Where Did You Come From? Where Will You Go? Human Evolutionary Biology Education and American Students' Academic Interests and Achievements, Professional Goals, and Socioscientific Decision-making

by

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ABSTRACT

In the United States, there is a national agenda to increase the number of qualified science, technology, engineering, and maths (STEM) professionals and a movement to promote science literacy among the general public. This project explores the association between formal human evolutionary biology education (HEB) and high school science class enrollment, academic achievement, interest in a STEM degree program, motivation to pursue a STEM career, and socioscientific decision-making for a sample of students enrolled full-time at Arizona State University. Given a lack of *a priori* knowledge of these relationships, the Grounded Theory Method was used and was the foundation for a mixed-methods analysis involving qualitative and quantitative data from one-on-one interviews, focus groups, questionnaires, and an online survey. Theory development and hypothesis generation were based on data from 44 students. The survey instrument, developed to test the hypotheses, was completed by 486 undergraduates, age 18-22, who graduated from U.S. public high schools. The results showed that higher exposure to HEB was correlated with greater high school science class enrollment, particularly for advanced biological science classes, and that, for some students, HEB exposure may have influenced their enrollment, because the students found the content interesting and relevant. The results also suggested that students with higher K-12 HEB exposure felt more prepared for undergraduate science coursework. There was a positive correlation between HEB exposure and interest in a STEM degree and an indirect relationship between higher HEB exposure and motivation to pursue a STEM career. Regarding a number of socioscientific issues, including but not limited to climate change, homosexuality, and stem cell research, students' behaviors and

decision-making more closely reflected a scientific viewpoint—or less-closely aligned to a religion-based perspective—when students had greater HEB exposure, but this was sometimes contingent on students' lifetime exposure to religious doctrine and acceptance of general evolution or human evolution. This study has implications for K-12 and higher education and justifies a paradigm shift in evolution education research, such that more emphasis is placed on students' interests, perceived preparation for continued learning, professional goals and potential contributions to society rather than just their knowledge and acceptance.

To my science teachers.

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through draft after draft was often easier knowing you were doing the same. You inspired me to take risks in my writing, to explore new avenues of thinking about the world, and be true to myself. Your insight gave me strength that I didn't know I had, to accomplish things I never thought I could. Thank you, dear friend.

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TABLE OF CONTENTS

CHAPTER Page

APPENDIX

LIST OF TABLES

Table Page

Table Page

Table Page

LIST OF FIGURES

Figure Page

Figure Page

PREFACE

"I know quite well that launching myself into this discussion is a very dangerous operation; that it is a very large subject, and one which is difficult to deal with, however much I may trespass upon your patience in the time allotted to me. But the discussion is so fundamental, it is so completely impossible to make up one's mind on these matters until one has settled the question, that I will even venture to make the experiment. A great lawyer-statesman and philosopher of a former age—I mean Francis Bacon—said that truth came out of error much more rapidly than it came out of confusion. There is a wonderful truth in that saying. Next to being right in this world, the best of all things is to be clearly and definitely wrong, because you will come out somewhere. If you go buzzing about between right and wrong, vibrating and fluctuating, you come out nowhere; but if you are absolutely and thoroughly and persistently wrong, you must, some of these days, have the extreme good fortune of knocking your head against a fact, and that sets you all straight again. So, I will not trouble myself as to whether I may be right or wrong in what I am about to say, but at any rate I hope to be clear and definite; and then you will be able to judge for yourselves whether, in following out the train of thought I have to introduce, you knock your heads against facts or not."

- Sir Thomas Henry Huxley

"On Science and Art in Relation to Education," 1882

CHAPTER 1

INTRODUCTION

Perhaps the most appropriate question with which to begin this dissertation is, where did the thesis come from? While following a traditional evolutionary anthropology Ph.D. program trajectory—examining variation in primate skulls, studying fossils, conducting field work and teaching undergraduates—I often thought about two questions. The first was whether and why it was important to teach others about evolutionary anthropology, including the concepts, findings, and methodologies of the science. I also was concerned with how students become interested in science and science careers. I thought about the story of how I came to be interested in science and how studying human origins had influenced me and shaped my views of the world and my place in it. I recognized that my personal curiosity about and desire to understand the story of where humans came from was what, from a young age, motivated my desire to be a scientist. This led me to wonder if learning about human evolution had influenced other students in the same way. I decided to explore these concerns as research questions. Thus, this study is an examination of the association between students' exposure to the science of human evolutionary biology and their interest, motivation, and achievements in STEM (science, technology, engineering and maths) disciplines and their decision-making about social issues that have a scientific basis.

The story of human origins is one that fascinated me even as a small child. But, as a child, I was presented with a variety of stories about life on Earth and how humans came to be. The story taught to me by the Roman Catholic Church said I was created by God in his image just thousands of years before I was born. I also read books about dinosaurs and other creatures that had gone extinct millions of years before present. I watched the Flintstones, in which human-like characters lived together with dinosaurs. On an episode of Gilligan's Island, the main characters imagined what it would be like to live 1,000,000 years ago and, in their fantasy of the past, they dressed in animal skins, spoke English and carved messages into stone tablets. Marshall, Will and Holly, of Land of the Lost, traveled back to a time when dinosaurs lived together with strange creatures that resembled modern apes and humans, like Chaka, a furry bipedal primate who could communicate with the human characters. That I remember, the science shows I watched, Newton's Apple and Mr. Wizard, did not address topics like the origin and evolution of life; I do not remember watching Cosmos with Carl Sagan until I was older. And I did not learn about the scientific evidence for evolution in elementary school.

When I was a bit older—in middle school— I occasionally laid on my bed and stared at the glow-in-the-dark stars stuck to my bedroom ceiling and thought about my place in the universe and the insignificance of my existence; how the things in my life that were important to me—my friendships, sporting events I competed in, the grades I earned—were not necessarily important to anyone else beyond my immediate circle of friends and family. I thought about how I was just one insignificant person among billions. Thinking about that sometimes caused me to feel very sad, but always left me curious. I wondered whether humans were created by a supernatural being; it seemed to make sense because of our differences from other living things. But, then again, I thought, humans and other animals are so alike in so many ways.

When I was 11 years old, my mother took me to the movie theater to see Gorillas in the Mist. I still remember the feelings it evoked in me, but I am certain I did not understand then everything I was feeling. I recognized that I felt a connection with the woman on the screen who cared so deeply for the animals she studied. I admired the woman's courage and commitment, and was fascinated by the idea of connecting with wild animals to which we were so similar.

A few years later, in high school, two things happened. First, my tenth grade biology teacher, Mr. Linton, taught our class about human evolution and primatology. I remember he told us if he could "do it all over again," he would have earned a Ph.D. so he could have been a primatologist. He related to us his opinion that human evolution was one of the most fascinating topics one could study. He taught us about the Leakey family, about fossil hominins and how to measure cranial capacity. And he took us to the Bronx Zoo. At the zoo, I was fascinated by the monkeys, by how similar their behaviors were to humans'. And I made up my mind then, at the age of 16, that what I wanted to do with my life was to study primates in Africa. I wanted to be like Dian Fossey, the researcher in Gorillas in the Mist. I wanted to study our closest living relatives to better understand human nature and human origins. I wanted to know where I came from. I believe I thought at the time figuring out where all of humanity came from would somehow also help me understand myself, why I was the way I was, not just as a human, but as an individual.

Then I read a book called Origins by Richard Leakey and Roger Lewin. And I wrote some of my college application essays about it, explaining that contemplating human origins and learning about the evidence for human evolution made me want to be a scientist. I wanted to be a biologist, even though biology was not my best subject in high school; chemistry was, but I knew I did not want to be a chemist. I knew I wanted to study evolution.

My freshman year in college, I was disappointed that there were no biology courses specifically about human evolution. Then, looking through the course catalog, I found the courses I was looking for in the Anthropology Department.

In my sophomore year, Roger Lewin spoke at the American Museum of Natural History. One of the other panelists was a researcher in the museum's Department of Vertebrate Paleontology who studied human evolution, Dr. Eric Delson. After the event, I approached Dr. Delson and asked him if he accepted undergraduate interns, which he did. The summer before my junior year of college, I volunteered in his graduate research laboratory for evolutionary primatology. I measured monkey skulls in the dark, cool depths of the museum among shelves filled with fossils. I fell in love with that museum.

Then, the summer prior to my senior year in college, I traveled to Africa and studied primates, as I hoped as a teenager I would one day do. It was a frightening and exciting experience. I spent long hours in the rainforest watching monkeys through binoculars. I had been studying Kiswahili in hopes of traveling to East Africa and found myself in Kenya confidently communicating with the local people. I felt an intense connection with the country and with the continent. I fell in love with Africa.

When I returned to school, I took a course in evolutionary anthropology with Dr. Delson and completed a senior thesis about an extinct monkey species. During that time, a real fossil calvarium of a human ancestor came through the

Vertebrate Paleontology department and I got to hold it in my hands. It was, as they say, a life-changing moment. I fell in love with hominin fossils.

I did not attend graduate school right after earning my bachelor's degree. In part, I did not think I was ready, but, also, I had other interests. I had spent three summers teaching chemistry and life science to gifted middle school students and discovered I was good at it and enjoyed it. In addition, the time I spent working in a natural history museum cultivated my interest in informal science education and the public understanding of science.

I decided to pursue a science educator position at a natural history museum or science center. I did work for a year in a science center developing and delivering science programming to the general public and to children in after-school clubs. I soon discovered, though, I could not imagine a life without scientific research—field research, especially. I wanted to go back to Africa. I wanted to pursue answers to questions about the origins of humanity. I wanted to find fossils.

One year later, as a M.A. student studying evolutionary anthropology at Arizona State University, I found I could not imagine a career that did not include educating children. So, during my M.A. and Ph.D. programs, I mentored young students preparing for regional science fairs and obtained an NSF-funded graduate fellowship that allowed me to work in public school classrooms helping teachers teach inquiry-based science. I was pursuing both of my passions, but in many ways, they remained mutually exclusive endeavors.

This doctoral dissertation is the synthesis of my experiences as a student of evolutionary anthropology and a science educator. Each contributed significantly to the project, as each practice was required to inform the other. As a student and an instructor of evolutionary anthropology, I have a proficient knowledge of the science and how it is traditionally taught. Without this understanding, I would not be able to connect the content of evolutionary anthropology instruction to the research concerns pertaining to STEM education and students' socioscientific decision-making. In other words, to generate theories regarding the potential outcomes of human evolutionary biology education, I had to understand what that education typically entails. My background in science education made me aware of the culture of the American educational system and the role of education standards and education policy, gave me an understanding of what is and is not traditionally taught in American public school classrooms, and guided the interpretation of my findings.

Since the thesis of this project is based on previously unexplored questions, I began my research with no *a priori* knowledge, outside of my own personal experience, of the potential correlates of learning about human evolutionary biology. The methods chosen reflect this lack of *a priori* knowledge; a mixed-methods approach was used, involving interviews with and a survey of Arizona State University students who attended public high school in the United States. The Grounded Theory Method was used to explore and analyze the data, so hypotheses were developed from theoretical conclusions based on recurring themes. The interpretation of the data and the development of my ideas about the potential implications of my results for K-12 and higher education required me, at times, to be both idealistic and pragmatic. Let's see where this thesis will go.

CHAPTER 2

REVIEW OF THE LITERATURE

Relevant to the research concerns and hypotheses of this study is a review of the education literature examining:

(a) the factors associated with American students' pursuit of academic degrees and career paths in science, technology, engineering or math (STEM; see Feller, 2011, and U.S. Government Expands STEM Degree Program List, 2011, for a list of STEM disciplines),

(b) the teaching and learning of human evolutionary biology in American high school science classrooms, and

(c) the connection between human evolutionary biology education and science literacy as it pertains to decision-making about societal issues that have a connection to science (i.e., *socioscientific*[1] issues).

The review and critical analysis presented here demonstrates:

(a) there is a gap in knowledge about the role of specific subject areas, including human evolutionary biology, in predicting students' entrance, persistence and success in the STEM pipeline,

(b) there is evidence that many students in America have limited exposure to the science of evolutionary biology in secondary school, thus we can investigate how students in two samples – those with and those without exposure to human evolutionary biology – compare and contrast with regard to academic interests and achievements, professional goals, and socioscientific decision-making, and

(c) there is a theoretical groundwork for, but a lack of empirical data supporting, the idea that human evolutionary biology education contributes to students' science literacy and socioscientific decision-making.

STEM: Entering the Pipeline, Persisting and Succeeding

There is a national initiative to stimulate American students' interest in STEM degrees, maximize students' success in STEM programs and motivate students to pursue STEM careers. According to the President's Council of Advisors on Science and Technology (PCAST; 2010, p. 33), "STEM education will determine whether the U.S. will remain a leader among nations and whether we will be able to solve immense challenges in such areas as energy, health, environmental protection, and national security."

The STEM initiative is strongly driven by the federal government (e.g., American Competitiveness Initiative, 2006; Committee on Prospering in the Global Economy, 2007; Jones, 2013; Kuenzi, 2008; PCAST, 2010, 2012; Tapping America's Potential, 2005) and industry (e.g., Feller, 2011; Vest, 2011) based on a perceived need to increase the number of American citizens who are qualified, employable, STEM professionals[2]. "Many high-tech companies report that they cannot find qualified U.S. citizens to fill critically important engineering and technology jobs" (Vest, 2011, para. 2) and it is predicted that there will be many STEM job-openings and approximately 1,000,000 new STEM jobs created by 2018, in part due to the retirement of baby-boomers (Carnevale, Smith, & Strohl, 2010; Lacey & Wright, 2009; Feller, 2011).

Universities, teacher organizations and research societies also play an important role in the initiative because they are responsible for educating, training, and supporting future STEM professionals (e.g., Carr, 2010; The Need for Science Education Reform, 2009; Simmons, 2011; American Institute of

Physics, 2013). PCAST (2012, p. i) reports that the number of undergraduates receiving STEM degrees needs to increase by about 34% annually over current rates “if the country is to retain its historical preeminence in science and technology” and meet the demands of the expanding job market.

Due to this national STEM agenda, the last decade has seen an increased emphasis on federal legislation focused on enhancing STEM education and research, expanded support for STEM teacher professional development, and a growing diversity of public-private partnerships highlighting the role of STEM education in workforce development. For example, according to the website for the National Math and Science Initiative (NMSI), this particular public-private partnership “was formed to address one of this nation’s greatest economic and intellectual threats—the declining number of students who are prepared to take rigorous college courses in math and science and equipped for careers in those fields” (NMSI, 2013). The “100Kin10” movement is a multi-sector initiative started in 2012 to employ 100,000 new, highly-trained STEM educators over 10 years (Carnegie Corporation of New York, 2012). The America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (COMPETES) Act, passed in 2007 and reauthorized in 2010, was a response of the U.S. government to concerns that the United States was failing to compete internationally and initially authorized $43.3 billion in federal appropriations spending for STEM research and education programs (Jones, 2013).

The national STEM initiative motivates science education researchers to investigate (a) how to increase the number of students pursuing and obtaining STEM degrees, (b) why students pursue STEM degrees, and (c) how and why students remain in the STEM pipeline. Typically, data are drawn from cross-sectional and longitudinal studies of students and taken primarily from questionnaires, interviews of students and student achievement test scores and enrollment databases. Statistically, these data are used to determine which variables predict or correlate with a particular desired outcome–e.g., students' intentions to complete a college or university degree or follow a STEM career path[3].

A review of the current STEM education research reveals some potential stumbling blocks to STEM persistence and training more qualified U.S. STEM professionals, including (a) the quantity and quality of science education available to and attractive to students at the secondary and post-secondary levels (*enrollment*) and (b) students' poor science knowledge structure, with recognition that students' knowledge structure tends to reflect that of their teachers (*achievement*; Rutledge & Mitchell, 2002). Indeed, data support the argument that American students' access to particular science classes in high school—such advanced placement science classes—and science aptitude are lower than they most likely need to be to produce the qualified STEM workforce required to meet the needs of the American economy (Grigg et al., 2006; Madrid, 2008).

With regard to enrollment, 29 states require less than three years of science education for graduating high school seniors, 40% of schools nationwide do not offer advanced placement science courses, and 62% of students with "AP potential" do not take an AP subject in high school (Educating America, 2004; The 8th Annual AP Report to the Nation, 2012, p. 17). And regarding achievement, in 2005, 48% of the nation's 12th-grade public school students tested by the

National Assessment of Educational Progress (NAEP) were below the basic achievement level in science and only 17% were at or above a proficient level (Grigg, Lauko, & Brockway, 2006). And based on the 2009 NAEP, 41% of 12th graders were below the basic achievement level in science and 20% were at or above the proficient level[4] (U.S. Department of Education, 2009). Though American students' performance on international STEM assessments varies, e.g., the Trends in International Mathematics and Sciences Study (TIMS) versus the Program for International Science Assessment (PISA), U.S. pupils do not fare well overall, relative to students in other countries (Kuenzi, 2008; Herschbach, 2011). Based on results of the 2012 PISA, which assessed 15 year-olds in mathematics, science and reading literacy, 7 percent of U.S. students scored at a top-performing proficiency level (a score of 5 or above) in science literacy, whereas 27 percent of students in Shanghai-China were at top-performing proficiency in science literacy. The U.S. results were lower than those of 17 international education systems. Eighteen percent of U.S. students performed below the baseline of proficiency (a score lower than 2), whereas just 3 percent of students in Shanghai-China were below baseline proficiency in science literacy (National Center for Education Statistics, 2013).

The sample for this project includes Arizona State University (ASU) students, a majority of whom attended at least one year of public high school in the state of Arizona; in Arizona, only about half of high school graduates qualify academically to enter one of its state universities (Arizona High School Eligibility Study, 2006). In 2005, 51% of Arizona's eighth-grade public school students were performing below the basic level of achievement in science based on the NAEP and, in 2008, 62% of AZ high school students (many of whom were in eighth grade in 2005) who took Arizona's Instrument to Measure Standards (AIMS) test failed the science assessment (Grigg et al., 2006; Madrid, 2008).

Approximately half of the students in this study had declared or planned to declare a STEM major at ASU. According to PCAST (2012, p. 6), "The first two years of college are the most critical to retention and recruitment of STEM majors." "Fewer than 40% of the students who enter college with the intention of majoring in a STEM field complete a STEM degree" and even high-performing college STEM majors "describe the teaching methods and atmosphere in introductory STEM classes as ineffective and uninspiring" (PCAST, 2012, pp. i and 5, and references therein). Researchers at the State University of New York Albany assessed attrition rates for introductory science courses at their public university and found that General Biology I had a 27% attrition rate, General Chemistry I a 34% attrition rate, and General Physics I a 45% attrition rate (Cavanagh, 2008).

So, STEM education researchers are tasked with finding ways to address students' low enrollment in advanced pre-collegiate STEM classes, students' poor knowledge or understanding of STEM material, and a level of student disinterest in introductory-level STEM college courses that leads to many students' early departure from the STEM pipeline. Thus, not only must they find ways to increase students' entrance into the STEM pipeline, but they must also increase STEM persistence and degree completion (PCAST, 2012). To do so, they must identify the factors that distinguish successful STEM students—those who complete a STEM degree and are qualified to enter a STEM profession—from (a) those who do not want to pursue a STEM degree or (b) those who want to, but fail to pursue or are unable to earn a STEM degree.

The list of factors used to test hypotheses about STEM entrance, persistence and success includes varied combinations of background variables such as gender, age, ethnicity and socioeconomic status, as well as measures of academic experiences and achievement, such as grade point average, standardized test scores, course grades, course enrollment, instructional quality, teacher enthusiasm, and additional measures founded on social cognitive theory, such as intrinsic motivation, self-efficacy and self-determination (see Appendix A; e.g., Bryan, Glynn & Kittleson, 2011; Federman, 2007; Kuenzi, 2008; Maltese & Tai, 2011; Masnick, Valenti, Cox, & Osman, 2010; Museus, Palmer, Davis, & Maramba, 2011; Myers III & Fouts, 1992; Nicholls, Wolfe, Besterfield-Sacre, & Shuman, 2010; Piburn & Baker, 1993; Riegle-Crumb, Moore, & Ramos-Wada, 2011; Schwartz, Sadler, Sonnert, & Tai, 2008; Sullins, Hernandez, & Fuller, 1995; Wai, Lubinski, Benbow, & Steiger, 2010; Ware & Lee, 1988; Woolnough, 1994). Of course, specific research questions drive individual studies and research methods, and not all researchers investigate all of these factors. Methods and choice of factors affect the results of the analyses, but within this body of research there are recent outcomes that are relevant to this study.

Maltese and Tai (2011) and Nicholls et al. (2010) reviewed the primary literature in STEM education published prior to 2010 and recognized a need to assess educational experiences in the context of actual STEM outcomes, such as attainment of a STEM degree, in addition to the more commonly used method of correlating background and performance variables to students' intentions. Both groups of researchers analyzed data from the National Educational Longitudinal Study of 1988 (NELS:88; their findings and the relevant conclusions of research papers published between 2010 and 2011, when this review was composed, are summarized in Appendix A).

