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Cognitive Apartheid: On the Manner in Which High School Students Understand Evolution without Believing in Evolution

Ronald S. Hermann

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Abstract High school science students are often unwilling to learn about evolution due to a perceived conflict with their religious beliefs. Other students are able to understand evolution despite the fact that they do not believe in evolution. According to Cobern (Sci Educ 80:579–610, 1996), students can wall off that which is believed from that which is not believed in a process he called cognitive apartheid. A mixed-methods study was conducted to determine the extent to which understanding of evolution differed among high school Advanced Placement science students who did and did not believe in evolution. Two students who demonstrate a sophisticated understanding of evolution despite their admonition that they do not believe in evolution were then interviewed. Eight themes emerged from the interview that provide insight into the views of students learning of evolution despite the fact that they do not believe in evolution. Based on these themes, several implications for the teaching of evolution are presented.

Keywords Evolution · High school students · Belief · Understanding · Cognitive apartheid

Introduction

One of the challenges in teaching is not necessarily teaching those who want to learn, but in teaching those students who do not want to learn. A subset of students in the science classroom may be unwilling, or unable, to learn evolution. Often, students are unwilling to learn about evolution due to a perceived conflict with their religious beliefs. This study examines students who are able to demonstrate a sophisticated understanding of evolution despite their admonition that they do not believe in evolution. Moreover, how are students able to separate their beliefs about evolution from their understanding of evolution? Cobern (1996) posited the notion of compartmentalization to explain some apparent student misconceptions. He argued that many misconceptions are the result of students' compartmentalizing or disregarding scientific knowledge rather than a true lack of understanding. This notion may also explain how students can simultaneously hold both scientific understandings and religious beliefs that may be counter to the scientific conceptions of the same phenomenon. According to Cobern (1996), students can wall off that which is believed from that which is not believed. As such, this study provides insight into what it is like for a group of students who do not believe in evolution to experience the teaching of evolution in a high school setting.

R. S. Hermann (✉)
Department of Physics, Astronomy and Geosciences,
Towson University,
Towson, MD 21252, USA
e-mail: rhermann@towson.edu

Belief and Understanding

In order to fully engage the research question of whether students can understand a scientific concept without believing it, we must delve into the meaning of the terms belief and understanding. Ha, Haury and Nehm (2012) stated that "believing, knowing and accepting are intimately related terms, all having a form of belief as a component" (p. 97). Cobern (1996) stated that knowing is the metaphysical process by which one accepts a comprehended concept as true or valid. In this view, knowing is characterized by the extent to which one accepts the validity of a concept. One must have a logical or rational justification for accepting the validity of a concept. Understanding is the thinking process that results in the comprehension necessary for knowledge (Cobern 1994). Sinatra et al. (2003) described knowledge as a proposition that has some sort of correspondence with

reality, and for which the learner must have valid reasons that justify the acceptance of that proposition. Beliefs are a subjective way of knowing. There is, however, considerable ambiguity in the use of the term "belief." Scientists may accept or reject a theory based upon the evidence provided, but scientists tend to refrain from stating that they believe in a theory. Belief conjures the idea of a personal judgment that may lack supporting evidence, often referred to as "blind faith." Smith (1994) articulated the inherent difficulty of using the word "belief" in science as most scientists and science educators assume that "belief" means acceptance on the basis of current evidence, whereas students and their parents assume that acceptance is a matter of personal faith that has no evidential basis. To that end, Smith suggested that scientists and science educators refrain from using belief when outside the company of those who share their understanding of the term. Other researchers have comfortably implemented the term belief when referring to scientific theories. Brickhouse et al. (2002, p. 582) stated that "justifying belief in a scientific theory is always a matter of practical reasoning in which a variety of criteria are weighed in making a decision on acceptance or rejection." Their research suggests that warrants for belief in a concept are largely dependent upon the topic discussed. Shipman et al. (2002) concluded that understanding implies knowledge of a scientific theory, including its supporting evidence, and the degree to which it is accepted by the scientific community, whereas belief is accepting an explanation as being correct. Therefore, one can believe an explanation without understanding it.

Adherence to a religious belief system has been claimed to influence the extent to which evolution is believed (e.g., Bishop and Anderson 1990; Demastes-Southerland et al. 1995a, b; Woods and Scharmann 2001), perceived (Hokayem and BouJoude 2008) or understood (e.g., Lawson and Worsnop 1992; Sinclair and Pendarvis 1997; Rutledge and Mitchell 2002). There may be, as Sinatra et al. (2003) suggest, no relationship between belief and understanding of evolution. However, Laswon and Worsnop (1992) suggested that strength of religious commitment may be negatively correlated with initial belief in evolution. Lord and Marino (1993) indicated that roughly three quarters of the 392 university students surveyed said they believe the theory of evolution but most don't understand the scientific mechanism of the theory. These findings remind us that it is just as probable that students believe and do not understand as it is for students to understand and not believe in scientific theories (Bishop and Anderson 1990; Demastes-Southerland et al. 1995; Jakobi 2010).

