	.678	.670	.618	.614	.654	.510	.593	.759
	.671	.608	.659	.667	.636	.473	.521	.640	.373	.656	.624
	.601	.579	.679	.633	.609	.557	.531	.658	.441	.548	.686
R11	R12	R13	R14	R16	R17	R18	R19	R20	R21	R22	

Appendix G: RARE 2.0 Item generation.

Scale	Qualitative example	Possible items
Reliable processes	I used to be on the fence about evolution until i started reading a magazine called Creation, it reconciled scientific facts and biblical events thus making me realize that Science in itself corroborates The Bible	Experts have presented evidence for and against evolution. The evidence seems to suggest evolution did not occur.
	No one has seen it happening,it is just a theory without firm facts.	Evolution has not been observed by humans therefore no one knows if it occurred.
	I'm studying science and strongly believe in the power of the scientific method to make objective conclusions regarding a subject. Evolution started as a hypothesis and has been put through the scientific method. there is sufficient evidence for it to be considered a valid scientific theory.	Evolution has been rigorously proven via the scientific method.
		Because the theory of evolution has been through many peer reviewed processes and scientists accept it, I believe in evolution.
		I have been told by my parents/church that evolution is false and I believe their testimony to be true.
Epistemic Aims and Value	- I also doubt it makes any difference to a rational person's life whether life is a product of God or spontaneous accident and research of human origins is a pitiful waste of resources. - Comparing Science & Religion serves virtually no purpose for me; it is often an insult to both when we do. - Life is way too short and complex to be placed on paper and somethings are too complicated for mere human understanding	There is no good reason to study evolution. Life is too complex to be explained through evolutionary theory.
	...for the fact that there are missing links we shouldn't conclude that it's true and some human body parts are far too complex to have evolved, like neurons, eyes and more...	The theory of evolution suffers from too many missing links thus there is not enough evidence to support this theory. Life is far too complex to be explained by evolutionary theory.
	The law of natural selection doesn't make sense-<u>Moral law</u> contradicts the existence of such law e.g killing for survival would be justified if law of natural selection was valid	If the theory of evolution were true, there would be no objective morality. Therefore, evolution is false.
		I learned about evolution during my studies (or personal research) and

		learning about evolution has led me to accept it.
Epistemic Ideals	• ...I'm Christian and therefore do not believe in human evolution as God created MAN not apes or fish that later turned into man. • reject. it is not a fact and has too many missing links whereas the bible doesn't • I reject theory of evolution because the Bible is clear as to how living things came into being.	I reject evolution because it stands contrary to my religious beliefs. My religion gives an account of the origin of species on Earth which I find to be credible
	• Additionally, a great number of scientists also disagree with this theory, hence a person with limited knowledge, such as I, would like to think that if this was an accurate theory, more scientists would agree with it rather than reject it.	Most scientists disagree whether evolution is true. If evolution were true, the clear majority of scientists would agree evolution is true. Therefore, evolution is false.
	• Creationism is illogical, evolution is sound • I have no faith to interfere with my beliefs. • It makes logical sense and a lot of research has gone into proving it. Also, I don't believe in god.	I have no religious affiliation and therefore have no reason to reject evolution.