Maltese and Tai (2011) were more concerned than Nicholls et al. (2010) with a longitudinal effect, building their statistical model in chronological blocks using data from eighth to 12^{th} grade and college or university transcripts, while Nicholls et al. (2010) focused on eighth grade predictors of STEM persistence (actually, departures from the STEM pipeline) and degree completion only. Therefore, Maltese and Tai's (2011) approach is more relevant to this study as it included data from high school biology classes, and so will be the focus of this discussion, but Nicholls et al.'s (2010) study also produced relevant results (Appendix A).

Maltese and Tai (2011) analyzed NELS:88 data and academic records from 4,700 American students. The results of their models identify the following factors as predictive of STEM persistence/degree completion:

- *10th grade block*: Students ranked *usefulness of science* high and/or desired STEM careers as eighth-graders.
- *11th/12th grade block*: Students were enrolled in 11th grade biology, had teachers who emphasized further study in science, and/or expressed a personal interest in STEM.
- *College block*: Students ranked *usefulness of science* high and/or completed more STEM credits in their first year of college than did other students.
- *Final (overall) model*: Students indicated an interest in STEM as eighth-graders, indicated an interest in pursuing a STEM major as 12^{th}-graders, and/or had high enrollment in high school science classes.

Based on their analysis, Maltese and Tai (2011) concluded that initiatives focused primarily on student enrollment and performance will not necessarily lead to more students pursuing STEM majors. The authors point out that students' expression of an interest in STEM content (*interest*) and wanting to pursue a STEM major and/or career (*motivation*) are underemphasized in the STEM education literature as predictive factors for STEM persistence; factors such as high school course grades, scores on standardized tests, and/or background factors such as ethnicity and gender are more often the focus (e.g., Museus et al., 2011; Riegle-Crumb et al., 2011). In their February 25, 2012, report to the President, "Engage to Excel: Producing One Million Additional College Graduates with Degrees in STEM," PCAST also recognized that STEM persistence is associated not only with achievement, but also with intellectual engagement and motivation.

At multiple levels of their analysis, Maltese and Tai (2011) identified student interest and motivation as predictive factors for STEM success. Other authors' research findings imply similar outcomes with anecdotal and qualitative evidence provided as support (Appendix A). Nicholls et al. (2010, pp. 220 – 221) identified "additional [eighth grade] students," in their study, "that [sic] were capable of achieving a STEM degree if they had been encouraged to develop an interest in the subject and motivation to major in STEM." Bryan et al. (2011, p. 2) specifically examined *motivation to learn science* ("an internal state that arouses, directs, and sustains science-learning behavior") in 14 to 16 year-olds and, when interviewed, students who were motivated to take AP science courses used words and phrases such as "enjoy," "fun," "I love it," "favorite subject," "challenge," "college," and "future career" and students with low motivation to learn more science used words or phrases such as “I don’t like,” “hate,” “boring,” and “I don’t really care,” suggesting that interest and motivation to learn are connected to each other.

These research studies demonstrate that students’ interest in STEM and students’ motivation to enter a STEM career pathway should not be overlooked as factors contributing to STEM persistence. To generate interest and foster STEM career motivation, Maltese and Tai (2011, p. 900) recommend STEM educators use “real-world science problems” that are “personal, local and relevant.” PCAST (2012, p. 6 – 7) recommends increasing student engagement via “types of classroom instruction that engage students in thinking or problem-solving,” also noting, “motivation is partially intrinsic but also is modulated by the college environment.” A 2011 report of the Association for the Study of Higher Education (Museus et al., 2011) on racial and ethnic minority students’ STEM education success identifies “interest in STEM careers” as well as “culturally relevant pedagogy” as two K–12 factors positively influencing STEM success.

Bryan et al. (2011, p. 14), who studied motivation to learn science, suggest that “science teachers should make a special effort to connect science concepts to students’ current and future lives.” Science educators at the forefront of STEM curriculum development advocate that new education materials should be relevant to students’ lives to stimulate interest (Hillis, 2007; Scotchmoor, 2011).

At Harvard University, the implementation of interdisciplinary science courses for undergraduates that emphasized current issues (e.g., the biology and treatment of AIDS and cancer) was associated with a more than 30% increase in undergraduate life sciences enrollment and an 18% increase in life sciences majors over time, suggesting that timely, relevant course content stimulates or maintains students' interest in STEM (National Research Council, 2009, p. 80).

In addition to interest and motivation, Maltese and Tai's (2011) block model found that some enrollment factors could be used to predict STEM persistence, but only one of those was specific to a particular high school science class – enrollment in 11th-grade biology. To better understand the relationship between high school biology enrollment and STEM entrance, persistence, and success, it is useful to consider (a) the content of public high school biology classes in America and (b) if class content can be personally and culturally relevant and engage students in problem-solving, with the assumption that meeting these criteria would make high school biology interesting and motivational for students.

Table 1 summarizes the National Research Council's (1996, pp. 181 - 201) National Science Education Standards (NSES) relevant to ninth to 12th-grade biology courses[5]. The NSES "outline what students need to know, understand, and be able to do to be scientifically literate at different grade levels" (p. 2). The NSES are not a curriculum, but a list of expected outcomes, and therefore a guideline for teachers to use when developing their curricula. The National Research Council (NRC) established the NSES to "enable the nation to achieve science literacy" via "a new way of teaching and learning about science that reflects how science is done" (p. ix). Though the NSES do not require that content be presented or organized in one particular way (NRC, 1996, p. 2), the NRC designed them to be used as a whole and state, "using only a subset of the standards will leave gaps in the scientific literacy expected of students" (p. 7).

As one can see from Table 1, the *science and technology*, *science in personal and social perspectives* and *history and nature of science* standards for ninth to 12th-grade are about humans – modern human behavior, technological innovation and humans' effect on the environment, for example. According to the NRC (1996, pp. 106-107), these three content standards are meant to "provide students with opportunities to develop decision-making abilities, to understand and act on personal and social issues," and to use history to "clarify different aspects of scientific inquiry, the human aspects of science, and the role that science has played in the development of various cultures." A curriculum designed to achieve these outcomes would be personally and culturally relevant to students because it deals with humans and would be engaging because it emphasizes science as a human endeavor and explores the interface of knowing and doing science, for example.

The *life sciences* standard (Table 1, first column) describes "science subject matter [which] focuses on the science facts, concepts, principles, theories, and models that are important for all students to know, understand and use" (NRC, 1996, p. 106). The subject matter content standards, as written, are not explicitly about humans, so it is not clear how or if they are perceived as relevant or engaging to students; that would depend on how teachers develop their curricula. To make the material relevant and engaging, high school teachers could write inquiry-based lesson plans using modern humans as the focus of the subject matter (e.g., human cellular and molecular biology, inheritance of traits in humans, etc.). In the case of the *evolutionary biology* life sciences content standard, the content could be made personally and culturally relevant by the teaching and learning of human evolutionary biology, which would complement many of the outcomes of the other three content standards presented in Table 1.

The benefits of this curriculum development approach, in terms of engaging students in STEM, have not been investigated. To know if it is possible to test for an association between learning human evolutionary biology in secondary school and students' persistence in the STEM pipeline, one first must know what is actually taught in America's public high school biology classrooms.

Human Evolutionary Biology in the Classroom

Since 1996, the National Science Education Standards have been the model for the development of state public education science standards for kindergarten to 12^{th}-grade[5]. Currently, there is no law requiring states to adhere to these guidelines; therefore, state science standards can, and frequently do, diverge from the NSES. State standards are written and approved by state standards committees, which may comprise teachers and/or administrators and state boards of education and so commonly reflect those groups' views and desires for K-12 public education outcomes in their state. Some states' science standards leave some NSES content standards out completely, which contradicts the goals of the NSES, as stated earlier. For example, though the National Research Council (and other national science research and science teaching organizations such as the American Association for the Advancement of Science (2006) and National Science Teachers Association (2011)) officially recognize the unifying nature of evolutionary biology and the importance of teaching evolutionary concepts in biology classrooms, the evolutionary biology content standard is left out of, or poorly addressed in, many states' science standards (Lerner 2000; Mead & Mates, 2009).

Table 1

National Science Education Standards Relevant to 9th - 12th Grade Biology

Life sciences standard	**Science and technology standard**	**Science in personal and social perspectives standard**	**History and nature of science standard**
The cell (cell structure and function)	Abilities of technological design (identify problems, propose, select and implement designs/solutions, evaluate, and communicate the problems, solutions and outcomes)	Personal and community health (e.g., sexuality is basic to the physical, mental, and social development of humans; selection of foods/eating patterns affect growth and development)	Science as a human endeavor (e.g., science can be a career or hobby; scientists value truthful reporting about methods/ outcomes; science is a part of society)
Molecular basis of heredity (e.g., DNA, chromosomes, zygote formation, mutations in germ cells as a source of heritable variation)	Understanding about science and technology (technology as interdisciplinary, creative, imaginative, driven by need to meet human needs, solve human problems, and help humans adapt)	Population growth (e.g., birth rate, death rate, fertility rate, emigration, immigration, effects of birth control, carrying capacity, technological influences on population growth)	Nature of scientific knowledge (e.g., science is distinguishable from other ways of knowing; scientists strive for the best possible explanations about the natural world)
Biological evolution (e.g., evolutionary mechanisms, species concepts, common ancestry, the fossil record)		Natural resources (e.g., human populations use resources to maintain/improve their existence)	Historical perspectives (e.g., diverse cultures have contributed scientific knowledge and technological inventions; changes in science occur as small modifications in extant knowledge)

Life sciences standard	**Science and technology standard**	**Science in personal and social perspectives standard**	**History and nature of science standard**
Interdependence of organisms (e.g., energy flow, cooperation, competition; humans modify ecosystems and destroy habitats)		Environmental quality (e.g., humans are changing many natural processes and the changes may be detrimental to humans)	
Matter, energy, and organization in living systems (e.g., solar energy, chemical/ molecular energy, energy needs of organisms)		Natural and human-induced hazards (e.g., earthquakes, volcanoes and slow environmental changes, as well, can all negatively affect society)	
Behavior of organisms (e.g., the nervous system, the senses, internal and external stimuli, behavior as adaptive and a product of evolution)		Science and technology in local, national, and global challenges (e.g. humans have a major effect on other species; individuals and society must decide on proposals involving the introduction of new technologies into society)	

Note. Adapted from National Research Council (1996). *National Science Education Standards*. Washington, D.C.: National Academies Press.

Lerner (2000) conducted an analysis of the treatment of evolutionary biology in state science standards. Each state was awarded a letter grade (F- to A+) for its treatment of biological evolution based on eight criteria, each with four to five scoring levels. According to Lerner (2000), only 31 states had *satisfactory*, *good* or *excellent* (C or better) evolution-based standards and 13 states either lacked science standards addressing evolution or their standards were deemed *useless* or even *disgraceful* (F-). Regarding human evolution, a 2007 review of state standards by Berkman & Plutzer (2010) showed that six states dropped any specific reference to human evolution from their science standards after 2000, and only three states – Michigan, Rhode Island, and Pennsylvania – "explicitly mention" human evolution in their standards (p. 157).

So, if public high school biology teachers are using their states' science standards to develop their curricula, a relatively small number of students are being exposed to human evolutionary biology in the classroom. And research shows that this number is even smaller than would be predicted based on state standards alone. Even in the states that include evolutionary biology and human evolutionary biology in their science education standards, the science teachers may not actually teach this content. Many studies have shown that state standards, particularly evolutionary biology content standards, do not predict what teachers are actually teaching (Berkman & Plutzer, 2010, pp. 158-173). For example, Rutledge and Mitchell (2002, p. 25) showed that in Indiana – a state judged by Lerner (2000) as having excellent treatment of evolutionary biology in its standards – 43% of teachers "avoid or only briefly mention evolution" in the classroom.

Studies by Rutledge and Mitchell (2002) and Berkman and Plutzer (2010) found significant associations between teachers' academic background, their knowledge structure and acceptance of evolutionary theory, and what they teach their students, as well as how much time they spend teaching evolution. Moore (2004) and Moore and Kraemer (2005) suggest that the reasons for teachers' not teaching evolutionary biology vary and are not simply a result of the teachers' religious beliefs, acceptance of evolution, or training, but also include external pressure from school officials and/or parents, unfamiliarity with laws about promoting religion in schools (an illegal teaching practice according to the Establishment Clause of the First Amendment), and lack of time (see also Berkman and Plutzer, 2010). In some states, teachers or school boards may even favor teaching creationism and/or intelligent design in addition to, or instead of, evolutionary theory (e.g., *Kitzmiller v. Dover Area School District*, 2005). A survey of the general American public reported that 47% of participants opposed the teaching of evolution in public schools (Coalition of Scientific Societies, 2008). In a separate poll, 56% of adult Americans said that they generally favored the teaching of creationism along with evolution in public schools (CBS News Poll, 2008).

Based on the responses of 552 public high school biology teachers in Indiana (again, a state with excellent treatment of evolution in its science education standards) to the question, "Do you accept evolutionary theory to be a scientifically valid explanation of the state of living organisms of the present and past?," 33% of teachers fell into the categories *Non-acceptance* or *Undecided* and 67% of teachers fell into the category *Acceptance* (Rutledge & Mitchell, 2002). But, as mentioned earlier, 43% percent of the teachers "avoid or only briefly mention evolution" in their classrooms (Rutledge & Mitchell, 2002, pp. 24-25). These data show there are some teachers who, despite accepting evolutionary theory, do not teach about it.

Regarding human evolution, the National Survey of High School Biology Teachers (Berkman & Plutzer, 2010; *N* = 926) found 61% of the participants self-reported a theistic evolution or young earth creation-based personal view regarding the evolution of humans and 31% an organic evolution-based view (8% gave no response). Among this group, 72% of the teachers spent ten or fewer hours out of a curricular year teaching about human evolutionary biology and 17% of teachers reported that they never taught about human evolution. Only two percent ($n < 20$) of teachers self-reported 20 or more hours of human evolutionary biology instruction, despite the acceptance level of 31%.

Survey data collected from American undergraduates demonstrate that rates of human evolutionary biology instruction in high school science classes may be even lower than what is reported by teachers. Data from 8,310 undergraduate students enrolled in introductory science courses at 55 different U.S. universities or colleges showed that fewer than 10% of students recalled biological evolution having been taught as a recurring topic in their high school biology courses and nearly 20% reported that their high school biology teachers never taught about evolutionary biology (Schwartz et al., 2008). Moore (2007a) assessed high school science teachers' evolutionary biology teaching practices by comparing and contrasting data from public high school teachers and public university undergraduate students in Minnesota and found "students perceive their high school biology classes to have contained much less evolution (and more creationism) than do teachers" (p. 270). Moore's (2007a, 2007b) observations reflect the findings of the 2000 National Survey of Science and Mathematics Education (Weiss, Banilower, McMahon, & Smith, 2001) that "the objectives that high school biology teachers claim that they emphasize do not always match the teaching strategies they actually use" (Moore, 2007b, p. 270).

Based on the study results presented above, at least 20 – 25% of public high school biology curricula do not include any evolutionary biology content. According to the National Research Council's (2009) Committee on a New Biology for the 21st Century, a lack of knowledge of just one of the organizing principles of biology, such as evolutionary biology, would have a negative impact on the potential success of any students seeking a professional career in STEM by limiting their knowledge structure and their potential for contributing to biological research as it is envisioned for the future–with an eye toward identifying biology-based solutions to societal problems (Figure 1). Maltese and Tai (2011) demonstrated that 11th grade biology class enrollment can be used to predict persistence in the STEM pipeline, which might be evidence that evolutionary biology education, when included in a pre-collegiate curriculum, could correlate with STEM persistence, but there is not yet empirical evidence to support this claim. To test this, students' motivation to pursue and persistence in STEM degree programs must be investigated for those students who have and have not been exposed to human evolutionary biology education.

This project examines how students' exposure to human evolutionary biology education is associated with STEM class enrollment and persistence in the STEM pipeline, specifically students' high school science class enrollment, undergraduate major and motivation to pursue a STEM or non-STEM related career. The framework for this investigation is the idea that human evolutionary biology is a personally and culturally relevant subject area for students because it deals with humans and encompasses "real-world" problems and that, as a result, it has the potential to generate or foster students' interest and engagement in STEM classes and degree programs and motivation to pursue a STEM career. No previous studies have investigated the relationship between human evolutionary biology education and STEM interest, enrollment and persistence.

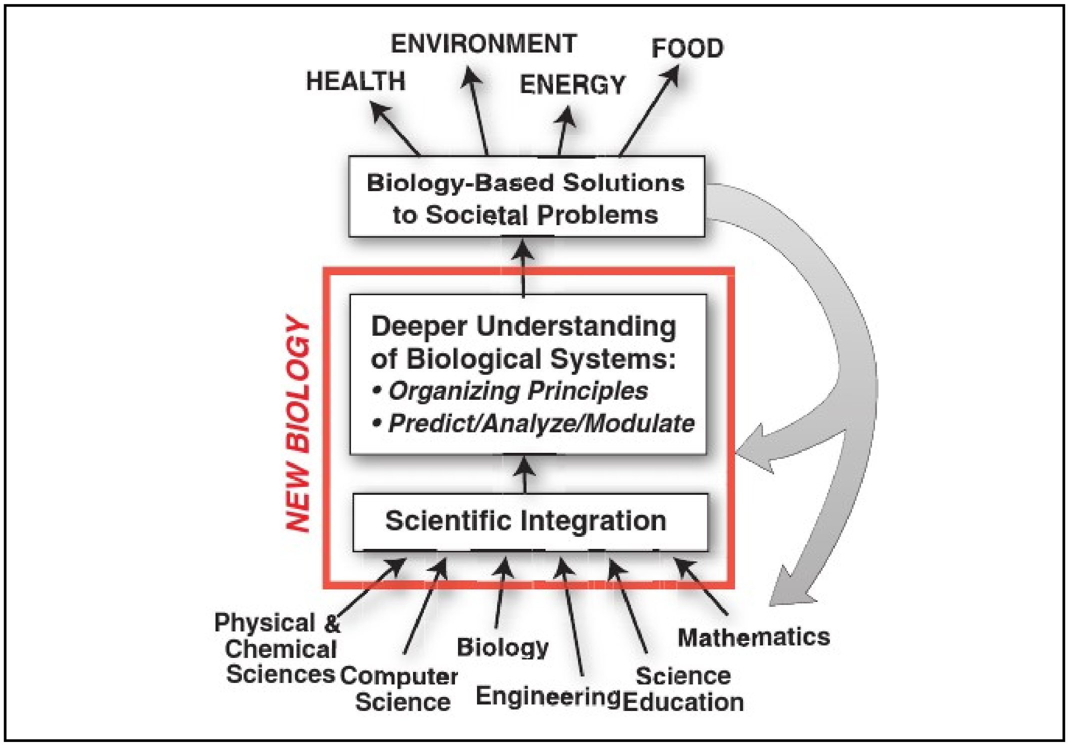

Figure 1. The New Biology. "The New Biology relies on integrating knowledge from many disciplines to derive deeper understanding of biological systems. That deeper understanding both allows the development of biology-based solutions for societal problems and also feeds back to enrich the individual scientific disciplines that contributed to the new insights." Figure and caption from National Research Council, 2009, p. 17.

Human Evolutionary Biology and Society

The National Research Council (1996, p. ix) established the NSES to "enable the nation to achieve science literacy" via "a new way of teaching and learning about science that reflects how science is done." The definition of science literacy used in this study is that of the American Association for the Advancement of Science's Project 2061 (Project 2061, 2009; see Holbrook & Rannikmae, 2007, 2009, Mooney & Kirshenbaum, 2010, and Zeidler, Sadler, Simmons, & Howes, 2005, and references therein, for alternative definitions):

> Project 2061 has undertaken, in [*Science for All Americans*], to identify the knowledge and habits of mind that people need if they are to live interesting, responsible, and productive lives in a culture in which science, mathematics, and technology are central—that is, to describe what constitutes the substance of science literacy.
>
> People who are literate in science are not necessarily able to do science, mathematics, or engineering in a professional sense, any more than a music-literate person needs be able to compose music or play an instrument. Such people are able, however, to use the habits of mind and knowledge of science, mathematics, and technology they have acquired to think about and make sense of many of the ideas, claims, and events that they encounter in everyday life. Accordingly, science literacy enhances the ability of a person to observe events perceptively, reflect on them thoughtfully, and comprehend explanations offered for them. In addition, those internal perceptions and reflections can provide the person with a basis for making decisions and taking action ("Vocabulary, Science Literacy," para. 1-2).

Advocates of teaching evolutionary biology in public school science classes commonly present the argument that it enhances science literacy. For example, the National Academy of Sciences and Institute of Medicine (2008) assert that evolutionary biology is "fundamental to a high-quality science education," and that without a consideration and understanding of evolutionary biology, science literacy cannot be achieved and wise decisions cannot be made on public policies and pressing socioscientific issues (p. 47).