In this study, the interaction of belief and understanding within a framework of cognitive apartheid is explored. In the context of this discussion, I use the terms knowing, believing, and understanding as follows: belief is used as a subjective way of knowing that lacks verifiable evidence, knowing is the acceptance of concepts as valid or invalid based upon verifiable evidence, and understanding is the comprehension of concepts and their supporting evidence.

The purpose of this exploratory mixed methods research study is to (1) investigate the relationship between belief in a scientific conception and ability to understand that scientific conception for high school Advanced Placement (AP) science students at a public high school in the mid-Atlantic region and (2) develop a deeper understanding of students' compartmentalization of scientific knowledge that is not consistent with their worldview because of opposing religious views.

Methods

A quantitative study was utilized to address the first purpose and a qualitative study to address the second. Creswell (2003) refers to this type of mixed methods study as sequential, in which the quantitative method allows the testing of theories or concepts followed by a qualitative study involving a detailed exploration with a few cases or individuals.

First, a causal-comparative study was employed to determine if students who believed in evolution and the big bang theory demonstrated a greater degree of understanding than those students who do not believe in these concepts. The questions required students to correctly write a brief constructed response regarding the scientific view of a concept and correctly state supporting evidence for the scientific concept. The questions were developed from information from current literature, textbooks, and curriculum guides.

Second, a case study was employed to understand AP science students' practice of compartmentalizing scientific knowledge that does not fit their natural way of thinking. Cobern (1996) used the phrase cognitive apartheid to describe students' ability to wall off scientific knowledge and later retrieve it on special occasions, such as school examination, while insulating their everyday lives from its effect. The case study component of the research seeks to understand how students retain and partition science knowledge even when they do not believe in the concept. This research also addresses the reasons students give for not believing in the concept, focusing on a perceived conflict with religious teachings. Finally, do students perceive, as Coburn suggests, sufficient pressure that keeps knowledge compartmentalized even if it is not currently being used? In other words, why do students keep this knowledge if they do not believe it and do not have to use it?

Quantitative Component

Participants from three high school AP classes were given a survey and a knowledge test. This population was selected

because AP science students are certain to have encountered these concepts and to have had ample opportunity to learn them at a degree of sophistication that is higher than that to which students in less rigorous classes would be exposed. Forty-seven student participants were drawn from three classes of one public high school: AP biology (n=9), AP chemistry (n=14), and AP physics (n=24). The average age of participants was 17.13 and 29.8% were female and 68.1% were male. More than half, 55.3%, currently attend church, 29.8% have attended a religious organization in the past, and 14.9% have not attended a religious organization. The majority of the participants (70.2%) have held their religious beliefs for over 13 years.

The survey and test were administered during the same week in all three classes to reduce the chance that participants would talk about the content with other students who might later be asked to participate. Participants were given the survey and test to complete during their regularly scheduled class. Participants were asked to complete the survey first and then begin the test section. The survey and test were completed within 30 minutes.

Instruments

The researcher-developed instrument used in this causal-comparative study contained two sections; a survey and a knowledge test. The survey included questions about demographic information, science experience, and religious experience. In this section, participants were asked to identify the extent to which they accept (believe in) scientific theories on a six-point Likert-type scale ranging from strongly accept to strongly reject. If participants responded that they reject the theory, they were asked to indicate the reason why they reject the theory.

The researcher-developed knowledge test contained a series of content-related questions regarding specific concepts such as evolution and the big bang theory. These knowledge questions were selected from current biology and earth science textbooks. Participants answered brief constructed response questions regarding their current understanding of scientific concepts. Brief constructed responses were scored with a four-point rubric, four (4) being the most correct and one (1) being the least correct response. The brief constructed responses were scored by two researchers and the mean score was recorded for analysis.