To clarify this argument, consider the role of evolutionary biology in science literacy and socioscientific decision-making through an example relevant to human health. If a person understands why antibiotics should not be used to treat viral infections–in other words, that bacteria and viruses are different types of organisms that must be treated with different drugs–she can use that knowledge to seek appropriate treatment and better comprehend and follow the directions given to her by her health practitioner regarding prescriptions and medication compliance. Unfortunately, because 57% of the American public thinks antibiotics kill viruses as well as bacteria, science illiteracy, in this case, is contributing to a global health epidemic (Choffnes, Relman & Mack, 2010; Coalition of Scientific Societies, 2008). Problems arise, for example, if someone keeps unused antibiotic pills in her medicine cabinet and chooses to take them when she has a viral infection, or when a patient fails to inform her new medical practitioner that she recently had a bacterial infection and completed a course of antibiotics and the new practitioner then prescribes that same antibiotic, resulting in the patient's overexposure to that treatment.

In 2010, the Institute of Medicine published a summary report (Choffnes et al., 2010) on a workshop regarding the implications of antibiotic resistance for global health and noted that "multi-drug resistant 'superbugs' have become a global challenge, aided and abetted by the use, misuse, and overuse of once highly effective anti-infective drugs," pointing particularly to the harmful outcomes resulting from overconsumption of this "common resource" (p. 1). The authors of the summary identify antimicrobial efficacy as a “scarce commodity in need of responsible management, on a par with energy, safe food, clean water and climate stability” (p. 6). The context for this last statement by Choffnes et al. (2010, p. 6) is their reference to ecologist Garrett Hardin’s (1968) “tragedy of the commons.” Taking a global view, the authors of the summary point out:

> Hardin’s “tragedy of the commons” has proven to be a useful metaphor for understanding how we have come to be at the brink of a number of environmental catastrophes–whether land use, global climate change, access to and availability of uncontaminated and abundant fresh water resources, or antimicrobial resistance. Simply stated, we face a serious dilemma—an instance where individual rational behavior, acting without restraint to maximize personal short-term gain—can cause long-range harm to the environment, others and ultimately to oneself (Choffnes et al., 2010, p. 6).

Using such examples, one can see how Americans’ science literacy has potentially personal, as well as national and global effects. There are many socioscientific issues, including those mentioned by Choffnes et al. (2010), that require informed decision-making by a science literate populace and many that can be connected to the science of human evolutionary biology, such as

- humans’ contribution to global climate change (e.g., Panel on Addressing the Challenges of Climate Change, 2010; PRRI/RNS Religion News Survey, 2011; Schreiner, Henriksen, & Hansen, 2005; Sharma, 2011),
- conservation of biodiversity and other natural resources (Novacek, 2008),
- human vaccination programs (Offit, 2008),
- human overpopulation (Ehrlich, 2011),

- stem cell research and human cloning (Kolarova, 2011),
- human skin color diversity and racial/ethnic tolerance (Jablonski, 2006),
- homosexuality and lifestyle/sexual prejudice (Horn & Heinze, 2011),
- and the conservation, environmental ethics and medical testing of humans' closest living relatives, the great apes (Hawkins, 2002).

This project will investigate connections between these issues and human evolutionary biology education. Though it is typical to hear advocates of evolution education make statements such as, "To be an engaged patient or citizen of [the] 21st century, you need evolution education!" (@JoshRosenau, 2011), there has not been an effort by education researchers to provide empirical evidence linking formal evolutionary biology education and American students' science literacy.

There have been a number of science education papers in the last decade that explore relationships between the decision-making process and socioscientific issues and students' epistemological views and cognitive structures (Bell & Lederman, 2003; Eggert & Bögeholz, 2010; Liu, Lin, & Tsai, 2011; Nahum et al., 2010; Sadler & Zeidler, 2009; Wu & Tsai, 2011; Zeidler et al., 2005). That body of research has some bearing on this study, even if just to distinguish this project from the rest of the efforts composing this burgeoning area of investigation.

Early work about science education, socioscientific issues and decision-making fell within the realm of the *science-technology-society* (STS), or *science-technology-environment-society* (STES), movement, which has been described as an "elusive construct" (Bell & Lederman, 2003, p. 353) and which is being nudged out of the science education literature by a more recent *socioscientific* *issues* (SSI) movement (Sadler, 2004; Sadler & Zeidler, 2009; Zeidler et al., 2005). Sadler (2004) provides a comprehensive review of STS and SSI studies relating socioscientific issues and informal reasoning ("informal reasoning involves the generation and evaluation of positions in response to complex issues that lack clear-cut solutions" (Sadler, 2004, p. 514)). Many of the authors who focused on informal reasoning at the beginning stages of the SSI movement presented the argument that socioscientific issues are "an important component of science literacy" (Sadler, 2004, p. 315). This statement is problematic because it oversimplifies the relationship between socioscientific issues and science literacy as viewed by the SSI movement, especially as the movement has progressed; the SSI movement, which has limited empirical data, integrates moral and ethical development and socioscientific issues as components of science literacy (Sadler & Ziedler, 2009; also see *cognitive moral reasoning perspective* in Zeidler & Keefer, 2003, and Figure 1 in Zeidler et al., 2005, p. 361).

Empirical research published in the last two years (Liu, Lin, & Tsai, 2010; Wu & Tsai, 2011) tested the correlation between high school and college students' decision-making and their scientific epistemological views or beliefs, thinking patterns, and cognitive structures, but the context of that research is the examination of the process of informal reasoning that is considered an essential part of the decision-making process as understood or defined by the SSI movement, so those data do not contribute to this study. This research project, though it deals directly with science literacy and decision-making about socioscientific issues, does not consider moral and ethical development as components of science literacy. Therefore, it follows a different logic concerning the potential relationship between science education, science literacy, and socioscientific decision-making than does the SSI movement (Figure 2). Instead, the logic of this study is rooted in Project 2061's (2009) definition of science literacy presented earlier – that a science literate person can use the knowledge and habits of mind provided by science education to think about and reflect upon socioscientific issues, make observations in the world around them, comprehend answers to questions they generate, and then make decisions, using formal and informal reasoning, about those issues and take appropriate action when needed. For this study, greater emphasis is placed on science literacy as the tool for decision-making, rather than as an outcome.

This project specifically examines how students weigh and reflect upon socioscientific issues and how they respond to specific questions pertaining to the socioscientific topics outlined above. The information provided by students is then assessed in the context of their exposure to human evolutionary biology in the secondary classroom and during college-level coursework. The assumption is that human evolutionary biology education provides information and resources that enhance science literacy and that expand and improve students' decision-making abilities and influence their actions related to socioscientific issues when applicable.

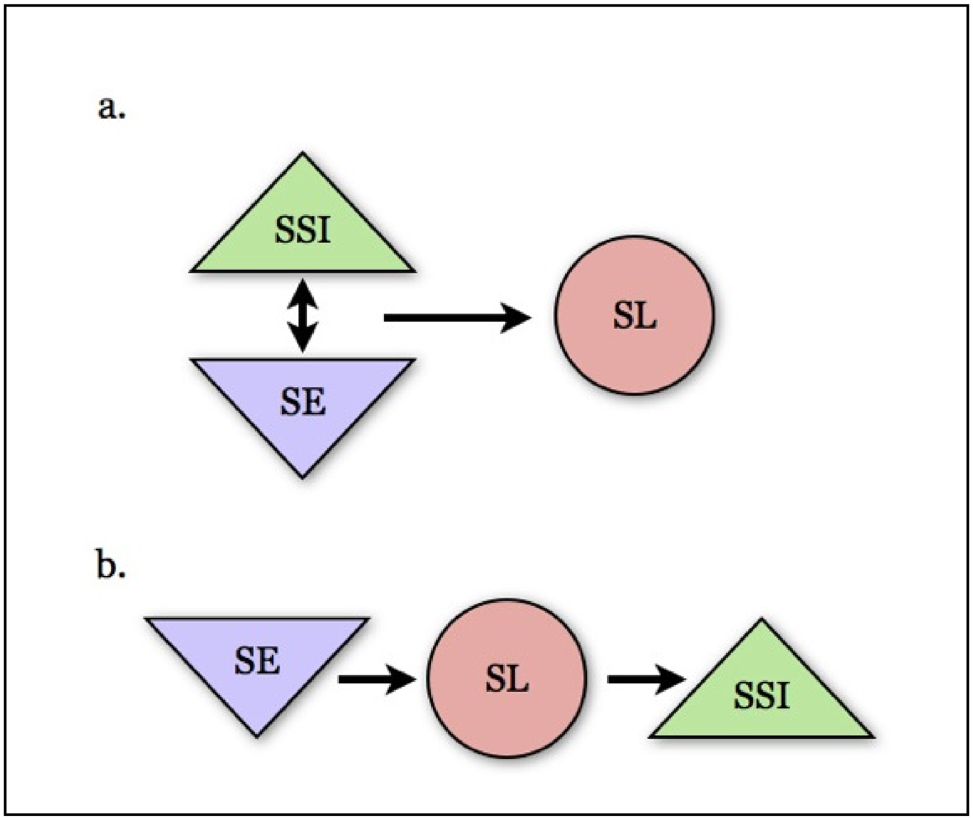

Figure 2. (a) A simplified model of the modern socioscientific issues movement: Socioscientific issues are a fundamental part of science education and tightly integrated with other issues (e.g., nature of science issues, classroom discourse issues), contribute to personal cognitive and moral development, and promote "functional scientific literacy" (Ziedler et al., 2005, p. 361). (b) The model used in this study to reflect the relationship between science education, science literacy and socioscientific issues: The traditional components of formal and informal science education contribute to science literacy and science literacy is the tool used in decision-making regarding socioscientific issues. SE = science education; SL = science literacy; SSI = socioscientific issues

CHAPTER NOTES

[1] Socioscentific issues "encompass social dilemmas with conceptual or technological links to science," for example, "cloning, stem cells, genome projects, global warming and alternative fuels" (Sadler, 2004, p. 513; see also Holbrook & Rannikmae, 2007, 2009; National Research Council, 2009; Sadler & Zeidler, 2009; Zeidler, 2003; Zeidler et al., 2005).

[2] After this research was completed, the argument was made that the need for more STEM professionals in America (and other countries) is "a myth" (Charette, 2013, p. i). For example, the Institute of Electrical and Electronics Engineers published a web article by Robert Charette arguing that the "STEM crisis" does not exist because the number of STEM-trained workers (including bachelor's degree to Ph.D. holders) exceeds the number of available American STEM jobs. Charette's (2013) article includes a critique of some of the studies referenced in this chapter (e.g., Carnevale et al., 2010) and pinpoints research studies that could not identify a shortage of workers in specific STEM fields (e.g., Wadhwa et al., 2007). It is not the goal of this review to support or deny the need for more STEM-trained workers, but to establish that there is a national agenda to improve STEM education, improve access to STEM degree programs and increase the number of students who successfully complete STEM degrees, and why that agenda exists. Charette (2013) does support the argument that there is a need to improve STEM literacy in America, regardless of workforce demands.

[3] Causalities cannot be deduced when interpreting results of association-based analyses such as survey research. As Nehm (2011) points out, one must employ randomized control trials to have the potential to identify causation and make generalizations. As of 2012, there were no published randomized control trials in evolution education research.

[4] The 2005 and 2009 NAEP results should not be directly compared, as the 2009 results are based on a NAEP revised to reflect an updated assessment framework from the National Assessment Governing Board.

[5] After this research was completed, the National Research Council released *A Framework for K-12 Science Education* (2012). The *Framework* was the basis for the development of a new set of science education standards, the Next Generation Science Standards (NGSS Lead States, 2013). The NGSS were released in April, 2013, and are similar to the 1996 NSES in that they establish what students should know and be able to do at the end of each grade or grade-band. The NGSS differ from the NSES by placing increased emphasis on science and engineering practices and cross-cutting concepts that appear in each discipline at every grade level. As of March, 2014, ten states and the District of Columbia committed to implementing the NGSS.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

The design of this study follows a pragmatic[1], mixed-methods research approach incorporating complementary qualitative and quantitative analyses. To address the research concerns[2], the qualitative analysis followed the basic principles of the grounded theory method. The research structure of developing testable hypotheses from the analysis of qualitative data was proposed by Barton and Lazarsfeld (1955) for use in social science research and has been advanced by the development of innovative computer-based tools and methods of analysis (e.g., Green & Salkind, 2010; Jick, 1983; Leech & Onwuegbuzie, 2011; Ragin, Nagel, & White, 2004). Qualitative, demographic and enrollment data were used in theory development and to generate hypotheses and the hypotheses directed collection of data for the quantitative analysis. Qualitative data were then used to deepen the interpretation of the quantitative outcomes.

For this study, all original data were provided by undergraduate students enrolled at Arizona State University (ASU), a large public university, during the academic years 2008-2009, 2009-2010, and 2010-2011. For the qualitative portion of the study, 45 students participated in interviews moderated by the researcher and submitted written responses to a questionnaire (see Appendix B); forty two of them granted the investigator access to their academic transcripts. These data were analyzed using NVivo 8 (QSR International Pty Ltd) computer assisted qualitative data analysis software (CAQDAS).

The data used in the quantitative analyses included responses to an online questionnaire (see Appendix C) provided by an anonymous sample of 486[4] ASU students. The questionnaire was developed using QuestionPro (Survey Analytics) online survey software available via a temporary university license. These data were analyzed using SPSS version 19.

Additional information was mined from the relevant empirical literature and sample survey questions were reviewed in online survey databases. Nationwide poll databases were mined using the iPoll Databank of the Roper Center Public Opinion Archives which was accessible to the researcher via the ASU Libraries. Survey questions available through the iPoll Databank contributed to the choice and phrasing of questions for the anonymous online survey.

The protocol for this study was submitted to the Office of Research Integrity and Assurance at ASU and deemed exempt from formal Institutional Review Board review (IRB protocol #0810003328; Appendix D). Interview participants provided formal consent by signing information letters (see Appendix B) and those who allowed access to academic records completed and signed Family Educational Rights and Privacy Act (FERPA) releases. Respondents to the online survey provided informed consent when they began the question portion of the survey (see Appendix C).

Qualitative Analysis

Grounded theory method. The grounded theory method (GTM) of qualitative data analysis, formally established by Glaser and Strauss (1967), was used as the foundation for this study, given the novel, initially open-ended nature of the research topic. The emphasis of GTM is investigation with the goal of discovering and refining a theoretical perspective based on observed regularities (i.e., repeated ideas or recurring themes) in information provided by study participants (Benaquisto, 2008; Charmaz & Bryant, 2008; Glaser, 1992; Ragin &

Becker, 1992; Strauss & Corbin, 1998). The refined theory is then translated into specific research questions and testable hypotheses. Clearly, GTM differs logically from the standard protocol of quantitative-based physical or life sciences research and differs in its use of the term theory (e.g., Flick, 2006; Maxwell & Mittapalli, 2008). To accomplish the goals of GTM, the researcher must constantly revisit the research concerns and data, reassessing and reanalyzing the data until no new information can be produced that would result in a different theory, or "version of the world," given the research concerns (Flick, 2006:100). The research concerns are the foundation for the theory that is generated and determine how and to what extent the data are analyzed (Benaquisto, 2008; Charmaz & Bryant, 2008; Glaser, 1992; Ragin & Becker, 1992; Strauss & Corbin, 1998).

GTM allowed the author to assess student perspectives and experiences and develop a theoretical understanding of possible relationships between human evolutionary biology education and participants' academic interests and achievement, professional goals and socioscientific decision-making. The investigator deviated from traditional grounded theory method, however, by incorporating the exploration of nominal and quantitative (discreet and derived) data into the process of theory development; typically, theory development is based only on the exploration of qualitative data. This novel approach allowed the researcher to expand her theoretical understanding by exploring relationships between students' statements of their perceptions and experiences and, for example, their gender, age, courses taken or level of acceptance of the scientific theory of evolution.

Data collection and analysis.

Overview. This study used convenience case sampling (Saumure & Given, 2008) and group and one-on-one semi-structured interviews (Ayres, 2008; Saumure & Given, 2008) supplemented with written questionnaire responses (see Appendix B). Two rounds of interviews were conducted with ASU students, resulting in a total of 19 interview sessions and 45 participants. Holding two rounds of interviews allowed the researcher to assess and revise the pre-interview questionnaire and interview procedures between rounds to maximize the accuracy and detail of information that was collected from the participants (see Chapter 4: Presentation and Analysis of Qualitative Data). Ultimately, one second-round participant was dropped from the study for reasons discussed later, reducing the total number of participants to 44.

Interviews were digitally recorded with consent from the participants (see Appendix B). Digital files were imported to NVivo 8 computer-assisted qualitative data analysis software (Gibbs, 2003) for coding (Böhm, 2000; Maietta, 2008). The interviews were subject to descriptive, topic, and analytical coding in the CAQDAS (similar to open, axial, and selective coding as described in the academic literature on qualitative analysis) through the identification of relevant text, repeating ideas, themes, and theoretical constructs shared within and between interviews (Auerbach & Silverstein, 2003; Benequisto, 2008; Böhm, 2000; QSR International Pty Ltd, 2008; Strauss & Corbin, 1998). After initial coding, the audio files were transcribed in NVivo and the transcripts were subject to coding and upcoding (i.e., coding of already coded data) in the software.

Semi-structured interviews. Focus groups (also called group interviews) are widely used in qualitative research to allow researchers to "orient" themselves to a field of study, to formulize theory and generate hypotheses and to develop questionnaires for hypothesis testing (e.g., Auerbach, 2003; Barnett, 2008; Flick, 2006, p. 198; Fontana & Frey, 2000; Merton, Fiske, & Kendall, 1956; Morgan, 1988; Patton, 2002; Puchta & Potter, 2004). Originally conceived for market research, focus groups allow the study participants to lead the researcher to a theory via analysis of the text (i.e., the audio recording or transcript) that comes out of the group discussion (Auerbach & Silverstein, 2003; Barnett, 2008; Flick, 2006). Focus groups provide tangible data, via firm statements, about the attitudes, beliefs, opinions, perspectives, knowledge, awareness and concerns of individuals in a chosen study group (Flick, 2006).

A semi-structured interview style was selected because of the open-ended nature of the research topic and to facilitate the grounded theory approach. In a semi-structured interview the moderator asks a set of questions that relate to predetermined topics, but the potential range of answers to these questions is not known by the researcher (Ayres, 2008). A relatively casual interview style, semi-structured interviewing allows the participants to freely express their views; however, it is the job of the moderator to maintain a good balance between (a) the depth of the interview and the range of the interview, and (b) the openness of the discussion and the structure of the discussion, and to prevent one participant, or a few, from dominating the discussion (Flick, 2006; Fontana & Frey, 2000; Hermanns, 2004). Moderation of semi-structured interviews is a practice the techniques of which the investigator researched extensively. Additionally, a practice focus group session with ASU graduate students was conducted and coded with NVivo 8 prior to initiating formal research.

Case sampling and recruitment. In qualitative analysis, case sampling and recruitment involve the selection of groups of individuals who can provide a source of information most relevant to the research question (Eide, 2008; Merkens, 2000). For the qualitative portion of the study, a broad sample of students was desired; exclusion criteria were limited because the results of the qualitative analysis would be used to inform sampling procedures and exclusion criteria for the quantitative analysis.

This study used a convenience sample (Saumure & Given, 2008) of students enrolled as undergraduates at ASU, the researcher's home institution, during the Spring 2009 semester. Based on the research concerns, the ASU undergraduate body was considered an appropriate group from which to recruit participants. ASU students attend a large, public university that accepts students from a broad range of personal and academic backgrounds and achievements (ASU Fact Book, 2009; Table 2). In the Fall 2008 semester, ASU enrolled 53,298 undergraduates in 21 colleges (ASU Fact Book, 2009). The greatest percentage of students (31.3%) was enrolled in the College of Liberal Arts and Sciences. The mean age of an ASU undergraduate in Fall 2008 was 22 years. Table 3 summarizes demographic data for the Fall 2008 undergraduate student body (ASU Fact Book, 2009).

Based on the mean age of 22 years, ASU undergraduates were expected to have an adequate ability to recall information and experiences from their secondary education. And based on the diversity of academic programs (143 baccalaureate degree majors) offered by the university (ASU Fact Book, 2009), students were expected to be interested in a broad range of subjects and career paths, including but not limited to STEM fields of study and research.

Table 2

Fall 2008 Admissions Requirements for Arizona State University

Requirement		Criteria
General aptitude[a]	Class rank	Top quarter
	GPA	3.0
	Transfer GPA (Resident)	2.00
	Transfer GPA (Nonresident)	2.50
	Composite score (Resident)	ACT 22/SAT 1040
	Composite score (Nonresident)	ACT 24/SAT 1110
High school competency	English	4 years
	Math	4 years
	Lab science	3 years
	Social science	2 years
	Foreign language	2 years
	Fine arts	1 year

Note. Source: ASU Fact Book
[a] Applicants must meet one of the general aptitude criteria.

Participants were recruited in person, via fliers distributed throughout the Tempe campus of ASU and electronically via emails from instructors or teaching associates and by announcements posted by faculty on course websites. When recruited in person, interested students provided contact and demographic information (name, email address, age, gender, academic status, and location where they received their high school diploma) to the investigator. The students alerted to the study by a flier or via electronic announcements were instructed to contact the researcher via email if they were interested in participating (see Appendix B for the email reply sent to students who expressed interest).

For convenience, students were recruited from introductory level STEM-related courses (e.g., chemisty, physics, biology, anthropology) and other introductory level courses that fulfilled students' general studies (GS) requirement for the university. According to the ASU Course Catalog, all

Table 3

*Demographic Data for Undergraduates Enrolled at Arizona State University During the Fall 2008 Semester (*N *= 53,298)*

Characteristic	Category	Value
Gender (University)	Female	51.6%
	Male	48.4%
Age (years)	<19	17.2%
	19 – 24	64.7%
	25 - 34	13.5%
	35 and older	4.6%
Academic status	Freshman	20.6%
	Sophomore	21%
	Junior	26.2%
	Senior	31.4%
	Non-degree seeking	0.8%
Residency status	AZ Resident	76.4%
	Nonresident	23.6%
State of home address at time of application (US students only) [a]	Arizona	79.9%
	Not Arizona	20.1%
Top nine home states after Arizona [a]	California	5.4%
	Illinois	1.6%
	Texas	1%
	Washington	1%
	Colorado	0.86%
	New York	0.88%
	New Jersey	0.8%
	Pennsylvania	0.7%
	Minnesota	0.7%
Ethnicity	African American	4.6%
	American Indian	2.3%
	Asian American	5.7%
	Hispanic	15.2%
	White	65.2%
	“International”	2.4%
	Unknown	4.6%
High school ranking	Top 10%	31%
	Top 25%	58%
	Top 50%	85%
SAT/ACT Scores (mean for freshmen)	SAT Verbal	534
	SAT Quantitative	548
	ACT Composite	23.5

Note. All data taken from the ASU Fact Book, 2008-2009. Retrieved from http://uoia.asu.edu/fact-book-2008-09
[a] *N*=52,034

students are required to complete 8 credit hours of study in the natural sciences, regardless of their declared major. The natural sciences that fulfill this requirement include anthropology, astronomy, biology, biochemistry, chemistry, experimental psychology, geology, microbiology, physical geography, physics and plant biology. The researcher informed 125 ASU faculty members of her research study and requested that the faculty send an email to, or otherwise make available to students, a prepared request for participation in the study (see Appendix B).

The researcher's goal was to interview approximately 50 undergraduate students who would compose a sample of heterogeneous composition with regard to age, gender and geography (home state). An initial target sample size of 50 was deemed adequate with the recognition that failure to reach theoretical saturation would require the recruitment of additional subjects for another round of interviews.

Students who wanted to participate in the study chose two or three dates and times at which they were available to be interviewed, based on a selection of dates and times provided by the researcher (based on the researcher's schedule and room availability; see Appendix B). Students were assigned to a group based on a desirable group size of four to six students (except when two one-on-one interviews were arranged due to students' scheduling conflicts) and a desirable mix of males and females from different regions of the country in each group.

Despite acceptable levels of expressed interest overall ($N > 100$), 30 students who committed to participation in interviews via email ($n = 75$) failed to arrive for their scheduled appointments, despite receiving reminder emails prior to the appointment. A no-show rate of 42.9% led to low participation ($n = 16$) in the first round of interviews; greater recruitment efforts and new incentives increased overall participation (*n* =29) in the second round, despite a no-show rate of 38.3%. During the first round of interviews, participants were told the interview would last up to 90 minutes and that they had the option to eat a meal (valued at approximately eight dollars) that would be provided and funded by the researcher (see Appendix B). For the second round, recruits were told they would receive 10 dollars in cash at the end of the interview session (instead of a meal). Additionally, they were told the interview sessions would last 60 minutes. The researcher was told by first-round participants that a 60-minute commitment was more appealing than a 90-minute commitment and the researcher deemed 60 minutes to be an adequate time limit for achieving the goals of the study based on her first-round experience.

In all, 19 interview sessions were conducted. The first round comprised seven interviews held during a period of nine days. The second round comprised 12 interviews held during a period of seven days. Of the 19 interviews, six of them were one-on-one interviews; four were a result of undergraduates' failure to attend their scheduled focus group appointments and two were a result of the researcher's decision to accommodate students who had scheduling constraints. Of the 13 interviews that involved two or more people, 10 involved both males and females and three comprised only females. The most common group sizes per interview were two or three individuals with a maximum group size of five. Table 4 summarizes basic demographic information for the 45 students who participated in interviews.

Interview process. Upon arrival at their assigned interview session, all participants were given three documents to review and return to the moderator.

All students read and signed a cover letter (see Appendix B) which provided a general overview of the study, acknowledgement of risks associated with participation and information about FERPA releases and the security of their personal information. Forty-two students accurately completed and signed FERPA releases, granting the researcher access to the students' academic transcripts (one student provided an invalid student identification number and two students chose not to complete the FERPA release).

Table 4

*Self-reported Demographic Characteristics of Interviewed Students (*N *= 45)*

Characteristic	Category	*n*
Gender	Female	30
	Male	15
Age (years)	18 – 19	23
	20 - 21	13
	22-23	4
	26	2
	31 – 32	2
	57	1
Academic status	Freshman	19
	First year with advanced status	2
	Sophomore	9
	Junior	11
	Senior	3
	Post-baccalaureate	1
Ethnicity	African American	2
	Asian American	1
	Asian	4
	Caucasian	24
	Caucasian & Brazilian	1
	Caucasian & Lebanese	1
	Hispanic	7
	Hispanic & Lebanese	1
	Latina/Latino	1
	Mixed (more than two ethnicities)	2
	Native American (Navajo)	1

A questionnaire (see Appendix B), requesting demographic, academic and personal information was filled in by all participants, to varying degrees of completion (some students chose to or accidentally left answers blank). Due to the nature of the qualitative analysis, all available questionnaire data were included in the study. The questionnaire also included a series of questions from the Measure of Acceptance of the Theory of Evolution[3] survey (MATE; Rutledge & Sadler, 2007; Rutledge & Warden, 2000) to measure students' level of acceptance of the theory of evolution and act as a stimulus to motivate students' thinking about human evolutionary biology concepts prior to the start of each interview. The questionnaires were associated with the information provided in the students' academic transcripts and interviews in NVivo.

Each participant was assigned a randomly generated participant number which was used to maintain the privacy of their information in a computer database and in NVivo. Each interviewee wore an identification sticker during the interview with his or her first name and participant number only. This allowed a participant to identify his or herself and other students during the audio recording and still protect his or her own and others' identities (no surnames were shared or used). Only the researcher can associate participant numbers with surnames, audio recordings, academic transcripts and questionnaire data.

The researcher (moderator) began the interview sessions by briefly summarizing the research project and its goals and providing basic instructions for participation in the interview (e.g., discouraging students from speaking at the same time as one another). The moderator informed the students that there were no "right or wrong" answers to her questions, or reasons to try to comply with any particular view or opinion or to assume bias on the part of the moderator. The students were encouraged to “teach” the moderator about their experiences and opinions. Finally, students were discouraged from sharing specific information regarding their fellow participants with anyone not associated with the research study. After the instructions, the participants had the opportunity to leave the session before the formal interview began.

Though the interview process was semi-structured, allowing students to propose topics of discussion or ask questions of other participants, the moderator’s research concerns directed the questioning. The researcher prepared the following questions to address the research concerns; however, questions were excluded or expanded upon as a result of each interview’s depth of discussion, time limit and number of participants, as well as the researcher’s identification of emerging themes throughout the course of the interviewing process (see Appendix E for actual moderator questions taken from two interview transcripts).

- Did you learn about evolution in school and, if so, how long did your teacher spend teaching evolutionary principles (e.g., one hour, one week, throughout the school year)?
- As a child, did your parents or guardians take you to zoos and museums?
- Was there a conflict for you between learning about evolution and your personal beliefs – cultural, spiritual, or religious? How were you raised with regard to religion and cultural practices?
- Did learning or not learning about evolution in school affect your performance in science courses here at ASU?

- If your teacher taught about evolution, did he/she talk about the evolutionary history of humans (e.g., fossils such as Lucy or our relationship to other primates)?
- How do you feel about the idea that humans are animals (are primates) and evolved from a common ancestor shared with other primates and, millions and even billions of years ago, with all other forms of life?
- Given the following two scenarios: (a) humans are a product of divine intervention and (b) humans are solely the product of biological evolution, how do you think each reflects on humans' role in protecting the environment or endangered species and/or monitoring humans' role in climate change?
- Do you (a) read or watch the news or regularly check news websites, (b) recycle or do any other activity associated with conservation and sustainability, and/or (c) vote?
- Would you describe anyone in your family as prejudice or racist? Why do you think there is variation in humans' appearance? Do you know why humans have different skin colors?
- If you are a STEM major, what do you think most influenced you to pursue a formal education in STEM (e.g., a teacher, a parent, a personal experience, an innate curiosity about the world)?

For groups of two, the moderator alternated between participants when asking questions. For groups of three or more participants, the moderator cycled among participants when asking questions (e.g., for a group of three participants, A, B and C, the order might have been A, B, C, then B, C, A, and so on). Through questioning and discussion, participants shared their beliefs, feelings, experiences and opinions.

At 57 years old, one second-round participant was significantly older than the mean age of all of the other interview participants. This participant was unable to recollect pre-college experiences in a manner that was necessary and relevant to the research study. Therefore, this participant's data and interview were ultimately discarded from the study. As a result, the total sample size of participants for the qualitative analysis was 44.

Coding and analysis. Each interview session was recorded with an Olympus WS-321M digital recorder, transferred to a computer and imported to the CAQDAS NVivo 8 for coding in the tradition of constant comparison analysis (Glaser & Strauss, 1967; Mills, 2008; Noerager Stern, 2008; Strauss & Corbin, 1998). According to Noerager Stern (2008):

> Constant comparison can be thought of as a qualitative approach that resembles the quantitative methods of factor analysis or multiple regression in that every data bit is compared with every other data bit; however, two major differences exist. First, rather than a computer, the analyzing instrument is the researcher's brain. Second, as the theory begins to take shape, the researcher is free to alter her or his study question. (p. 1)

Coding is a method of systematically breaking down the data into bits for the purpose of revealing major themes and discarding data irrelevant to the research concerns (Benaquisto, 2008; Glaser, 1978; Glaser & Strauss, 1967; Strauss, 1987; Strauss & Corbin, 1998; for a review of the coding process in GTM, see Böhm, 2004). The researcher coded the interviews by selecting time spans of audio data she considered relevant to the research concerns and organizing them into virtual containers; in NVivo, these containers are called *nodes*. In addition, any meaningful phrases or statements were transcribed into the interview file after coding. Audio and transcribed content from the interviews was first coded to *case nodes* using the randomly assigned participant numbers so that all of the content associated with a particular student was contained within a single case node for that student. In addition, digital scans of the participants' questionnaires were added to the NVivo project as external sources and the students' written questionnaire responses were coded, as well.

The categories chosen for early-stage content coding were based on the research concerns and the interview questions formulated by the moderator. They included the nodes *exposure*, *conflict*, *religion*, *preparation for college*, *acceptance*, *environment*, *news-voting-current events*, *diversity*, and *STEM motivation*. The results of coding for each interview were visualized using colored coding stripes (Figure 3).

Assigning data to case nodes is also useful because case nodes are associated with *attributes*. Attributes included demographic or other discreet data taken from the questionnaires and interviews (e.g., *gender*, *age, STEM major*). Eighty-five attributes were created (Appendix F); however, not every case could be assigned a value for every attribute, as the assignment of values depended on the information provided by the students. Additionally, some attribute values (e.g., *HEB exposure – interview*) required the researcher to compare students' responses and gain an understanding of relative differences and similarities between them before creating a list of attribute values.

Figure 3. Example of coding in NVivo. The coding results are visualized using coding stripes. Each stripe corresponds to a section of the audio that has been coded. Participant numbers were used for nodes that were specific to one student.

Early-stage category coding was useful to the assignment of attribute values; for example, to see if participant 203 said anything in her interview about her parents' religion, an *advanced coding query* was used to compile everything she said about religion. This information was then used to fill in a *profile sheet* for each student. Each profile sheet included brief hand-written notes by the researcher about the students' interview responses. This information was used when assigning attribute values to the case nodes. In this example, information about participant 203's parents' religions was used to assign values to the attributes *mom religion* and *dad religion* at node 203. The profile sheets and coding queries were especially useful when comparing students' responses to one another and gauging the range of answers given to a particular question, with the purpose of determining the discreet values for each attribute.

Using both early-stage coding and attribute assignment, the researcher could also look at what was said by all participants, a group of participants, or a single participant for each category. By simply opening a category node, such as religion, all of the content assigned to that node, across all interviews, was automatically compiled by NVivo. Likewise, the researcher could use the advanced coding query and see all content coded to religion for only the female students, or, more specifically, all content coded to religion for participant 203.

NVivo's data exploration tools were used to explore and visualize coding and attribute data. These tools include queries, charts, and cluster analysis. For example, Figure 4 shows how two attributes were used to create a 3D rotatable chart; the attribute values for *evolution acceptance* are plotted on the X axis and the values for *STEM career desire* are plotted on the Z axis. Data exploration and visualization of this type led the researcher to a deeper understanding of the data and assisted in further coding and in the identification of emergent themes.

While exploring the data, more advanced coding–or upcoding—took place. As themes and new ideas emerged, new nodes were created, either on the same hierarchical level as the early-stage coding categories, or as *daughter nodes* within the preliminary nodes. Nodes were also aggregated, such that a parent node contained all of the information assigned to its daughter nodes.

After early-stage coding and data exploration, it was determined that the best approach to organizing the interview data was to further transcribe the audio into the *content areas* of NVivo (Figure 5). Initially, only fragments of statements had been transcribed that corresponded to already-coded sections of audio. The researcher found that having access to the complete text permitted broader coding contexts in NVivo (i.e., existing coding of a phrase or term is spread to the surrounding paragraph)—often essential to theory development—and a more rapid review of the interview content overall, which was more efficient than listening and re-listening to audio when synthesizing results. All audio files (a total of 16 hours and 55 minutes of audio) were fully transcribed.

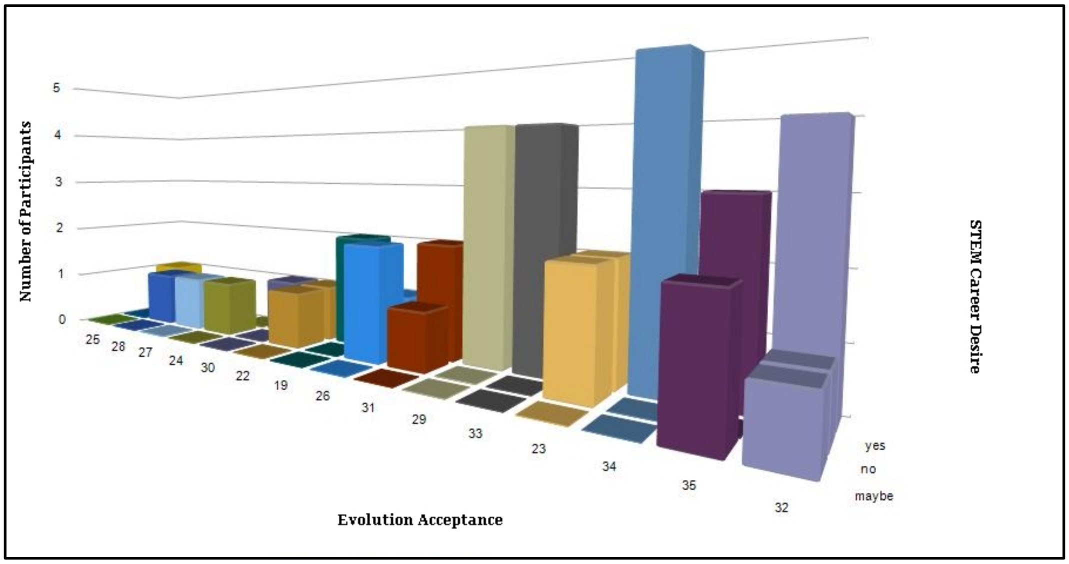

Figure 4. An example of data visualization in NVivo using case attributes. In this example, STEM career desire is plotted against evolution acceptance. In NVivo, this graph can be rotated and examined in three dimensions.

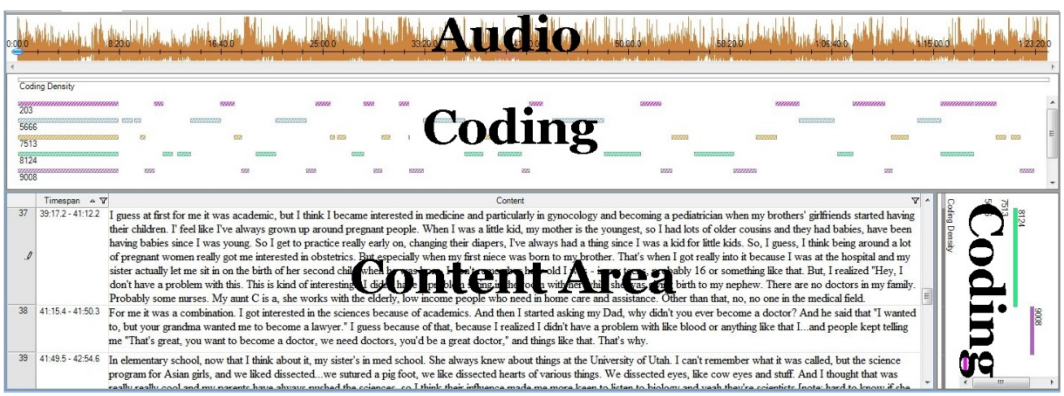

Figure 5. An example of case node coding of transcript content in NVivo. Each time-stamped entry in the content area is coded to a case node. Coding is visualized with coding stripes below the audio track and to the right of the transcript.

Memos (Groenewald, 2008) were also created which allowed the researcher to link transcript and questionnaire content to her own reflective thoughts and ideas. Memoing is a crucial part of the coding process:

> Memos evolve and increase in complexity, density, clarity, and accuracy as the data analysis progresses. Memos written later may negate, amend, extend, and/or clarify earlier written ones. Memos keep the researcher embedded in the empirical reality and contribute to the trustworthiness of qualitative research. (Groenewald, 2008, p. 1).

A project-wide memo titled *journal* was used to record the researcher's thoughts and observations about the project as a whole and contributed to theory development. The journal was also useful in early-stage data collection for the purpose of recording notes about the aspects of the interview process that needed to be improved upon for the second round of interviews. When appropriate, the content of memos was coded, as well.

Once the researcher determined that revisiting the data and creating new nodes no longer lead to new ideas or theoretical understanding, theoretical saturation was reached. Ultimately, some nodes or daughter nodes were renamed and others thrown out when deemed irrelevant to the research questions. The concepts, categories, and connections that were identified among all of the sources and references were used to develop theory. This theory was used to generate a series of testable hypotheses relevant to the research concerns (Chapter 4: Presentation and Analysis of Qualitative Data includes the coding results, node structure and hypotheses).

Quantitative Analysis

Survey design. The theory and hypotheses developed from the qualitative analysis drove the design of the anonymous cross-sectional survey of ASU undergraduates (Appendix C). The survey was conducted in two independent rounds during the Fall 2010 and Spring 2011 semesters (students who participated in the Fall were not permitted to participate in the Spring). The descriptive design of the survey was aimed at comparing groups within the population as well as identifying generalizable patterns and making predictions for the sample and the population it represents. The survey instrument (Appendix C) was supplied to participants as an online questionnaire comprising carefully written, primarily supplied-response questions (a write-in "other" category was included as necessary). Question types included list, category, and scale. The questionnaire was designed to be completed in 30 minutes or less.

Frequently, question and response wording mimicked or copied that of relevant questions mined via the iPoll Databank. The goals of using mined questions were to (a) include questions that, from the researcher's point of view, were known to produce desirable outcomes and (b) avoid ambiguity and imprecision (Bell, 2010; Fink, 2003), thus maximizing validity and reliability.

The questionnaire was created using QuestionPro (Survey Analytics) online survey software. QuestionPro supports a wide variety of question types and survey logic. Branching logic was used to prevent respondents from seeing questions they did not have to answer (e.g., students who attended public high school did not have to see questions about home schooling experiences) and to automatically terminate surveys of individuals who did not meet the eligibility criteria. QuestionPro also prevented "ballot box stuffing" because the questionnaire could only be submitted once from a particular computer (based on IP addresses).

Sampling and recruitment. Sampling procedures were based on the qualitative analysis outcomes, research hypotheses, and a priori statistical power analyses. The investigator determined that a sample of more than 368 students between the ages of 18 and 22 years (inclusive) who were enrolled in at least one ASU course during the Fall 2009 or Spring 2010 semesters constituted a representative sample of Arizona State University undergraduate students who followed a traditional or nearly-traditional academic path, entering college within four years of high school graduation[5].