According to participant responses on the first part of the instrument, which queried the extent to which evolution and the big bang theory were believed, participants were placed into two groups that are at the extremes of belief in the scientific theories. Participants that selected a response indicating a strong or mild belief in a theory were grouped together and participants that selected a response indicating a strong or mild rejection of a theory were grouped together. Gall, Gall, and Borg (2003) state that the extreme groups method assumes that extreme groups are more likely to differ on the measured variables than comparison groups that also differ on score distribution. Though there are limitations associated with the approach, extreme groups analysis has been widely used within the social sciences for decades and has been found to be suitable when research is still in the exploratory phase (Preacher et al. 2005). This exploratory study assumes that the extreme groups of the belief variable are more likely to differ among understanding of scientific explanations.

Qualitative Component

A qualitative research approach was taken to identify the interactions between participants' scientific understanding and religious beliefs. Specifically, how can participants compartmentalize scientific knowledge they do not believe? Beyond the description of Cobern (1996) on cognitive apartheid and the description of Roth and Alexander (1997) on students' scientific and religious discourses, minimal empirical research has been conducted on this topic. While cognitive apartheid may be a descriptive term that describes the result, the mechanism by which knowledge is compartmentalized is unfamiliar territory. To date, an in-depth understanding of how students may deal with conflicting conceptions has not emerged within the context of science and religion issues. The purpose of this exploratory study is to provide a deeper understanding regarding students' perceptions of the interaction between the scientific understandings and religious beliefs through the development of a grounded theory of cognitive apartheid. Bogdan and Biklen (1998) define grounded theory as deriving universal statements of general social processes. Such statements are possible because human behavior is not random. The current research seeks to derive a general, abstract theory regarding the ability to conduct cognitive apartheid and the methods employed to compartmentalize knowledge not believed by participants. By shedding light on how students deal with a conflict between understanding and believing, educators may be more likely to facilitate an understanding of science even though students may not believe in the scientific knowledge.

Participant Vignettes

Two students who achieved a high score on the test on the science conceptions of evolution and the big bang theory participated. Both participants identified themselves as not believing (rejecting) evolution and the big bang theory because of their conflicting religious beliefs.

Aidan is an eleventh grade student who is known by peers and teachers alike as an outgoing, intelligent, athletic

African-American male. Aidan has maintained a 4.0 grade point average throughout most of his educational history. Currently, Aidan plays two sports and is actively involved in student government as class president.

Krista is a senior who is also well regarded by peers and teachers as an intelligent and athletic Caucasian female. Krista aspires to become a veterinarian upon completion of post-secondary education. Krista has been a master tutor in an earth science course taught by the author. In this role, Krista acts as a peer helper to younger students with learning disabilities who are currently enrolled in special education services. As such, she has been present during classroom discussions of the big bang theory within the earth science class.

Semi-Structured Interviews

Data collection consisted of semi-structured interviews and written responses to essay questions on the knowledge test. Each participant was requested to participate in a semi-structured interview on the topic of belief and understanding. The interviews were recorded for the purpose of transcription. The interview with Krista lasted approximately 30 minutes and resulted in ten transcribed pages of text. The interview with Aidan lasted approximately 25 minutes and was transcribed to 13 pages of text. Both participants were presented with the transcribed interview for review and were given the opportunity to clarify any misunderstandings, and later they read a summary of the findings.

Analysis of the Data

Descriptive statistics were computed for both comparison groups in the study, those who accept (believe in) the science theories and those who reject the science theories. The mean and standard deviation of scores on the knowledge test were computed using the Statistical Package for the Social Sciences. An independent samples *t* test was computed to compare the mean scores for two groups, those who accept the science concept and those who do not, for each science concept. Each *t* test was computed as a two-tailed test of significance.

The method of qualitative data analysis conformed to the approach known as constant comparative analysis. This process involves open and axial coding in which data are broken into pieces and coded. The coded pieces of data were repeatedly sorted and recombined in the search for categories and patterns. Initial codes were sometimes derived from participants' words *in vivo* and sometimes from the categories that appeared in the existing literature on this topic (Barbour 1997; Shipman et al. 2002; Nord 1999). Emerging categories and patterns were confirmed by comparison with other pieces of data and by a deliberate search for disconfirming evidence. Creswell (2003) describes this method of constant comparison as one of the primary characteristics of a grounded theory.

Ninety codes were assigned to the data. There were 14 codes that were common to both participants, and 76 were present in only one or the other of the two participants. The coded data was analyzed to establish categories. Each category was arrived at by an analysis of the 76 codes. The codes were clustered together to form eight categories. To validate the categories, each original transcription was read to reexamine the meaning of the code. For example, Krista spoke of being in conflict at times, and at other times she spoke of trying to "put the two together." Based on the body of literature previously mentioned, these data were coded as "conflict" and "integration," respectively. Both of these codes were put back together, axial coding, to form a category labeled "science and religion relationship." The initial codes were reexamined to identify data that also could be assigned to this category.