The inclusion criteria – age and enrollment status – were chosen based on the research hypotheses and to limit the potential for outliers with regard to age, which was a complication during the qualitative portion of the study. Students who participated in the interviews for the qualitative analysis were not excluded from completing the online survey. Given the low percentage of international students who attend ASU as undergraduates (approximately 2.5%; ASU Fact Book, 2009), they were not deliberately excluded from participation, though their responses were not considered for the purposes of hypothesis testing.

A desired sample size greater than 368 students was deemed adequate based on power analyses performed using G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) free online statistical software. A commonly accepted statistical power (1-β) value of 0.8 (there is an 80% chance of rejecting the null hypothesis when it is, in fact, false; Connolly, 2007; Knapp & Brown, 2007; Levy, 2009), the conventional significance level (α) of 0.05, and an effect size (δ) of 0.3 (Levy, 2009) were used for power analyses. Power analyses of exact tests of a correlation (two tails) assumed a bivariate normal model (required sample size = 84) and a linear multiple regression model with 100 predictors (required sample size = 187). A power analysis was also done for chi-square (contingency tables) with 10, 20 and 30 degrees of freedom (required sample sizes = 181, 233, 273) and for Wilcoxon-Mann-Whitney t tests (two tailed, normal distribution) with an allocation ratio of one (required sample size = 184/group = 368). A power analysis for a one-way, fixed effects, omnibus ANOVA was performed for five groups (required sample size = 140).

Participants were recruited heavily via fliers distributed on the Tempe campus of ASU and electronically via emails or announcements from faculty and teaching associates (Appendix C) as well as on social media (Facebook and Twitter) pages directly associated with ASU. Recruitment materials included a URL for the survey. The study was advertised as a “general science survey” to limit bias toward the survey topic and maximize the likelihood that students would follow the link to the survey regardless of their feelings and opinions about or knowledge of the topic of evolution generally or human evolution specifically. The information letter on the first page of the questionnaire (Appendix C) provided more details about the research project and students could exit the survey at any time.

The information letter included a brief description of the study goals, eligibility criteria and incentive; participants could enter a drawing for a gift card worth 150 dollars upon completion and submission of their questionnaires. Drawing entry involved a separate questionnaire (Appendix C) that was contingent upon, but not directly associated with, the study questionnaire. That way, students who chose to enter the drawing could provide identifying information without jeopardizing the anonymity of their contribution to the research project.

Data management. QuestionPro automatically prevented multiple entries from a single participant, but data were reviewed by the researcher in Excel to ensure that repeat submissions were excluded. Students' responses were reviewed for consistency, particularly in the case of alternate-worded questions with a Likert scale of response options (i.e., to be sure that a students' responses to different questions about the same issue were not contradictory). If participants provided contradictory or problematic responses, they were dropped from the sample.

As a first step, variables and values were generated from students' responses to single questionnaire questions ("question-based variables") in Excel. Question-based variables were nominal, ordinal or scale. Nominal and ordinal variables were coded appropriately with whole numbers (e.g., for SEX, 1 = female, 2 = male); for ordinal variables, the most correct or science-based responses were typically coded with higher numbers and inaccurate or non-science-based responses were coded with lower numbers. Some scale variables were converted to ordinal variables by assigning the data to categories. Additional variables were created and IF formulas in Excel were used to generate their values based on a composite of students' responses to multiple survey questions. Missing data were represented by 999 when data should have been provided and by -1 when a question was skipped due to survey logic. For some ordinal variables, a response of "I don't know" was also coded as missing data (-1) if appropriate. Three individuals not associated with the research study reviewed the data in Excel for coding errors and all errors were corrected.

The single-question based and composite variables for the statistical analyses were then entered into SPSS 19. Frequency tables were generated to check for outliers and miscoded data. In some cases, a new composite variable was calculated in SPSS based on students' responses to a series of questions that were developed to assess specific knowledge, beliefs or behaviors. Before the new variable could be computed, the series was subject to factor analysis and internal consistency reliability analysis. Based on those results, the single-question based variables that best represented the factor of interest were used to calculate scores for the new composite variable. Due to the low number of missing responses, missing values were not imputed.

Data analysis. All analyses of survey data were performed using SPSS. Choice of descriptive statistic and statistical test depended on the variable types, and the purpose of an analysis—whether descriptive, comparative, associative (correlative) or predictive—or the hypothesis being tested (Fink, 2003:6).

Data exploration. Frequency tables, scatterplots, histograms and Chi-square (contingency) tables were generated to explore the data and check for normality in the case of scale variables, homogeneity of variance (heteroscedasticity), or linearity when appropriate. Given that the majority of variables were categorical and the scale variables were not normally distributed, nonparametric methods were used. It should always be noted, that power ($1-\beta$) is not as great with nonparametric tests as parametric tests.

Relationships between variables. Boxplots were used to examine the relationship between categorical and scale variables; for example, to compare medians between categories of a nominal variable. A nonparametric Levene's F-Test (Nordstokke et al., 2011) was used to test for homogeneity of variances between groups for scale variables. Heteroscedastic variables were root or log-transformed.

Spearman correlations were performed to analyze the relationship between ordinal and scale variables or between two ordinal variables. SPSS' crosstabs procedure was used to test for independence of binary nominal variables based on row or column proportions; Phi was calculated to determine effect size. Mann-Whitney U tests (the nonparametric equivalent of a student's t-test) were performed when testing for a relationship between a binary nominal variable and an ordinal variable. Effect size for a Mann-Whitney U test was calculated as ($|Z|/\sqrt{N}$).

Kruskal-Wallis tests were used to identify relationships between a nominal variable with more than two categories and an ordinal variable. Kruskal-Wallis tests are comparable to a one-way ANOVA; however, a Kruskal-Wallis test tests the null hypothesis that the probability of a random observation from one group being greater than one from another group is 0.5. This nonparametric test uses ranks, which makes it less powerful than an ANOVA. Though data do not have to be normally distributed to perform a Kruskal-Wallis test, the test assumes that the distributions of values for each of the groups have the same shape. The effect size (Eta^2) for a Kruskal-Wallis test was calculated as ($\chi^2/n\text{-}1$). Post-hoc multiple comparisons tests were conducted automatically in SPSS (which provided Bonferroni corrected and uncorrected p-values) when it was appropriate to use rankings based on all groups, not just the two groups being compared; otherwise, Mann-Whitney U tests were performed. Bonferroni corrected p-values for post-hoc multiple comparisons were only used for cases with more than four groups.

Predictive analyses. Binary logistic regression was used to predict group membership for binary nominal variables. Both SPSS' "Enter" method and backwards stepwise (LR) method were used as appropriate to force variables into a model or reduce a model, respectively. Calculations included as part of a binary logistic regression included Nagelkerke R^2 ("pseudo R^2" based on maximum likelihood estimations) and Hosmer-Lemeshow Goodness of Fit (ideal for sample sizes greater than 400). Odds ratios were based on Exp(β), or exponentiated beta weights (which are like unstandardized beta weights). Beta weights (β) and the significance of the Wald statistic were used to interpret the results of the binary logistic regression. In the case of evidence of multicollinearity or suppressor effects, particular variables were removed from the model either manually or via the backwards stepwise (LR) method.

Multiple regression could not be used for predicting values of scale variables due to heteroscedasticity and a lack independence of residuals based on a Durbin-Watson statistic, therefore, scale variables were recoded as ordinal variables and cumulative odds ordinal logistic regression with proportional odds was used instead. Ordinal logistic regression is a type of Generalized Linear Model (GLM) suitable for use with categorical or non-normally distributed dependent variables. Dummy independent variables and binary variables representing cumulative splits of the dependent variable were created as needed to test model assumptions; multicollinearity diagnostics were calculated by SPSS and the assumption of proportional odds was tested via the PLUM syntax in SPSS. If assumptions are met, that means there is no problem of multicollinearity (independent variables are not highly correlated with each other) and each independent variable has an identical effect at each cumulative split of the dependent variable (based on the odds ratios for each slope coefficient). Once met, independent variables were entered appropriately for the ordinal logistic regression; ordinal variables were treated as continuous and categorical covariates were identified and the appropriate contrast chosen for each. Results were based on the Beta weights, Wald Chi-square statistics and odds ratios.

CHAPTER NOTES

[1] Grounded Theory Method (GTM)—is described here as pragmatic, reflecting its practicality and reliance on logic and reasoning for inducing conceptual theories. As described in this chapter, GTM assumes no *a priori* knowledge of a subject and relies on data exploration and coding for discovering themes and ultimately generating hypotheses regarding what is happening and why. This description lends itself to a discussion of the philosophical meaning of pragmatic and of epistemology (the theory of knowledge). Pragmatism, as exemplified by William James, C.S. Pierce, John Dewey, and Chauncey Wright, was an American-born late 19th Century philosophy. Simply put, pragmatists' view of "the truth" was one that depended on the utility of the answer to a question; in other words, the truth depends on what one wants to know and the pleasantness of the outcome, or the beneficial impact it has on one's life (Ruse, 2012; Warburton, 2012). This take on the truth would seem to be in opposition to GTM, the goal of which is to reveal truth by identifying what is actually happening in reality for a study sample—a view more along the lines of Kant or Lorenz (realism) or even Ayer (logical positivism), and involving induction. An important review of the history and philosophical groundings of GTM by Bryant (2009), addresses the elements of these different philosophical views in the "family" of approaches to GTM outlined by the author.

[2] See Auerbach and Silverstein (2003, pp. 15-16) for a discussion of research hypotheses versus research concerns.

[3] Not all participants in the online survey answered every question. Some questions were optional; therefore *n* varies depending on the question.

[4] The M.A.T.E. is a 20 question survey which "assesses acceptance, rather than belief in, evolutionary theory as a scientifically valid and explanatory theory" (Rutledge & Warden, 2000; Rutledge & Sadler, 2007, p. 333). Rutledge and Sadler (2007) claimed internal consistency and test-retest reliability of the M.A.T.E. and recommend that the M.A.T.E. be used by researchers of evolutionary biology education in conjunction with other research instruments that generate quantitative data.

[5] According to the U.S. Census Bureau, in 2010, there were approximately 21,000,000 non-institutionalized civilians between and of the ages 18 and 22, approximately 6,250,000 of whom were high school graduates.

CHAPTER 4

PRESENTATION OF QUALITATIVE DATA

The qualitative portion of the research project served two main purposes: (a) to develop a theoretical understanding of possible relationships between human evolutionary biology education and undergraduate students' experiences, opinions, beliefs, achievements, interests and goals and (b) to develop hypotheses to be tested via quantitative analysis. The qualitative analysis is based on data collected from one-on-one and group interviews with students and a pre-interview questionnaire. The pre-interview questionnaire was used to collect participant data, but also as a way to identify the strengths and weaknesses of the questionnaire questions in consideration of using them in a survey for the quantitative analysis.

This chapter includes a detailed presentation of the demographic data for the research sample, a summary of how the interview data were coded and upcoded for particular nodes in NVivo, and an explanation of how data were used to assign attribute values to case nodes, when applicable. In the next chapter, emerging themes are identified and hypotheses are generated regarding students' (a) STEM enrollment, achievement, interest and motivation and (b) socio-scientific decision-making in relationship to their human evolutionary biology exposure, with consideration given to the influence of students' religion and their evolution acceptance.

Demographic data

Table 4 in Chapter 3: Research Design and Methodology summarizes some basic demographic data for the 45 interview participants. One participant was dropped from the study for reasons stated in Chapter 3, therefore the data presented in this chapter apply to the 44 participants whose pre-interview questionnaires (see Appendix B) and interview responses were used in the qualitative analysis. Academic transcripts were obtained for 41 of the 44 participants, which meant that, for three of the students, university course enrollment data were limited to the information provided in the pre-interview questionnaire and interviews, and their university GPA was unknown. Figures 6 through 14 present detailed demographic and academic data for the 44 students in the study sample.

The sample comprised more female students (n = 29) than male students (n = 15; Figure 6). The majority of the students (n = 37) were between the ages of 18 and 22 (Figure 7) and were underclassmen (n = 30; Figure 8). The primary self-reported ethnicity was Caucasian (n = 24), followed by Hispanic (n = 7; Figure 9). The most common religions were Catholicism (n = 8) and Mormonism (n = 3); however, 15 students reported on the questionnaire that they were not members of any religion and six students did not provide an answer to the question concerning religion (Figure 10). Most of the students (n = 35) graduated from a public high school (Figure 11). Though the majority of the participants (n = 25) graduated from a high school in Arizona (Figure 12), seven of those 25 students reported during their interviews that they attended at least one other high school than the school from which they graduated. More than half (n = 30) of the interviewees were STEM majors (Figure 13), including eight biology majors (some with dual majors or concentrations) and two anthropology majors (Figure 14).

Coding and Attributes in NVivo

As described in Chapter 3, Research Design and Methodology, the pre-interview questionnaires and interviews were used to explore a suite of research concerns relevant to the research topic. As the data were reviewed in NVivo, they were coded and upcoded to nodes and the data assigned to each node were then used when assigning attribute values to the cases. The following parent nodes were created:

- exposure
- religion
- acceptance
- STEM appeal
- career goals
- environment
- news-voting-current events
- diversity

A detailed description is provided in this chapter of how the interview data were coded and upcoded for the nodes exposure, religion, and acceptance, and how the data were used to assign related attribute values to the case nodes; in other words, I explain how I defined and measured exposure, religion, and acceptance, and how I created discreet variables for each. I discuss the other five nodes in Chapter 5, which addresses theory development and hypothesis generation.

Defining and measuring human evolutionary biology exposure. Pre-collegiate exposure to human evolutionary biology (*HEB exposure*) was assessed using information from the pre-interview questionnaires and interviews. Ultimately, each participant was assigned a value for the HEB exposure attribute

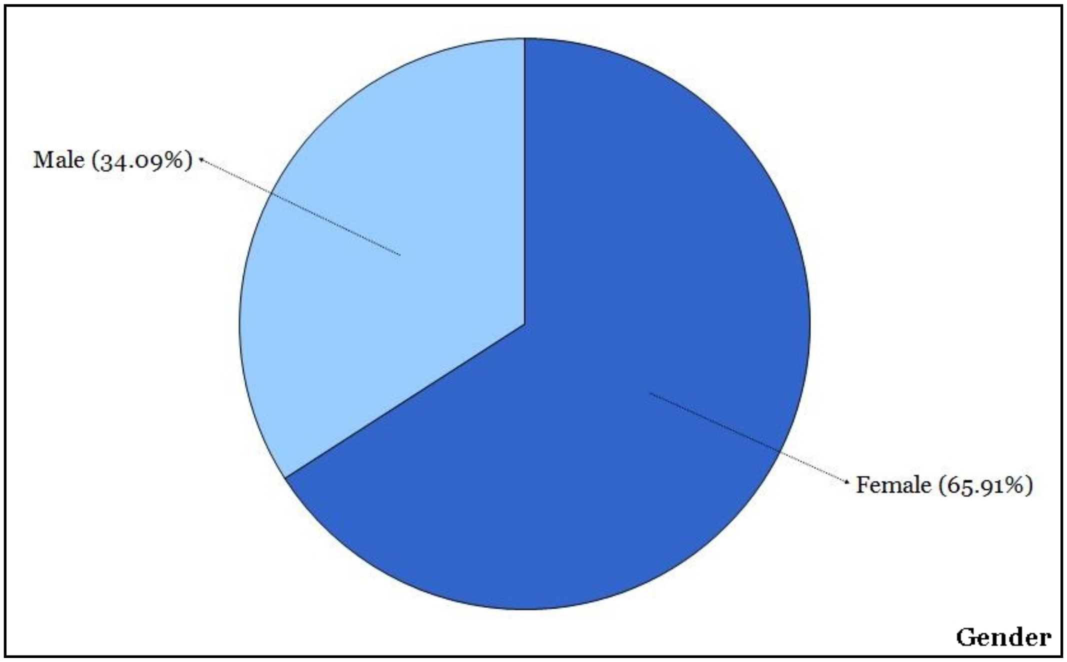

Figure 6. Gender distribution for the sample of interview participants (*N* = 44).

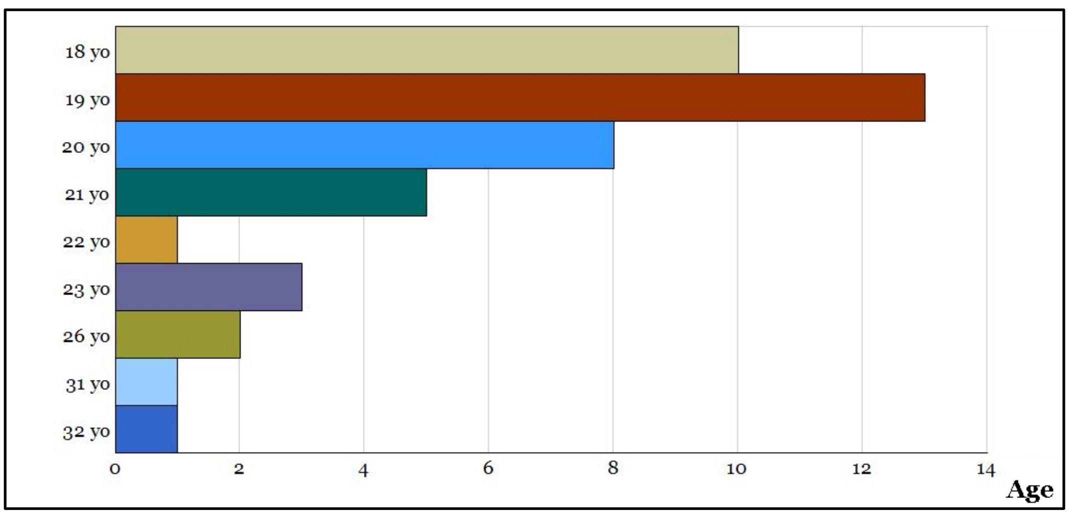

Figure 7. Age distribution for the sample of interview participants (*N* = 44). Participants ranged in age from 18 to 32 years old. The X axis is the number of participants.

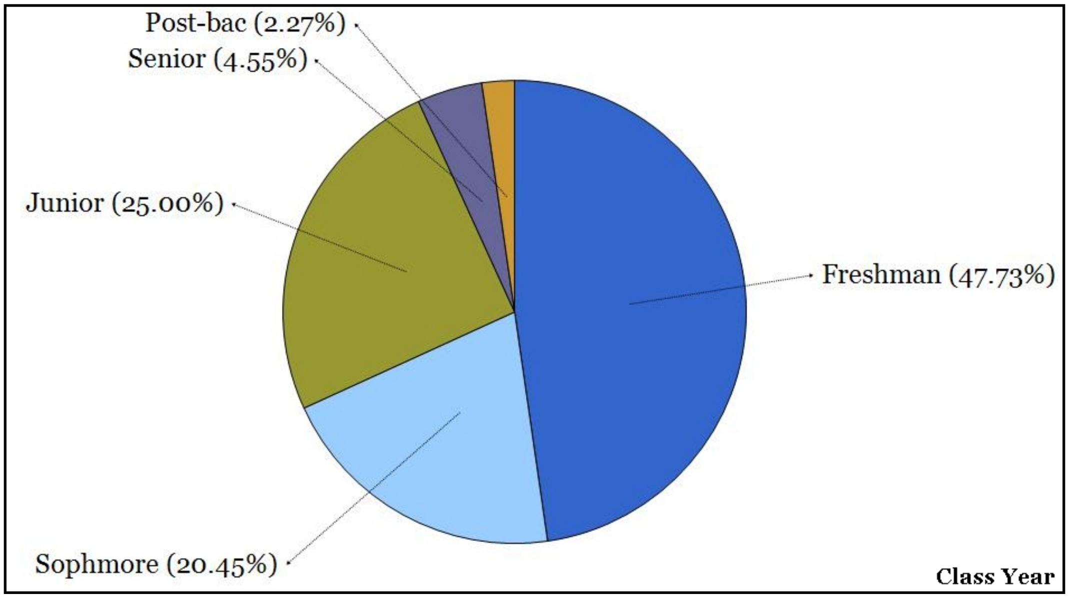

Figure 8. Class year distribution for the sample of interview participants (*N* = 44).