Quantitative Findings and Discussion

The following results compare the knowledge scores as determined by paper-and-pencil test for two extreme groups: those that believe in evolution and the big bang (referred to as "believe science") and those that do not believe in these science concepts (referred to as "don't believe science"). The results of the *t* test (Table 1) indicated that no significant difference ($t=-0.71$, $p=0.48$) exists between the two extreme groups, those that believe in evolution and the big bang theory ($n=37$) and those who do not ($n=10$), on the understanding of the concepts as indicated by the combined score of the six paper and pencil test questions (total score). These results are for all three classes combined: biology, chemistry, and physics. In some instances, students who do not believe in the scientific concept scored higher than those students who do believe in the concept, though the difference was not statistically significant.

The results of the statistical analysis of the scores on the knowledge test suggest that belief in evolution or the big bang theory is not related, positively or negatively, to understanding of the science concepts. The mean score for the knowledge test did not differ significantly for students who believe and students who do not believe in evolution or the big bang theory. The mean was slightly, although not statistically, higher for the students who do not believe as compared to those who do believe. Bishop and Anderson (1990), Demastes-Southerland, Settlage, and Good (1995), Lord and Marino (1993), and Sinatra et al. (2003) have found similar results, each concluding that the interface between belief and understanding is incomplete, and one may understand regardless of belief.

Table 1 Comparison of knowledge question scores for AP science students who do and do not believe in evolution and big bang theory

Knowledge question	Believe science (n=37)		Do not believe science (n=10)		95% CL	
	Mean	SD	Mean	SD	t Value	p
Please provide a statement that you think a scientist would give to describe evolution	3.57	0.77	3.70	0.48	−0.52	0.61
What evidence do you think a scientist would provide for the theory of evolution?	3.27	0.84	3.60	0.52	−1.18	0.25
Please provide a description of natural selection and the role of natural selection in the evolution of a species	3.65	0.63	3.80	.0.63	−0.67	0.51
Please provide a description of how a scientist would describe the origin of the universe	3.49	0.99	3.50	0.71	−0.04	0.97
What evidence do you think a scientist would provide for the big bang theory?	2.57	1.17	2.40	1.17	0.40	0.69
According to scientists, how old is the universe?	2.24	1.30	2.70	0.82	−1.05	0.30
Upon what evidence do scientists base this age?	18.78	3.82	19.70	2.75	−0.71	0.48
Total score for all six knowledge questions						

One notable factor that may have impacted these findings is that 10 of the 47 participants (21.3%) of the sample did not believe in evolution or the big bang theory. This may be due to the fact that AP science class enrollment is made up largely of students with a developed interest in the sciences. These students may be predisposed to accepting a more scientific worldview as compared to the general student body. Future research with science students in general science classes may yield additional insights. A wider sample population may have provided results that would address the findings of Lawson and Worsnop (1992) who suggest that students with less developed reasoning skills are more likely to maintain nonscientific beliefs.

The results of this study indicate that understanding of controversial issues is not predicated upon one's belief in a concept or set of concepts. Cobern (1996) speculated that this may be due to pressure, perhaps in the form of examinations, which requires students to maintain sufficient understanding of science concepts. As with most research, these findings led to several other questions which seek a deeper, richer understanding of how and why 10 of the 47 students in this study can maintain a high degree of understanding for two controversial topics which they vehemently reject. Pressure exists for every AP science student to learn content knowledge, but how do students who do not believe maintain just as thorough an understanding as those who do believe in the concepts? How do students maintain the walled off concepts that they don't believe? Do they view these concepts as conflicting with their religious beliefs? With these questions in mind, we designed a follow-up qualitative case study in an attempt to provide a fuller understanding of what Cobern called cognitive apartheid.

Qualitative Findings and Discussion

The analysis of the data resulted in a grounded theory for cognitive apartheid of science concepts, which contains several interrelated assumptions. The use of the term "students" is used in the following sections to mean students of science who do not believe some science concepts because of conflicting religious beliefs. Krista and Aidan are examples of students as described in this context.

Relating Science and Religion

Students seem to lack a consistent worldview concerning the relationship between science and religion issues. Participants seem to hold integrated views, conflicting views, and religious views simultaneously. One aspect of cognitive apartheid appears to be a search for an integrated position. Aidan talked about trying to integrate science and religion based on a movie portraying the Scopes trial which he once saw in a science class. Aidan stated,

> God created the earth in seven days, but the Bible doesn't specifically say how long, it doesn't specify how long a day is. I mean, it may be God's day is different than a twenty-four hour day. And I thought that to be a good point so maybe, and that kind of came together with what one of my teachers said how for all we know God could have created animals through evolution, and so I kind of piece those together as a possibility.

Inevitably, however, the position becomes one of conflict. In searching for an integrated view, a discrepancy arises between science and religion. A barrier to an integrated view exists due to a disagreement with an accepted scientific conception. Krista provides an example of an attempt at integration that resulted in a conflict. "You just have that, the, the man being from God's, like, his own image. And that can't come from, like, evolution. Cause I was thinking, well, what if God just made all the animals evolve and that's how He created them. But then no, cause that doesn't work with humans." As students try to sort out

that which they understand from that which they believe, students with a strong religious background may uncover a conflict which they cannot overcome. The conflicting statements ultimately result in the adoption of a religious perspective since students are coming to science classes after they have formulated a deep religious worldview. Aidan described reverting to religion when he perceives a lack of personal scientific understanding, "I don't know enough to make a real good judgment. I just try and take the Bible as its literal interpretation, and kind of leave the science stuff alone."

Compartmentalization

Another aspect of a grounded theory for cognitive apartheid is the ability of students to compartmentalize that which they believe from that which they do not believe. At the outset, this appears to be a simplistic interpretation, but the process is very complex and not fully understood by the students themselves. The existence of clear guidelines for what is believed and what is not believed are lacking and may form at any instant. The lack of clear rules for acceptance is bothersome to the student, but indicates a desire to avoid thinking about the process. Aidan indicated a clear distinction between what he understands and what he believes. "the science stuff we learn about evolution and stuff like that all the time, like I understand it, but I definitely don't believe in it." When asked about how he could understand something without believing it, Aidan remarked, "Like this is what is being taught, just understand it and (unintelligible), and I don't really think much of it." He spoke of the need to "block it out" and learn the information for school to maintain his academic standing. Later Aidan seemed to contradict this notion by stating, "I think I should understand where other people are coming from, so I just can't block it out, that's not going to make it go away, you know."

So it seems that the process of "blocking it out" is unclear and ambiguous in nature. From Aidan's perspective, the way to compartmentalize is based upon what is believed, but to also understand that which is not believed. "Just understand where it's coming from, understand the theory and take it just as a theory, you know, don't take it as this is what you have to believe, but just look at it as pure science, not religion." Aidan has a compartmentalization scheme based upon categories of belief. To explain how he understood evolution, despite his lack of belief in the concept he stated, "I know the theory and I have it categorized in my mind as, as what I think of it, you know, like, like an opinion on it." This ambiguous designation is evident within Aidan's understanding of the theory of evolution. Aidan rejects the theory as a whole but accepts some parts of the theory, stating "I believe that species adapt. I believe that's probably true" but went on to placing limits to this belief such as, "I don't believe that we necessarily evolved from apes."

For Krista, the process of compartmentalizing information was far more ambiguous. She felt a great deal of uncertainty and acknowledged a feeling of being hypocritical about the process, feeling as though she was "picking and choosing" what to believe in. Krista spoke of a compartmentalization scheme that was dependent upon the topic. She spoke of the small and the large. The "large is little molecule things" meaning the conceptual leap of understanding how evolution at the molecular level can result in changes at the macro level, such as speciation. An example of small changes was the difference in beak structure and function among the finches of the Galapagos Islands as described by Darwin. Krista accepted the small changes but not the large changes.

Krista stated that it made sense for cats and dogs to share a common ancestor at some point, but "that apes and humans have a common ancestor that would be wrong." A lack of belief in the theory of evolution seemed to be more apparent when the discussion centered on human evolution. Krista chose to accept several tenets of the theory of evolution, but rejected the aspects of the theory regarding human evolution.

Cognitive apartheid, or the compartmentalization of knowledge, appears to be determined by a flexible notion of what is believable and what is not. The guidelines for what is compartmentalized do not appear to be firm, and in-depth thinking on the topic has been avoided. Both participants seemed to know what they would accept, but expressed difficulty or discomfort with stating the guidelines for acceptance. The selective nature of cognitive apartheid seems related to the struggle to integrate science and religion. However, when the integration leads to conflict, the religious perspective is adopted and the concept enters into a compartment of that which is not believed within the cognitive apartheid scheme.