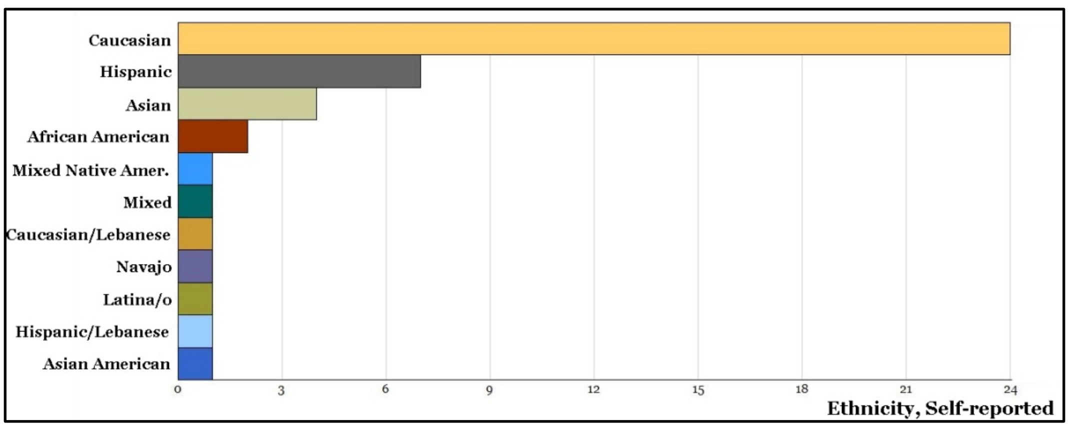

Figure 9. Ethnicity (self-reported) distribution for the sample of interview participants (*N* = 44), based on the ethnicity indicated by each participant on the pre-interview questionnaire. The X axis is the number of participants.

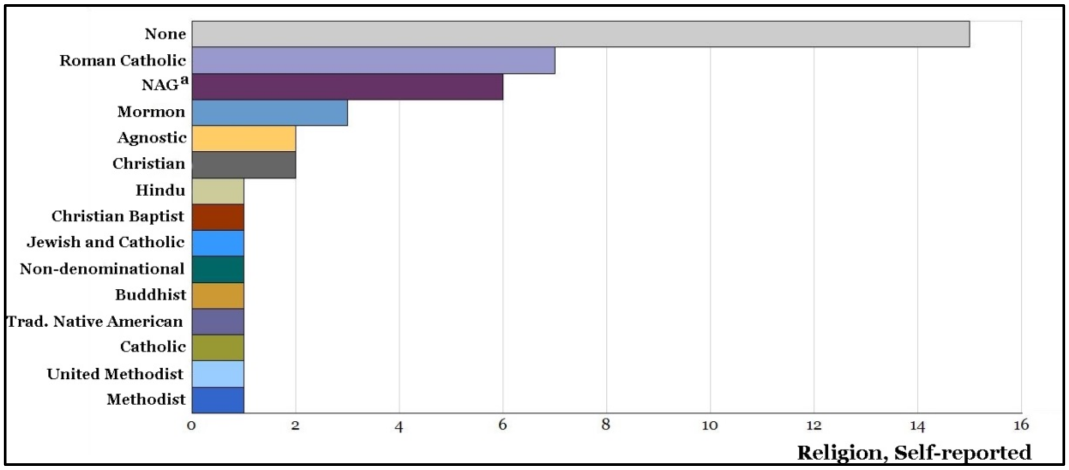

Figure 10. Religion (self-reported) distribution for the sample of interview participants (*N* = 44). The X axis is the number of participants.
[a] NAG = No answer given

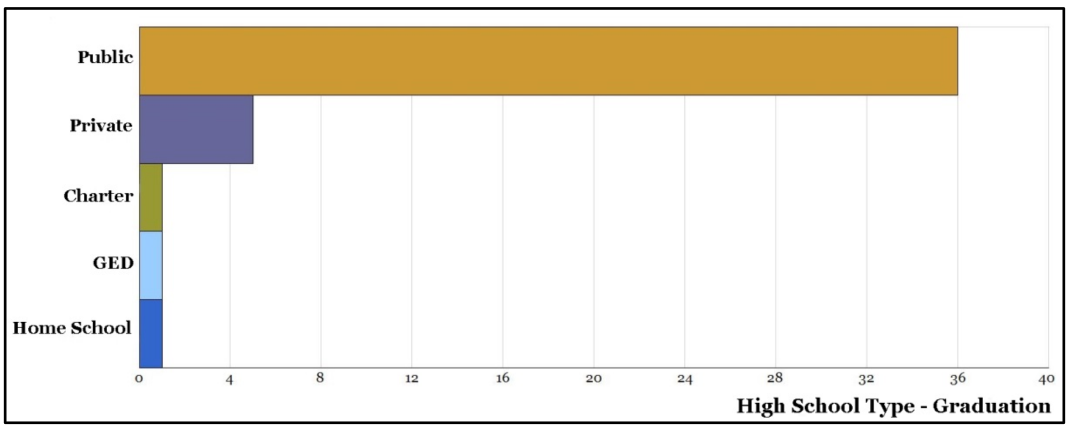

Figure 11. Type of high school from which interview participants graduated (*N* = 44). The X axis is number of participants. One student was home-schooled and one student took the GED exam.

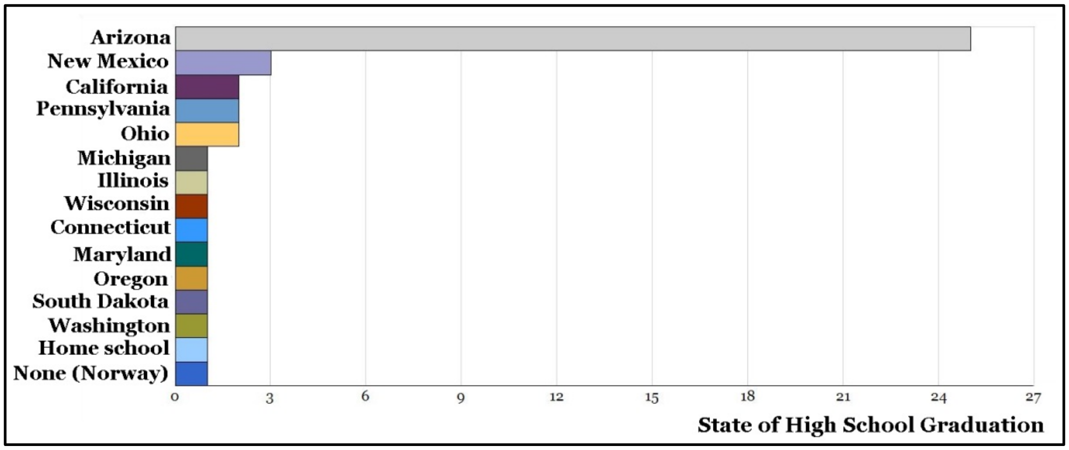

Figure 12. U.S. states where interview participants graduated high school (N = 44). The X axis is the number of participants. One student was home-schooled in multiple states and one student graduated from a high school in Norway.

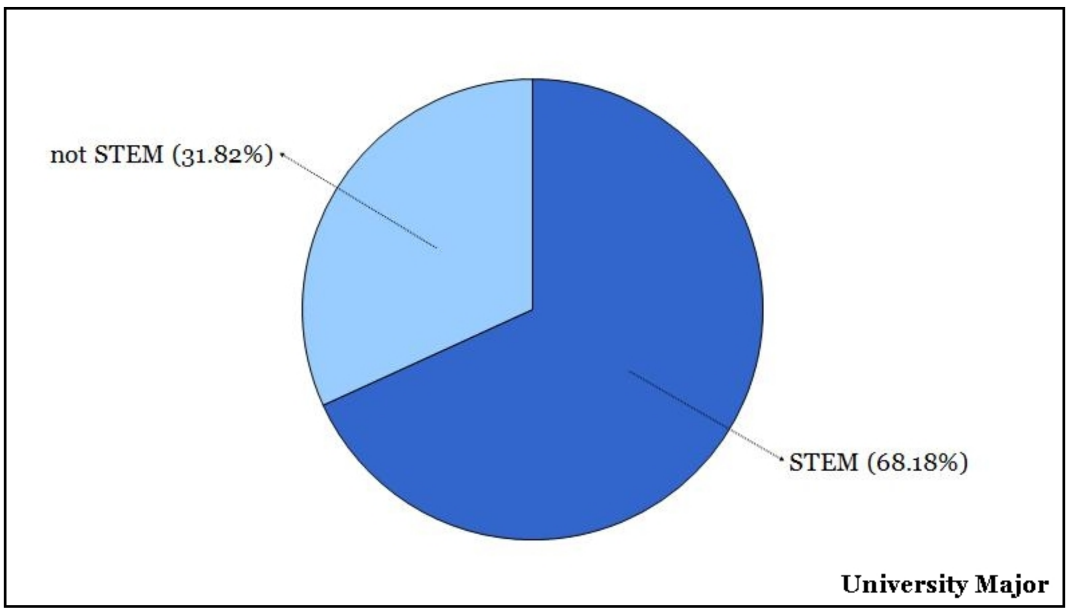

Figure 13. Distribution of STEM and non-STEM majors for the sample of interview participants (N = 44).

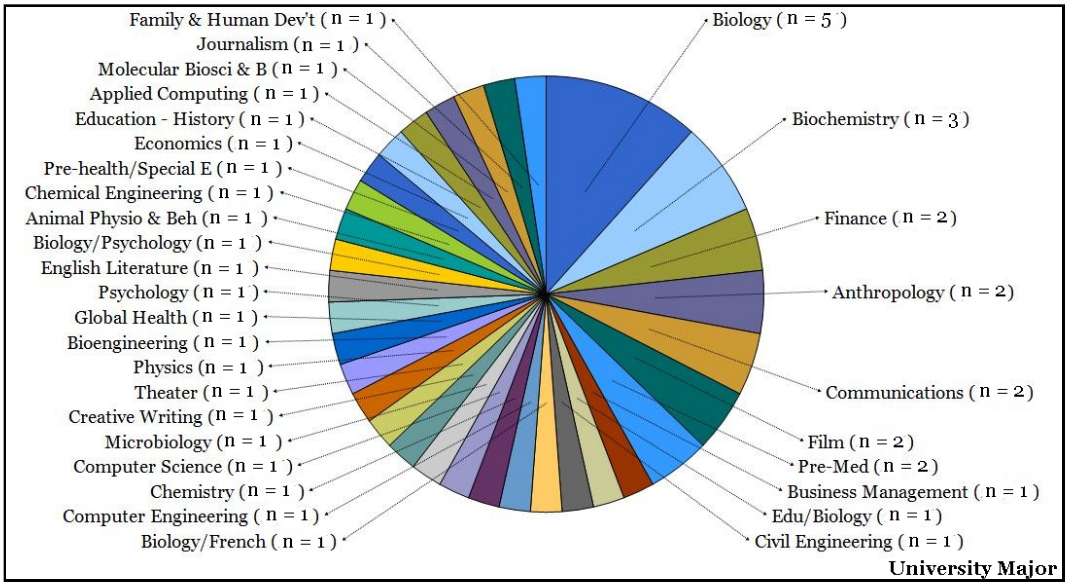

Figure 14. Distribution of university majors for the sample of interview participants (N = 44). A slash (/) indicates a dual major or a major with a concentration or minor.

of either *none*, *minimal*, *moderate*, or *high*. Two qualitative variables were considered when assigning attribute values to each participant's case node: (a) students' responses on the pre-interview questionnaire regarding their recollection of learning about specific human evolutionary biology-related topics during high school and (b) students' recollections of their exposure to human evolutionary science generally and the fossil record of human evolution, specifically, during any of their pre-college schooling (K-12). The results for the first (Table 5) and second (Table 6) rounds of interview participants are presented separately below.

Regarding HEB exposure, the information students provided in their interviews did not always reflect their pre-interview questionnaire responses. This outcome was recognized after the first round of interviews was completed and, as a result, the questionnaire was revised accordingly prior to the second round of interviews. This was acceptable because one of the goals of providing a pre-interview questionnaire was to determine how best to compose items to capture exposure accurately.

Table 5

*Assessment of K-12 Human Evolutionary Biology Exposure for First Round Participants (*N *= 16)*

Participant	Exposure: Origins/Fossils/Primates (Questionnaire)	Exposure: General HEB/ Fossil Record (Interview)	Overall HEB exposure
4506	no/no/no	no/no	none
7096	yes/yes/yes	yes/yes	high
6006	yes/no/yes	minimal/no	minimal
5666	yes/yes/yes	minimal/yes	moderate
8124	yes/yes/yes	minimal/no	minimal
7513	no/no/yes	no/no	none
9008	yes/yes/yes	yes/no	moderate
203	yes/yes/yes	minimal/yes	moderate
1462	yes/yes/yes	minimal/no	minimal
729	no/no/yes	minimal/no	minimal
108	yes/yes/yes	no/no	none
4261	yes/no/no	no/no	none
1214	yes/yes/no	minimal/no	minimal
7218	yes/yes/yes	yes/yes	high
365	yes/yes/yes	no/no	none
2436	yes/yes/yes	yes/yes	high

During the first round of interviews, the pre-interview questionnaire (see Appendix B) asked:

- Do you recall being taught about any of the following concepts/topics in your high school science course(s)?

and the following response options relevant to human evolutionary biology were provided:

- the origin of humans

Table 6

*Assessment of K-12 Human Evolutionary Biology Exposure for Second Round Participants (*N = *28)*

Participant	Exposure: Origins/Primates/ *Australopithecus*/Lucy (Questionnaire)	Exposure: General HEB/ Fossil Record (Interview)	Overall HEB exposure
7761	no/yes/no/no	no/no	None
4272	yes/yes/yes/yes	yes/yes	High
974	yes/no/no/no	no/no	None
3066	no/no/NAG/no	no/no	None
5886	yes/yes/no/yes	minimal/minimal	Minimal
4262	yes/yes/no/no	no/minimal	Minimal
2439	yes/no/no/yes	NAG/yes	High
6004	yes/yes/no/yes	minimal/minimal	Minimal
7561	no/no/no/no	NAG/minimal	Minimal
5522	yes/yes/no/no	minimal/no	Minimal
1104	yes/no/no/no	minimal/no	Minimal
7634	no/yes/no/no	minimal/no	Minimal
4763	no/no/no/no	minimal/no	Minimal
7201	yes/yes/NAG/NAG	no/no	None
483	yes/no/no/no	no/no	None
922	yes/yes/no/yes	yes/no	moderate
8406	yes/yes/no/yes	minimal/yes	moderate
1692	yes/no/no/yes	no/no	None
1123	no/no/no/no	no/no	None
2206	yes/yes/no/yes	minimal/yes	High
502	yes/no/no/no	no/no	None
206	yes/NAG/no/yes	yes/yes	High
1192	yes/yes/no/yes	no/minimal	Minimal
317	yes[a]/yes/NAG/no[b]	minimal/no	Minimal
913	yes/yes/no/no	minimal/no	Minimal
6243	yes/yes/yes/yes	minimal/NAG	Minimal
362	yes/yes/no/yes	yes/yes	High
7677	no/yes/yes/yes	no/no	None

Note. NAG = No answer given
[a] The student wrote in “sort of” next to the response.
[b] The student wrote in “the sheep?” next to the response.

- paleontology (fossils)
- primates (apes and monkeys)

For each response option, the students checked a box for an affirmative response and left the box blank to indicate a negative response.

For the majority of students in the first round, their questionnaire responses were reflected in the information they provided during the interview process (see Table 5); however, four of the 16 students indicated on the questionnaire they had been exposed to one or all of the HEB topics in school and then contradicted that information in their interviews or explained that any formal education related to paleontology or primates did not involve a discussion of humans. Therefore, prior to the second round, the questionnaire response options were revised to also include the terms *Australopithecus* and *Lucy*, in addition to the response options mentioned above, with the goal of better assessing students' exposure to the human fossil record and human evolutionary biology in general. In addition, the question was reworded to inquire about middle school, as well as high school, because some first-round students reported learning about human evolutionary biology in sixth, seventh or eighth grade.

Of the 28 students who participated in the second round of interviews, 11 indicated they learned about *Australopithecus* and/or the australopithecine Lucy in school and did indicate at least minimal formal exposure to HEB in their interviews. Only two students indicated on their pre-interview questionnaire that they had learned about australopithecines and/or Lucy, but stated in their interviews that they had no exposure to HEB as part of their formal schooling. The use of the terms *Australopithecus* and Lucy among the response options was therefore considered an effective component of capturing accurate exposure information, although one student noted that she thought Lucy was the name of a sheep (confusing the australopithecine specimen, Lucy, with the sheep, Dolly, that was used in cloning experiments, presumably), so there was a need to clarify the reference to the Lucy skeleton when writing the survey for the quantitative analysis.

Overall, asking students via the questionnaire if they remembered learning about the origin of humans and primates proved less effective than was desired for assessing actual exposure to HEB; for example, eight of 28 students in the second round indicated on the pre-interview questionnaire either: (a) they did not learn about the origin of humans when, according to their interviews, they did (n = 3), or (b) they did learn about the origin of humans, but did not indicate so during their interviews (n = 5). It was considered that the phrase *the origin of humans* could include non-scientific explanations of the origin of humankind. As a result, more specific wording was used when developing the survey for the quantitative analysis. The question and response options used in the survey (see Appendix C) to assess HEB exposure included:

- Do you recall being taught about any of the following concepts or topics in your middle school or high school science classes or as part of your official home schooling in science?
    - scientific explanations for the origins of humans
    - alternative explanations for human origins (e.g., Native American explanations or Bible-based explanations)
    - primates (apes and monkeys)
    - the fossil skeleton called Lucy.

An additional, similarly worded, question was included in the survey that asked about students' exposure in non-science classes, as some students told the researcher that they learned about HEB in history or social studies class.

For both rounds of interviews, any discussion by a student of his or her exposure to general evolution or to human evolutionary biology was coded at the node called exposure and its daughter node, HEB exposure, respectively. The exposure node was associated with the densest coding among all nodes, with 599 references to evolution education generally, including 123 references to human evolution education specifically, across the 19 interviews. Examples of HEB exposure references include the following statements from students:

- I remember the attitude that my teachers took about [human evolution] was that it was sort of like, "This is a theory and a lot of scientists like to explain it or use these examples from other primates, other animals, to explain human evolution," but it was kind of like they took an apprehensive approach to it. It wasn't like they...I guess they were kind of scared to get in-depth of how the reasons why a lot of scientists want to use examples from other primates to explain human evolution. They didn't really explain the kind of research that was going on or anything like that. It was just sort of a mentioning. We mostly talked about other primates, but there was not a whole lot at all talking about human evolution except for, you know, like the ape to human chart thing that you see. I mean they showed us that and talked about that a little bit, but it wasn't in-depth (Participant 8124).
- Interestingly enough, [in] geology, we covered her name, what was her name? Linda, Lisa, Luna? [Moderator: Lucy?]. I knew it was an L! It

was interesting that when he talked about fossils, of all the fossils that he could choose, he chose Lucy (Participant 5666).

- Um, actually, it's kind of funny, the only thing I clearly remember [about being taught about human evolution] - because I took biology my freshman year - was the 99% of DNA between chimpanzees and people. That's the only thing I remember clearly. But as far as the fossil record goes, I remember in, I think it was 6th grade – that was elementary school for us – learning about *Australopithecus* and the different hominids. For some reason, that really stood out in my mind. [Moderator: Like Lucy?] Yeah, that was the first time I'd heard about Lucy (Participant 2436).

Based on the content coded to the exposure node, the researcher assessed the degree of exposure for each student and noted on each student's profile sheet an exposure ranking of *yes, no,* or *minimal* (Tables 5 and 6). If, from the interview, it was clear that the student had been exposed to human evolutionary biology generally and/or the fossil record of human evolution via a lesson or lessons in school, the ranking was *yes*. If, however, it was either unclear whether there had been formal exposure (usually because a student's answers were vague) or it was clear there was an extremely limited amount of exposure (relative to what other students experienced), then the ranking was *minimal.*

The overall HEB exposure attribute values mentioned earlier–none, minimal, moderate or high— were based on these interview-based rankings and, to a lesser degree, the rankings of the pre-interview questionnaire responses (Table 7 and Figure 15). In addition, any transcribed interview content was explored with tools in NVivo, such as coding queries and text searches, to compare and contrast what was said by the individuals assigned to each group; this was done to evaluate the assignments made and make any changes necessary. For example, a coding query compiled the audio and transcript content coded at the exposure node for the participants who had high HEB exposure, generating a new node called *HEB exposure high*. Likewise, new nodes were created for the other three exposure groups – none, minimal and moderate HEB exposure.

Table 7

*Overall Human Evolutionary Biology Exposure, All Interview Participants (*N = *44)*

HEB Exposure Attribute Value	Participants	n
none	4506, 7513, 108, 4261, 365, 7761, 974, 3066, 7201, 483, 1692, 1123, 502, 7677	14
minimal	6006, 8124, 1462, 729, 1214, 5886, 4262, 6004, 7561, 5522, 1104, 7634, 4763, 1192, 317, 913, 6243	17
moderate	5666, 9008, 203, 922, 8406	5
high	7096, 7218, 2436, 4272, 2439, 2206, 206, 362	8

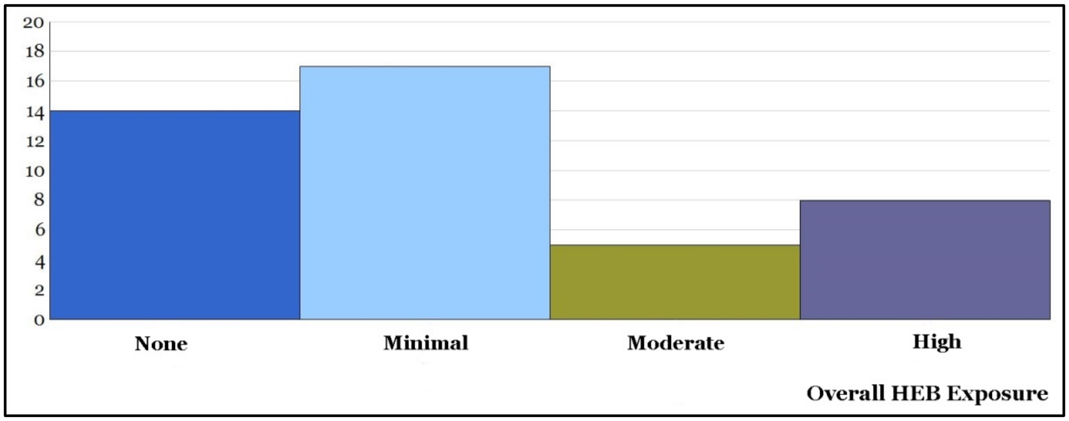

Figure 15. Distribution of overall HEB exposure for the sample of interview participants (*N* = 44).