Ways to Deal With Science and Religion Issues

When faced with science conceptions that conflict with religious beliefs, students devise ways to deal with the conflict. The process of cognitive apartheid is not without conflict and ambiguous categorization; nevertheless, the rejected science concepts remain in long-term memory. As such, students maintain several views that facilitate the process. Primarily, students seek to distance themselves from the conflict that they experience. By viewing the science conceptions as facts, students are able to categorize the concept differently than a belief. Krista stated, "I don't think I, like, put my emotion into it." and "I don't really think about it." Aidan had a similar view expressed as, "I

really don't think of it much." An avoidance of reflecting on science and religion issues is one way to deal with the issue; attempts at integration is another.

One example of integration of science and religion issues was identified by Krista, who said that by relating what is written in science books to what is written in the Bible, she is more likely to remember the science concepts. She also related the evolution issues to her love of animals, "I probably wouldn't forget it, cause I like animals and I like learning about that kind of stuff anyway." While these examples illustrate an attempt at integration, they also describe an attempt to relate what is not believed to something that is believed. This sort of analogous belief is a method of comparing accepted beliefs to rejected beliefs in hopes of better understanding the rejected belief.

Going Against Religion

Within the science classroom, there are times when students must be able to demonstrate an understanding of scientific knowledge even if it conflicts with religious belief. While this may be viewed as a conflict, it also demonstrates the strength of external pressure of examinations. In a sense, the study of science concepts can be a cause of conflict by creating a pressure that goes against religious teachings. From this standpoint, pursuing some aspects of science can be viewed by students as going against religion. The following excerpt from an interview with Krista illuminates this view:

> KRISTA: If you go more on farther into the science field, um you, I don't want to, like, lose my relationship with God or whatever. You know?
> INTERVIEWER: Do you think you, you would?
> KRISTA: Ah, yeah I think I would and I'd be upset.

Aidan also expressed a similar notion stating, "Sometimes it feels like I'm going against my beliefs." When asked how scientists with a deep religious faith might deal with this issue, Krista said they probably try to integrate science and religion. However, it appears that the students are unable to integrate science and religion in this manner, resulting in the perceived conflict. A feeling of losing religious faith emerges and the student adheres to the religious view, further rejecting and compartmentalizing the scientific concepts. It should be noted, though, that Bishop and Anderson (1990) have reported that their results indicated that improved understanding of evolution did not change student's convictions about the truthfulness of the theory or cause students to abandon religious beliefs.

Reasons to Understand

Although students do not believe the scientific concepts that they perceive to be in conflict with religious belief, there appears to be significant pressure to understand the concepts. This pressure takes several forms, some of which are self-imposed, while others are perceived as being forced by external sources. A common characteristic of AP science students appears to be a desire to learn and understand. To that end, one reason to understand science concepts that are not believed is to fulfill an internal motivation to learn. A desire to learn and, to an extent, enjoying science provides a pressure to compartmentalize science concepts.

The fear of a lower grade is an external pressure; as Aidan stated, "I just block it out and do it because, I mean, otherwise I fail or something like that, and I'm not going to sacrifice that." This view was more important for Krista, who was going to take the AP biology examination, and expressed the unlikelihood that a religious answer to an evolution question would be viewed as acceptable. Krista said, "For the AP bio test, cause you can't write on there, God created humans and all the things cause they'll just be, like, zero [score]." Another type of pressure is the need to know the science concepts for future coursework at institutions of higher education. One other form of pressure emerged: the scientific understanding could be useful for debating issues like evolution. Aidan put this idea rather succinctly, "If you're going to argue against it, you kind of got to know everything about it." Regardless of the form of perceived pressure, there does appear to be both internal and external pressure to understand science conceptions that are not believed, resulting in compartmentalization of controversial science concepts.

Lack of NOS Understanding

Another aspect of a grounded theory for cognitive apartheid is a lack of understanding regarding the nature of science (NOS). Both participants had completed numerous science courses and were taking an AP science course at the time of the study. However, inconsistencies arose regarding the nature of science. A poor understanding of the methods and underlying philosophy of science was evident throughout the interviews. Whether this lack of understanding of NOS was legitimate or a mechanism by which to differentiate science and religion is unclear.

There appears to be a good understanding of the need for accumulated evidence to substantiate claims made within the realm of science. Participants spoke of evidence within the context of the discussion and used the evidence to substantiate their claims. They were clearly able to speak about specific aspects of theories. However, there may be an acceptance of evidence based upon the role of the scientist as expert. At times, the role of the scientist and knowledge produced by scientists seemed to be placed higher than other forms of knowledge. For example, "It's kind of hard, because, your, like, wow these scientist people have a lot of

proof (Krista).” Krista seemed to distance herself from the scientists by positioning them in an authoritative position of more worth than herself. Despite the fact that she may be a scientist in a few years, she seemed to view the work of scientists as being of great worth, assigning the word “proof” to the compiled evidence of scientific theories.