Text search queries were then used to search for specific words, such as *fossil*, *Lucy*, *related*, *monkey*, *chimpanzee,* etc., among the content of the new nodes. This allowed the researcher to confirm that the coding of the content was consistent with the assignment of values for the HEB exposure attribute. For instance, a text search for the word fossil pointed to statements from three participants in the high HEB exposure group, including:

- Yeah, [we learned about] fossils, like *Australopithecus* [and] genetically how we appeared to evolve (Participant 7218). [Note that the student's use of the term *Australopithecus* was not prompted by the moderator.]
- We looked at pictures of fossils, and we read, I guess, in, like, class books or whatever about what like, I don't know, it didn't talk about how these, how each hominid evolved into the next one, but it talked about what each one did and how they were different and their different characteristics, but the pictures of course, you know were lined up in such a way that you could see how the different skeletons were changing over time (Participant 2436). [Note that the student's use of the term hominid was not prompted by the moderator.]
- Um, I ...we did [learn about other fossils besides Lucy], but I just don't remember it. We did go through the...I know three days we went through watching videos and reading about scientists who found like caves and found, you know, fossils and missing links and like going through the whole thing where you know monkeys learn to stand and then they learn to walk and then the whole brain size. And then we did

do comparisons between modern day apes and humans (Participant 206).

A text search for the word fossil produced statements from two of the participants who had moderate formal HEB exposure, including the following statement:

- Yeah, it actually wasn't in science class, it was in World History that I had to take and that also talked about Lucy and ancient man and woman, finding different fossils and that was when [the teacher] was saying, you know, um, in order for this to be correct, this would have to imply that evolution rather than creationism, is dominant and he said, "I personally am like, was raised and still am a devout Catholic, so, I don't necessarily believe in these certain things, but it's just, uh, variable upon what the person wants to, um, take in and what they don't" (participant 8406).

A text search for the word fossil produced statements from two of the participants who had minimal formal HEB exposure, including the following statement:

- [We were] just [taught] that [human evolution] exists. Um, nothing in-depth. Not fossils of humans or anything. All I remember was that there was talk of a "missing link" and that it exists, they just haven't found the rest of it yet, or something like that (participant 1104).

A text search for the word fossil produced statements from four of the participants who had no HEB exposure, but none of the statements were relevant to whether they received any formal HEB education. For this example—using the word fossil—the HEB exposure attribute values (minimal, moderate and high) assigned to the students' case nodes were deemed appropriate.

It is important to note that the final values for HEB exposure are relative for the participants in this particular study; a student with a high HEB exposure rank had, among the 44 students who were interviewed, more exposure to HEB than any of the students with a minimal or moderate ranking. Most students had no (n = 14) or relatively minimal (n = 17) exposure to human evolutionary biology in middle school or high school. Five students had relatively moderate exposure to HEB and eight students had relatively high exposure to HEB (Table 7).

Defining and measuring religion factor. Students' religious affiliations and practices and overall exposure to religious and/or spiritual cultural traditions were assessed using information from the pre-interview questionnaires and interviews. For each student, multiple variables were considered, including: (a) the student's religious or spiritual cultural affiliation at the time of the interview, (b) the frequency with which a student attended formal religious services at the time of the interview, (b) the student's mother's religion, (c) the student's father's religion, (d) the student's upbringing with regard to religion or spiritual cultural practices, (e) if the student participated in religious education, such as Sunday school or Confraternity of Christian Doctrine (CCD) classes, (f) if the student described his or her home community as religious and/or culturally traditional or conservative, and (g) if the student described his or her school, teachers, classmates, school administrators or classroom environment as religious and/or culturally traditional or conservative. Not every student provided information for every one of these variables, but for at least most of the variables. Using this information, it was possible to gauge the general role of religion or spiritual cultural traditions in each student's life and characterize each student's *religion factor* as *none*, *low*, *moderate* or *high*. Note that the attribute, religion factor, was equally, if not less, influenced by the students' self-reported religious or spiritual cultural affiliation at the time of the interview as it was by all of the other variables. Thus, a student who had a high religion factor could have been an atheist at the time of the interview, and a student with low religion factor could have been a newly practicing Christian at the time of the interview.

The pre-interview questionnaire asked two open-ended questions about religion:

- Is there a religious and/or cultural group with which you associate? If so, please identify the group(s).
- Do you attend regular meeting or gatherings of this group? If so, about how often do you gather?

The students' written questionnaire responses and all of the interview content related to religion were coded at the node *religion* in NVivo, creating a total of 239 references at that node.

The researcher compiled relevant data on the student profile sheets and created attributes in NVivo to capture the information as discreet variables. The attributes included: *high school type; public and private school - mix of both; religion – questionnaire; religious services attendance – questionnaire; teacher religious views; religion – community; religion – school; religion – mom; religion – dad; religion – raised interview; religion – attend CCD or Sunday school;* and *religious service attendance - interview*. Table 8 defines each of these attributes (see Appendix F for attribute values).

Table 8

Attributes Related to Religious Affiliation, Practice and Exposure

Attribute	Definition
high school type	whether the high school from which the student graduated was public, private non-denominational, private denominational, or if the student was home schooled
public and private school – mix of both	if the student attended both public and private school during his or her K-12 education
religion – questionnaire	the student's current association or lack of association with a particular religious group, based on the questionnaire
religious services attendance – questionnaire	how often the student currently attends religious services, if at all, based on the questionnaire
teacher religious views	whether a student's school teacher(s) expressed a personal religious view in the classroom
religion – community	whether a student described the community in which they lived during K-12 as religious
religion – school	whether a student described the attitude of K-12 classmates or school administrators as religious
religion – mom	the student's mother's religion
religion – dad	the student's father's religion
religion – raised interview	how the student described being raised with regard to religion, based on the interview
religion – attend CCD or Sunday school	if the student attended religious classes, such as Sunday school or CCD/CCM during K-12
religious service attendance – interview	if the student attended religious services in the past, regardless of current attendance, based on the interview

Religion and school. As reported earlier, five students graduated from private high schools, but two of them noted that their high schools were non-denominational private schools. Six additional students, who graduated from public high schools, reported attending private school at some point during their K-12 schooling and five of them noted that some aspect of their schooling – the denomination of the school or the attitudes of teachers, students, or administrators – contributed to a religious or socially conservative environment in the classroom. Thirteen students who attended public schools for all of K-12 commented at some point in their interview that the community in which they attended school and/or the students, teachers, or administrators in their school had expressed religious perspectives or restricted the learning of particular content in the classroom due to socially conservative viewpoints. For example, one student recalled that she and her fellow students were required to obtain parental permission to learn about evolutionary biology in her sophomore year biology class, because the state in which her school is located "is a pretty conservative state" (Participant 108). Another public school student related the attitude of students in her science class when the teacher began to teach about evolution:

- It was awkward because the majority of the class was Mormon. That's not to say that there are Mormons who didn't want to learn about evolution. But there were kids who were like, "I don't believe this, so why am I listening to this, why are you teaching this?" (Participant 4506).

Four students who attended public school for all of K-12 shared that their science teachers expressed or implied a particular religious viewpoint in the classroom; for example, one student said, "[Biology] was taught by this highly Christian woman and she was like, 'Well, this is just a theory,' just to stress [that idea] and she kept saying that a lot."

Religious upbringing. During the interviews, all but one of the 44 interviewed students discussed the spiritual or religious traditions in which they were raised (or lack thereof; Table 9). Seventeen students mentioned that they attended religious classes, such as CCD classes or Sunday school, during childhood or adolescence and 33 students said that they attended formal religious services at some point in their lives. Other students may have attended religion classes or services, but did not say so during their interviews. All but one of the students communicated information about the religious affiliations of one or both of their parents or a parent's extended family (Table 9).

Religious affiliation. Students' religious affiliations, as reported on the pre-interview questionnaires, did not always correspond to the religious environment in which the students were raised and/or their parents' religions (see Table 9). Ten students were practicing members (i.e., attended formal services at least on holidays) of the same religious faith in which they were raised and four students could be described as non-practicing or questioning members of the faith in which they were raised. Four students were raised without religion, or in a primarily secular environment; at the time of the interviews, one attended services at a non-denominational church and described herself as Baptist, another described herself as agnostic and the other two described themselves as having no religion on the questionnaire, but stated in their interviews, "I'm still kind of forming what I believe" (Participant 362) and "I don't associate with any religion but I do believe in [a non-Christian] God" (Participant 922). Twelve students who were raised in a particular religious environment reported that they were agnostic or atheist at the time of the interviews. Six students changed their religion from the one with which they were raised to a different religion or a non-denominational faith. One student did not clearly identify the religious environment in which he was raised, but stated in his interview that he was not affiliated with a religion at that time. One student was raised with and followed the cultural traditions of the Navajo Native Americans. Six students did not answer the religion questions on the pre-interview questionnaire and, of those six students, four did not provide additional information about their religious or spiritual cultural affiliation at the time of the interview and two clarified that they did not follow a particular religious faith.

Based on all of the information provided, each student's religion factor was ranked as none, low, moderate or high (Figure 16). As with human evolutionary biology exposure, the attribute values were relative for the study, meaning a student with a high religion factor had the highest level of exposure to religious or spiritual cultural traditions and attitudes and greatest engagement in religious or spiritual cultural practices among the 44 research participants.

Religion factor. Only one student had a religion factor of none; her parents did not associate with a particular religion, she attended public school and described herself as agnostic in her interview (Participant 502). Of the 15 students with a low religion factor, one attended a non-denominational private

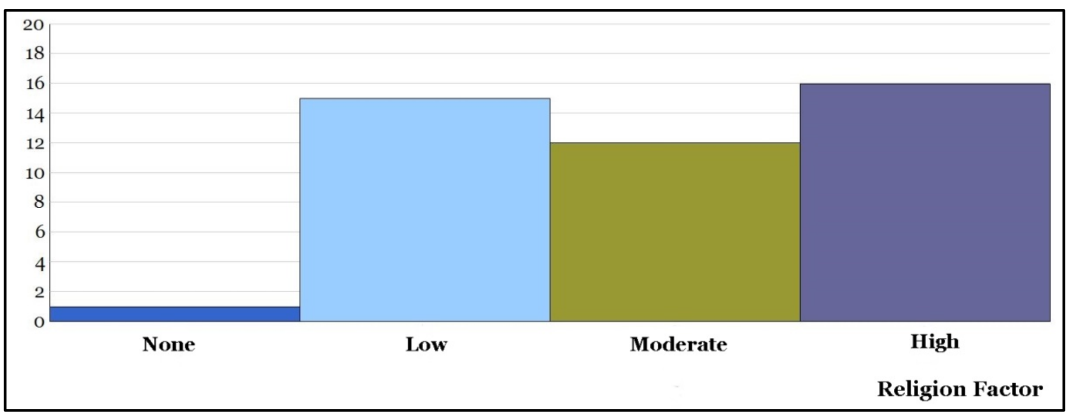

Figure 16. Distribution of the attribute *religion factor* for the sample of interview participants (*N* = 44).

Table 9

Interviewed Students' and Their Parents' Religious Affiliations

Participant	Religion – Dad	Religion - Mom	Religion – Raised	Current Religious Affiliation	Same as Parent(s)?
4506	Catholic to Lutheran	Lutheran	Lutheran	Agnostic	No
7096	Catholic	Catholic	Catholic	Catholic	Yes
6006	Jewish	Catholic	Catholic and Jewish	NAG[a]	-
5666	Trad. Native American	Mormon	Mormon	Non-practicing Mormon[b]	Yes
8124	non-practicing Baptist Christian	Non-practicing Catholic to Baptist	None	Baptist; non-denominational church	Yes
7513	Lapsed[c] Christian	Christian to "probably agnostic"	Christian	None	No
9008	Catholic	Lapsed Mormon	Catholic	Catholic	Yes
203	Hindu	Hindu	Hindu	Non-practicing Hindu [Atheist]	Yes
1462	Lapsed Catholic	Protestant	Catholic	NAG	-
729	Christian	Christian	Christian	NAG	-
108	Catholic	Catholic	Catholic	None	No
4261	None	Catholic	Catholic	None[d]	Yes
1214	Mormon (LDS)	LDS	LDS	LDS	Yes
7218	Catholic	Catholic	Catholic	Jewish	No

Participant	Religion – Dad	Religion - Mom	Religion – Raised	Current Religious Affiliation	Same as Parent(s)?
365	"Not Christian"	Catholic	Catholic	Christian - United Methodist	No
2436	Lapsed Christian	Catholic	Catholic	Catholic	Yes
7761	None	Lapsed Baptist ("still spiritual")	Baptist	None	Yes
4272	Lutheran	Catholic	Lutheran	None	No
974	Non-practicing Christian	Non-practicing Christian	Christian	None	No
3066	Catholic	Protestant to Catholic	Roman Catholic	Christian (non-Catholic)	No
5886	Catholic	Catholic	Catholic	Catholic	Yes
4262	Extended family religious	-	-	None	-
2439	-	Catholic	Catholic	NAG [None]	-
6004	-	Catholic	Catholic	Non-practicing Catholic	Yes
7561	Buddhist	Buddhist	Buddhist	None	No
5522	Methodist	Catholic	Catholic	Catholic	Yes
1104	Catholic	Methodist	Catholic and Methodist	NAG	-
7634	Catholic	-	Catholic	Catholic	Yes
4763	Catholic	Catholic	Catholic	Catholic[e]	Yes
7201	-	-	Methodist	Non-practicing Methodist	Yes

Participant	Religion – Dad	Religion - Mom	Religion – Raised	Current Religious Affiliation	Same as Parent(s)?
483	Christian	Christian	Christian	Non-denominational	No
922	Lapsed Jehovah’s Witness	Lapsed Jehovah’s Witness	None	None[f]	
8406	Lutheran to Christian	Catholic to Christian	Christian	None	No
1692	“Not very religious”	Non-practicing Catholic	Catholic	Agnostic	No
1123	“No longer religious”	Mormon	Mormon	Mormon	Yes
2206	Mormon	Mormon	Mormon	Atheist	No
502	“No longer religious”	“No longer religious”	None	Agnostic	Yes
206	Buddhist	Buddhist	Buddhist	Buddhist	Yes
1192	-	Catholic to Christian	Catholic	Christian	Yes
317	Non-practicing Suni Muslim	Christian and Muslim	Christian and Muslim	None	No
913	Christian	lapsed Christian	Christian	NAG [None] [g]	Yes
6243	Traditional Navajo	Traditional Navajo	Traditional Navajo[h]	Traditional Navajo	Yes
362	Muslim (lapsed or non-practicing?)	Catholic (lapsed or non-practicing?)	None	None[i]	No
7677	Catholic	Catholic	Catholic	Catholic[j]	Yes

[a] NAG = no answer given on the pre-interview questionnaire or in the interview

[b] The student wrote “(spiritual)” and “Mormon” on the pre-interview questionnaire.
[c] *Lapsed* is used when a student describes a parent as “no longer religious” and the parent’s previous religion is known; this differs from *non-practicing*, which is used when a parent is described as having a religion, but as someone who does not practice or attend services for that religion.
[d] The student wrote “no” on the pre-interview questionnaire, but then said in the interview, “I still have, like, a strong belief system, but not as strong as it was.”
[e] In the interview, the student said, “I do believe in a higher power, I don’t know if it’s a god or gods or a Buddha or some figure, I don’t know what it is yet...”
[f] In the interview, the student said, “I don’t have a religion, but I do believe in God,” and when asked if that God is a Christian God, the student replied, “No.”
[g] The student did not answer the pre-interview questionnaire question, but in the interview said, “When I became a teenager, I just found that I didn’t...I wasn’t a Christian and I didn’t believe in that anymore.”
[h] In the interview, the student related that he did not start learning about Navajo cultural traditions and beliefs until his teenage years.
[i] In the interview, the student said, “I don’t think I necessarily reject religion...I don’t know what I think now...I’m still kind of forming what I believe.”
[j] In the interview, the student said, “...so I’m not exactly really into it [Catholicism] because I’m open to other religions, too.”

high school, one student was home-schooled, and 13 graduated from public high schools. Of the 13 who attended public high school, one student attended private school for seventh and eighth grade. Ten of the students with a low religion factor said they did not attend religious services at the time of the interviews, but eight of the 10 recalled attending some formal religious services during childhood or adolescence. One student with a low religion factor reported she rarely attended religious services at the time of the interview and followed Buddhist traditions at home and one student followed traditional Navajo cultural practices in his home. Three students with a low religion factor did not answer the questionnaire questions about religion and service attendance; in interviews, one of them related that she attended various types of religious services when growing up (at a church, mosque and a temple), the second mentioned that he attended religious services briefly as a small child with one parent, and the third attended Catholic church services with her Mom as a youth, but said multiple times that she was not religious. Three of the 15 students mentioned they attended religious classes (e.g., Sunday school or CCD classes) at some point in their lives. Ten of the 15 students answered "none" or "agnostic" to the questionnaire question about their personal religious or spiritual cultural association. One student wrote that he was a member of the Methodist religion, but was non-practicing.

Of the 12 students who had a moderate religion factor, 10 graduated from public high schools, one from a non-denominational charter school (that the student described as "pseudo-religious") and one student from a non-denominational private school, though the last student said, "even though it's not religious or anything – it's just a generic private school – the headmasters, both of them, were very strong Catholics and they really have a huge influence on the teachers" (Participant 365). The student who graduated from the private school attended a public school for ninth and tenth grades and transferred to the private school where she completed eleventh and twelfth grades. Seven of the students mentioned that their school, teachers, classmates or school administrators expressed a religious or socially conservative point of view. Ten of the 12 students said they were raised in a particular religious tradition and two of them did not discuss how they were raised. At the time of the interviews, at least five of the 12 students attended religious services on holidays or once per week and five did not attend services; another did not answer the questionnaire question about attendance. Nine of the 12 students mentioned attending religious services as a child or adolescent and five mentioned that they attended religious classes outside of school. Seven of the students with a moderate religion factor had at least one parent who was a practicing member of a particular religion or traditional or spiritual cultural practice. Five of the students did not associate with a religion or specific spiritual cultural practice at the time of the interviews, one student did not answer the questionnaire question about religious affiliation and one student described herself as agnostic. The remaining five students with a moderate religion factor said they were Catholic (n = 2), United Methodist, Baptist, or non-practicing Mormon.

Sixteen of the 44 interviewed students had a high religion factor. Of the 16, one student received his GED, three graduated from private high schools (two Catholic and one Christian), and the remaining 12 graduated from public high schools. Two students who graduated from public school also attended private elementary or middle schools. At least 10 of the students encountered a religious perspective in a formal school setting, either from teachers, classmates or administrators. All 16 students had at least one parent who was a practicing member of a particular religion. At least 11 of the students attended religious services as a child or adolescent and at least 11 students attended religious classes outside of school. All of the students discussed having been raised in a particular religious tradition. Eleven students were raised in Catholic or primarily Catholic faiths, two students were raised with the Mormon faith, two with a Christian (non-Catholic) faith and one student was raised in the Hindu tradition. Six of the students who were primarily raised in the Catholic tradition still considered themselves Catholic at the time of the interview. Two of the students with high religion factors who were raised Catholic converted to a non-Catholic form of Christianity and one other student converted from Catholicism to Judaism as a teenager. One student who was raised primarily as a Catholic, but who also attended a Methodist church and was baptized by Southern Baptists as a teenager, did not answer the questionnaire question about her religious association at the time of the interview, but said she would like to attend church services (denomination unspecified) if her boyfriend would go with her. Both of the students who were raised in the Mormon faith still considered themselves to be Mormons. The two students who were raised with (non-Catholic) Christian faiths reported they did not associate with a religion at the time of the interviews. The student with a high religion factor who was raised in the Hindu tradition described herself as non-practicing Hindu on her questionnaire, but described herself as an atheist in her interview.