On the other hand, a lack of understanding regarding the nature of scientific knowledge and the merits of scientific evidence was manifested by the need for truth and proof. Aidan made statements including “just as a theory” and “I’ll just accept that it’s not true until it’s actually proven.” That evolution and the big bang theory are just theories suggests that these concepts are viewed as an idea without much supporting evidence. The theories were assigned the label of not being true, suggesting that evolution and the big bang theory are more of a belief than a theory to be rejected based upon insufficient of disconfirming evidence. Finally, the word “proof” was used by both participants and in Aidan’s case as a prerequisite to belief. However, the requirement of proof cannot be met by science or by religion. So the need for proof is something that is an unobtainable prerequisite for belief in a science concept, but is not seen as a barrier within religious belief systems.

These findings are inconsistent with previous research (Scharmann and Harris 1992; National Academy of Sciences 1998; Lombrozo et al. 2008) suggesting that understanding NOS is related to the understanding of the theory of evolution. This study was not specifically designed to measure the participants’ understanding of NOS, but their interview responses warrant speculation about the extent of their NOS understanding. The lack of understanding of NOS allows for the compartmentalization of knowledge by categories of belief. In the absence of a requirement of verifiable and replicable experimental evidence, a requirement of truth and proof are substituted. Since truth and proof cannot be obtained within the realm of science, a theory can be designated as “just a theory” and disregarded as a way of knowing. In place of the theory, a religious understanding is maintained despite the fact that it, too, lacks the aforementioned criteria of truth and proof. Again, the ambiguous nature of compartmentalization surfaces within the context of NOS to justify the exclusion of scientific belief from one’s belief system.

Suggestions for Teaching Practices

Students who do not believe the science concepts of evolution and the big bang theory may feel uncomfortable about the teaching method used to convey knowledge on these topics. Teachers can present these controversial topics in ways that lessen the disconnect between student and science content. The common perception was that science teachers only teach the science concept and rarely, if at all, mention that science is one of myriad ways in which we can understand the world. Krista stated, “I can’t even remember if she [the teacher] gave, like, a little introduction” and “It was just like another day of class” when describing her teacher’s failure to discuss the controversial nature of evolution. Aidan said his teacher “beat around the bush” and only presented science concepts as “ultimate,” leaving him to feel that his teacher was saying “this [evolution] is true.” Presenting science topics that are controversial without making reference to other ways of knowing (religion) can alienate students. Krista talked about how she and her friends wondered if the teacher was Christian. Regarding the lack of discussion about religion, Aidan said, “I have a problem with that, in other words, that religion is completely excluded.”

Having felt excluded, Krista and Aidan are in a position to describe ways to reduce the feeling of alienation among students. Aidan was most vocal with suggestions. He felt that teachers need to acknowledge that religious beliefs are present and felt that they were often ignored or altogether omitted from class discussions. Similarly, BouJaoude et al. (2011) also found that religious beliefs influence Muslim Egyptian and Lebanese students’ positions regarding evolution, and the students felt biology classes should include religious explanations of animal and human history. When asked how he would like to see controversial science topics taught, Aidan said, “I would go through all of the, well, the predominant religious ones [ideas] and scientific ones, and just be like, make your own decision.” He realized that teachers often don’t do this because of First Amendment issues, but was adamant that teacher should “present both sides or, at least, examine both sides.” Aidan felt that it was unfair of teachers to put students in a position where they are required to make statements that are counter to their religious beliefs in order to receive a passing grade. Aidan elaborated, “I think it is unfair to make him take the test if he’s having trouble, if he doesn’t want to be persuaded, necessarily, towards what the teacher’s interested in finding out and I don’t think the test should put the pressure on him to necessarily do that.”

Students may benefit from a more inclusive approach to teaching controversial science concepts. By recognizing that religious beliefs can impact students’ desire or ability to learn science concepts, teachers may facilitate a greater depth of understanding among students. These findings are consistent with the writing of Reiss (1992) who advocates one of three possible approaches to teaching controversial concepts: (1) advocacy occurs when the teacher argues for the position he or she holds, (2) affirmative neutrality occurs when the teacher presents multiple sides of the controversy without revealing which side he or she supports, and (3) procedural neutrality occurs when information about the

controversy and different points of view are elicited from students and from resource material. Further research may identify which approach best facilitates students' understanding of science concepts by avoiding feelings of alienation.

Conclusions

The compartmentalization, or cognitive apartheid, of controversial science concepts is contingent upon several dynamic, interrelated variables. The need to compartmentalize science concepts that are not believed from those that are believed exists because of a discomfort that students experience when trying to integrate scientific knowledge with religious beliefs. Lack of integration can lead to a perception of conflict resulting in rejection of scientific concepts. Compartmentalization is ambiguous in nature, lacking consistent guidelines. Concepts are categorized based on a loose set of ill-defined guidelines, such as degree of belief in the concept. Belief in science concepts decreases when concepts conflict with religious doctrines. Viewing science concepts as facts and disassociating belief and emotional attachment from those facts strengthens students' ability to compartmentalize by creating an emotional distance between the scientific conception and religious beliefs. In part, students compartmentalize because they feel they are going against religion and may lose their faith. However, students realize the practical benefits of understanding scientific conceptions, and sufficient weight exists to maintain this understanding within long-term memory. Weight may be perceived as an examination, a need to understand for future scholastic endeavors, a need to understand both sides of an issue for debate, or the desire to learn. Categorizing by degree of belief in science concepts is rationalized by parameters typically excluded from science, such as lack of proof or degree of truth, suggesting an alternative conception of the nature of science. The degree of conflict may diminish if teachers treat the relationship of science and religion issues more compassionately, presenting alternative views to the accepted scientific perspective.

One approach to teaching evolution is to focus students on the goal of understanding evolutionary concepts and not on influencing their acceptance of evolution or the extent to which students believe in evolution (Cooper 2001). The ability to compartmentalize knowledge is beneficial because one does not have to reject any prior beliefs when confronted with contradicting knowledge claims. This finding is in agreement with those of Meadows et al. (2000), indicating that changing religious beliefs is not necessary for students to learn about controversial science topics. While this may not be the ideal learning scenario, it is less invasive to those students with strong religious convictions. Teachers may facilitate an understanding of controversial science topics by engaging in class discussions about various ways of knowing without attempting to show deficiencies in nonscientific beliefs which may serve to further alienate students with strong religious beliefs.

Implications

While research has been conducted on the compatibility of science and religion, the research thus far has only begun to illuminate the role that belief plays in the understanding of science concepts. Some research indicates that strength of religious commitment is negatively correlated to initial belief in evolution (Lawson and Worsnop 1992; Moore et al. 2011). Sinatra et al. (2003) stated that their data indicates no evidence of a relationship between understanding evolution and its acceptance. The current research findings are closely aligned with the findings of Sinatra et al. (2003). The results indicate there appears to be little relationship between understanding of controversial science concepts and their acceptance. Students who believe in evolution and the big bang theory do not outperform students who do not believe these theories on knowledge tests. These findings imply that science educators should not focus on trying to persuade students to believe socially controversial science concepts but may describe why scientists accept the theories and provide supporting evidence for the knowledge claims inherent within the theory. Educators may require students to demonstrate an understanding of the theories and their supporting evidence but may be better served by presenting the scientific worldview as one of several ways of thinking about the natural world. It appears that a healthy discussion regarding other knowledge systems, such as religion, does not impede students' understanding.

Some researchers (Lawson and Weser 1990; Lawson and Worsnop 1992; Lawson 1999; Scharmann and Harris 1992) have suggested that through interventions applying conceptual change theory, teachers and students may lessen nonscientific beliefs in favor of scientific beliefs. These researchers reported that by exploring alternative conceptions students realized that nonscientific beliefs are not supported by the hypothetico-deductive analysis of current scientific evidence. To the contrary, Meadows et al. (2000) have stated that trying to change teachers' or students' personal worldviews is dangerous and unethical. The results of a study by Peker, Comert and Kence (2010) indicated that improving understanding of evolution is relatively easier than changing acceptance of evolution. Moreover, Rice et al. (2011) found that biology majors' theistic positions did not change as a result of evolution instruction, although their understanding and acceptance of evolution increased.

The findings of this research suggest that students who do not believe science concepts because of opposing

religious beliefs will benefit from a discussion of the controversial nature of science and religion issues, though they may only be controversial in a cultural context. Students possess the cognitive schemata to compartmentalize knowledge that does not fit their worldview, and maintain an understanding of that knowledge in long-term memory. By providing an open discussion regarding science and religion issues, students may construct a more complex schema which connects beliefs to understandings, thereby lessening the need to compartmentalize. These results clearly indicate that students can successfully compartmentalize scientific knowledge; however, they also indicate that the need to compartmentalize is an uncomfortable strain placed on the learner. By discussing alternative knowledge claims with respect to controversial issues, students may be more accepting of scientific knowledge without rejecting their religious beliefs, which should be the ultimate goal of science education.

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