To evaluate the assignment of religion factor attribute values for each case, the NVivo content coded to the religion node was upcoded via coding queries to four new nodes – one for each of the religion factor attribute values –

none, low, moderate and high. The transcribed content was reviewed carefully at each new node. At the low religion factor node, transcribed content included statements such as:

- Um, well, we went out to like a Baptist church in my little area. My Mom said you can go if you want to. My Dad never went ‘cause he’s not religious at all. So, like, I’d go with her and then I started asking, like, ‘cause it was like a Sunday school, so I started asking questions and just...and then eventually just kind of phased out and I didn’t keep going (Participant 7761).

At the moderate religion factor node, students’ interviews included statements such as the following:

- My Dad was very lapsed Catholic. He's not really religious too much, you know, he goes to church on holidays. My Mom was Protestant and brought up very religious, like extremely religious, she went to Christian high school but she believed that evolution happened, but that the Bible is a metaphor, like the oceans and the land and all that that was a metaphor for evolution. The grade school I went to, I went to both public school and private school and I went to religious school for a couple years where they were fanatics. There were people there who thought dinosaur bones were a test of faith, like that fanatical (Participant 1462).

And at the high religion factor node, students shared recollections of their upbringing such as:

- My parents, my entire family for the most part, is very conservative, they are all Roman Catholic, we went to church every Sunday and I

> was always in the religious education and was confirmed into the Catholic Church and my family is just very conservative and always has and probably will believe that creationism is the answer (Participant 108).

Based on the careful review of the upcoded content, the attribute values, as summarized in Figure 16, were upheld.

The assessment of religious affiliations, practices, and overall exposure for the 44 interview participants benefitted from the amount of information that was collected from the students about their experiences involving religious and spiritual cultural traditions. The number of questions that could ultimately be asked in the survey for the quantitative analysis was limited by the survey's length, however, so it was necessary to identify the best predictive variables, or combination of variables, for estimating the role of religion in students' lives while also considering the limitations of the survey question format (i.e., multiple choice, with short open-ended option boxes). In addition to gathering information about the students' personal religious associations at the time of the survey, it was considered necessary to also inquire about the students' parents' or guardians' faiths. Based on the qualitative analysis, parents' religious practices generally reflected how students were raised with regard to religion and spiritual cultural practices. Therefore, the survey questions for the quantitative analysis asked:

- Which of the following, if any, best describe(s) you?
- Which of the following, if any, best describe(s) your parents/guardians?

The answer choices were comprehensive, including options for those of interdenominational faith, atheists, agnostics, wiccans, and pagans, as well as those following more traditional eastern and western religions (see Appendix C). In addition, students could select the *other* option and type their response. Among the variables considered in the qualitative analysis, attendance at religious services also played a key role in identifying students' overall religious exposure. Therefore, the survey also asked:

- Do you or have you ever attended religious services?

And if a student answered *yes*, he or she would be asked:

- In the past year, approximately how often have you attended religious services?

Thirty-six of the 44 interviewed students provided information related to each of these four questions during their interview or on the pre-interview questionnaire, though the information was not always as specific as the data that would be obtained from students responding to the online survey. An assessment of the interviewed students' religion factors, based on only those four variables, led to the same attribute value assignments as in Figure 16 for 27 of the students' cases. For six students, low and moderate religion factors were overestimated as moderate and high, respectively, and for three of the students, high and moderate religion factors were underestimated as moderate or low, respectively. For no cases was a low religion factor assigned when it should have been a high religion factor, or vice versa.

Defining and measuring evolution acceptance. General evolution acceptance and human evolution acceptance were assessed using information from the pre-interview questionnaires and interviews. Two variables were considered when assigning attribute values to each participant's case node for the acceptance attributes: (a) students' scores from a Likert-scaled section of the pre-interview questionnaire based on the Measure of Acceptance of the Theory of Evolution (M.A.T.E.) survey (Rutledge & Sadler, 2007; see Appendix B) and (b) students' answers to questions about acceptance during their interviews. A comparison of students' interview and questionnaire responses was conducted to check for internal consistency reliability of the seven M.A.T.E. questions in consideration of using them in the survey for the quantitative analysis. In addition, the relationship between evolution acceptance and human evolution acceptance was explored to see if acceptance of general evolution would predict students' acceptance of human evolution.

As described in Chapter 3, Research Design and Methodology, Chapter Note 3:

> The M.A.T.E. is a 20 item survey which "assesses acceptance, rather than belief in, evolutionary theory as a scientifically valid and explanatory theory" (Rutledge & Sadler, 2007, p. 333). Rutledge and Sadler (2007) demonstrated the internal consistency and test-retest reliability of the M.A.T.E. and recommend that the M.A.T.E. be used by researchers of evolutionary biology education in conjunction with other research instruments that generate quantitative data.

For the purposes of this study, and to keep the pre-interview questionnaire at a reasonable length, seven items from the M.A.T.E. survey were selected from the original 20 (see Appendix B). The M.A.T.E. uses equivalent item rewording for the purposes of alternate form reliability-testing. Since the goal of using the items for this study was, in part, to compare students' questionnaire answers with their interview content, it was not necessary to maintain this redundancy. In addition, the researcher knew the entire M.A.T.E. could not be used on the survey for the quantitative analysis (primarily due to length-restrictions), so it was useful to check for internal consistency reliability for the seven selected items (i.e., to determine how well the group of seven items measured evolution acceptance generally and human evolution acceptance, specifically).

The students' answers to the M.A.T.E. items were scored using a Likert-scaling system. For each item, the highest-acceptance response was equal to a score of 5 and the lowest-acceptance response was given a score of 1. For example, for the following statement:

- Organisms existing today are the result of evolutionary processes that have occurred over millions of years,

a response of *strongly agree* was scored as a 5 and a response of *strongly disagree* was scored as a 1. Therefore, a score of 35 reflects the highest total level of evolution acceptance as measured by the series of seven items and a score of seven reflects the lowest level of evolution acceptance.

One of the seven M.A.T.E. items dealt specifically with human evolutionary biology:

- Modern humans are the product of evolutionary processes that have occurred over millions of years.

Again, a student who strongly agreed with this statement received a score of 5 and a student who strongly disagreed with the statement received a score of 1.

Evolution acceptance (questionnaire data). The lowest total score for the seven items was 19 and the highest was 35 (Table 10 and Figure 17). One participant did not respond to the two items bulleted above according to the instructions, but instead wrote on his questionnaire: "Religiously, I disagree, but I accept it scientifically" (Participant 7218). The score for his answers to the other five questions totaled 16, so his total score would have ranged from 20 to 24, depending on if he responded to the two items from a scientific or a religious perspective. Twenty-three students scored 31 to 35, 10 students scored 26 to 30, and 10 students scored 19 to 25.

Table 10

*Interviewed Students' Evolution Acceptance and Human Evolution Acceptance (*N = *44)*

Participant	Evolution Acceptance (Q[a])	Evolution Acceptance (Int[b])	Human Evolution Acceptance (Q)	Human Evolution Acceptance (Int)
4506	35	Yes	5	Yes
7096	26	Und twd sci	3	Und twd sci
6006	33	Yes	5	Yes
5666	32	Combination	5	Combination
8124	34	Combination	5	Combination
7513	35	Yes	5	Yes
9008	35	Yes	5	Yes
203	30	Yes	5	Yes
1462	35	Yes	5	Indifferent
729	29	Yes	4	Yes
108	33	Yes	5	Yes
4261	23	Und twd rel	4	Und twd rel
1214	31	Combination	5	Und twd sci
7218	N/A[c]	No	N/A[c]	No
365	33	Yes	5	Yes
2436	32	Combination	5	Und twd sci
7761	34	Yes with ques	5	Yes
4272	34	Yes	5	Yes
974	26	Yes	5	Yes
3066	23	Combination	3	No answer[d]
5886	24	Yes with ques	5	Yes with ques

Participant	Evolution Acceptance (Q[a])	Evolution Acceptance (Int[b])	Human Evolution Acceptance (Q)	Human Evolution Acceptance (Int)
4262	31	Yes	5	Yes
2439	35	Yes	5	Yes
6004	33	Yes	5	Yes
7561	23	Yes with ques	4	Yes
5522	26	Combination	4	Yes with ques
1104	27	Combination	3	Und twd sci
7634	32	Yes with ques	5	Undecided
4763	29	Combination	4	Yes
7201	32	Yes	5	Yes
483	19	Undecided	3	No
922	22	Combination	2	Und twd rel
8406	29	Combination	4	Yes
1692	28	Yes	4	Yes
1123	19	Combination	2	No
2206	34	Yes	5	Yes
502	32	Yes	5	Yes
206	32	Combination	5	Combination
1192	22	Undecided	3	No
317	31	Und twd sci	5	Und twd sci
913	34	Yes	5	Yes
6243	25	Combination	5	Combination
362	29	Und twd sci	4	Und twd sci
7677	23	Undecided	3	Undecided

Note. Und twd sci = Undecided, leaning toward scientific view; Und twd rel = Undecided, leaning toward religious view; Yes with ques = Yes, with questions; Combination = see text for explanation

[a] Questionnaire

[b] Interview

[c] This student wrote on the questionnaire: “Religiously, I disagree, but I accept it scientifically.”

[d] This student said in her interview she did not want to answer the question about human evolution.

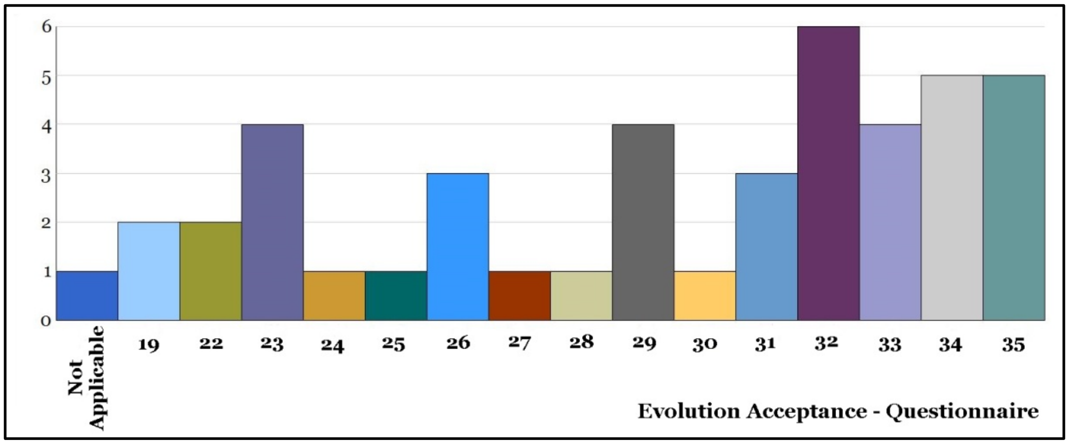

Figure 17. Distribution of the attribute values for the attribute *evolution acceptance - questionnaire* (*N* = 44). The X-axis values are the scores based on the Likert-scale (19 = low acceptance, 35 = high acceptance). One participant did not respond to all of the items, so a score could not be calculated and *not applicable* was used for the attribute value.

Human evolution acceptance (questionnaire data). The range of scores for the question dealing specifically with human evolution acceptance was 2 to 5 (Table 10 and Figure 18). The majority of students (n = 27) responded to the statement about human evolution with *strongly agree,* eight students with *agree,* and two students with *disagree.* Six students were undecided and one student, as mentioned, did not answer the question using the scaling system.

As was done for the exposure and religion factor attributes, a careful analysis of interview content was conducted to assess acceptance based on what students said about the extent of their acceptance of both general evolutionary science and human evolutionary biology. All interview content pertaining to the issue of acceptance was coded at the node *acceptance* in NVivo, producing 149 references. The key points students made pertaining to their acceptance were recorded on the student profile sheets and were used to create relevant attributes and attribute values (see Appendix F). Table 11 defines the attributes that were considered when assessing acceptance. A variety of perspectives were expressed by the students, requiring the creation of seven attribute values for the attribute *evolution acceptance – interview* and nine attribute values for the attribute *human evolution acceptance – interview*.

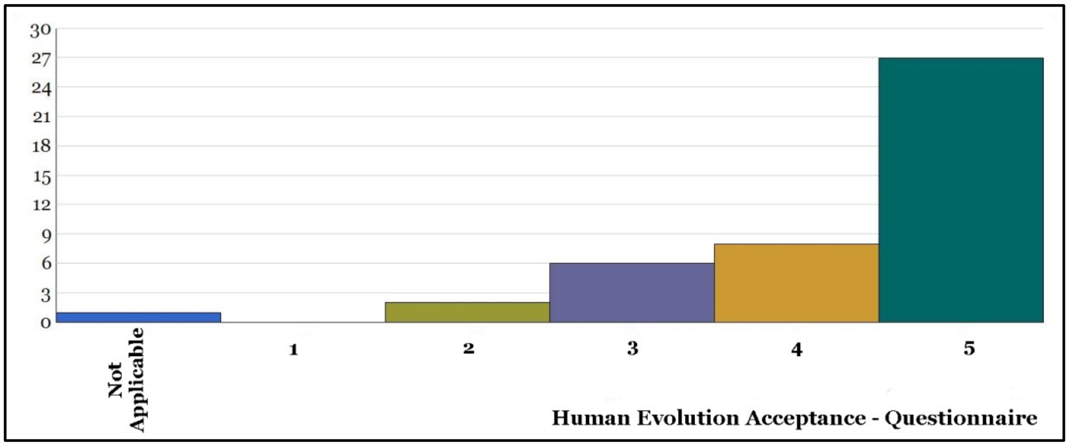

Figure 18. Distribution of the attribute values for the attribute *human evolution acceptance - questionnaire* (N = 44). The X-axis values are the scores based on the Likert-scale (1 = no acceptance, 5 = high acceptance). One participant did not respond to the item about HEB acceptance, so a numeric score could not be used for the attribute value and *not applicable* was used instead.

Evolution acceptance (interview data). The attribute values for evolution acceptance ranged from complete acceptance (*yes*) of evolutionary science as an explanation for the origins and diversity of life on Earth (without the involvement of a supernatural being or power) to complete rejection (*no*) of evolutionary science (Figure 19). The one student who was assigned the attribute value of no is the same student who wrote on his questionnaire, “Religiously, I disagree, but I accept it scientifically” (Participant 7218). In his interview, he described himself as a young-Earth creationist who rejected evolution as a person of faith (he was raised in the Catholic faith, but converted to Judaism as a teenager), but explained he understood evolution and when he was in high school he recognized he had to learn about it be successful in his science coursework. Based on this student’s interview, for the purpose of the analysis, it was deemed more appropriate to consider him as someone who rejected evolutionary science, rather than a person who accepted it.

Table 11

Attributes Related to Evolution Acceptance (Interview) and Human Evolution Acceptance (Interview)

Attribute	Definition
Evolution acceptance – interview	A student's acceptance of the scientific theory of evolution as an explanation for the origins and/or diversity of life on Earth, as expressed during his or her interview
Human evolution acceptance – interview	A student's acceptance of the scientific view that modern humans and human origins are the result of evolutionary processes and that humans are biologically related to other living organisms, as expressed during his or her interview.

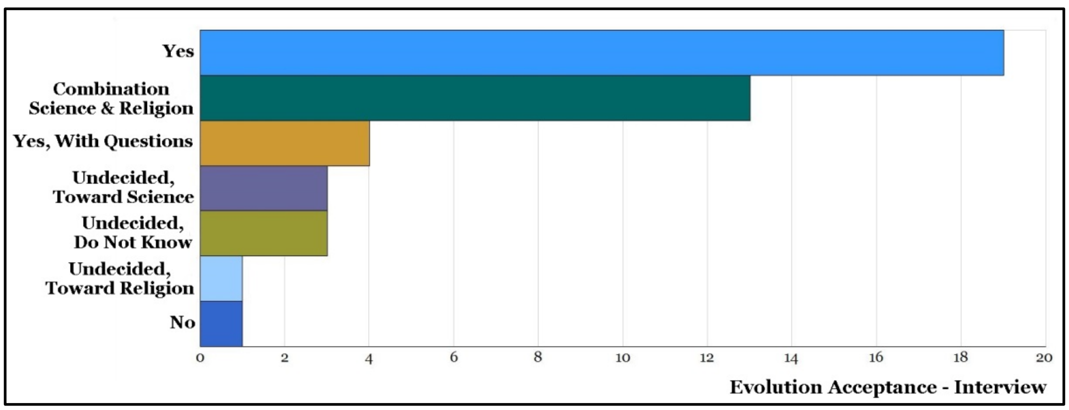

Figure 19. Distribution of the attribute values of the attribute *evolution acceptance – interview* (N = 44). The X-axis values are the number of participants. Yes = complete acceptance; No = Complete rejection; see the text for definitions of the other attribute values.

Five additional attribute values were used to capture the full range of evolution acceptance for the 44 participants (Figure 19). If a student completely accepted that the process of evolution occurs, without question, but also expressed a belief that a supernatural being or power played a roll in the existence or diversity of life, then the attribute value *combination science and* *religion* was used. If a student said in her interview that she accepted evolutionary science, but had questions about how evolution works or how it applies to certain organisms (e.g., if the student was not familiar with the mechanisms of evolution), then the attribute value *yes, with questions* was used. A student who said she did not know whether or not she accepted evolutionary science, but that evolution seemed like the more logical explanation for the origins and diversity of life (versus invoking supernatural explanations), then the value *undecided toward science* was used. If a student expressed indecision or said she did not know if she accepted evolutionary science and was not drawn toward a scientific or religious viewpoint, the value *undecided or do not know* was assigned. And, finally, a student who was undecided but considered a supernatural explanation for the origins or diversity of life more appealing was assigned the attribute value *undecided toward religion*.

The majority (n = 36) of the 44 interviewed students said they accepted that evolution occurs (Figure 19). Thirteen of those 36 students expressed a belief that a supernatural being or power had some involvement in creating or directing the course of life on Earth. Seven of the 44 students were undecided about whether evolution occurs; three of the seven students leaned toward a scientific viewpoint, three were completely undecided or did not know enough about evolution or religion to provide an answer, and one student expressed a preference for a religious viewpoint. Overall, for 39 of the 44 interviewed students, evolutionary science appealed to them, to some degree, as a valid explanation for the origins and/or diversity of life on Earth.

Human evolution acceptance (interview data). More than half (n = 28) of the 44 interviewed students said they accepted that modern humans are the product of evolutionary processes and are biologically related to other organisms (Figure 20). Four of those 28 students expressed a belief that a supernatural being or power had some involvement in creating humans or directing the evolution of humans. Ten of the 44 students were undecided about whether humans evolved; six of the ten students leaned toward a scientific viewpoint, two were completely undecided or did not know enough about human evolutionary biology or other explanations for the existence of humans to provide an answer, and two students expressed a preference for religious or supernatural explanations for human origins. Overall, for 34 of the 44 interviewed students, evolutionary science appealed to them, to some degree, as a valid explanation for the existence of modern humans. Four of the 44 students rejected the idea that humans are the product of evolution and/or biologically related to other organisms. When asked specifically about her view on human evolution, one student stated that she did not want to answer the question, thus the attribute

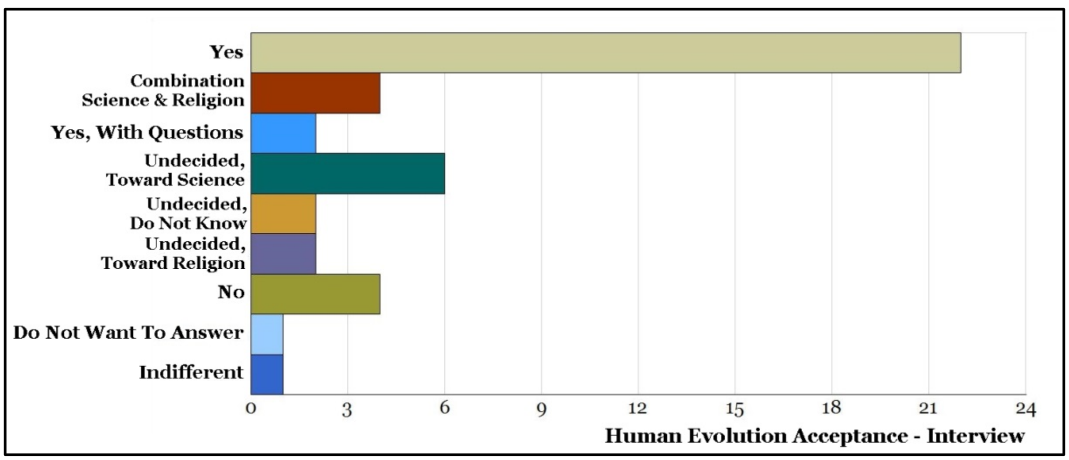

Figure 20. Distribution of the attribute values of *human evolution acceptance – interview* for the sample of interview participants (N = 44). The X-axis values are the number of participants. Yes = complete acceptance; No = Complete rejection; see the text for definitions of the other attribute values.

value *do not want to answer* was used. Another student said that whether humans had evolved via biological processes or were created in their present form by a supernatural being or power did not matter to her either way, so the attribute value *indifferent* was used.

Internal consistency reliability of M.A.T.E. scores. Ideally, the students' responses to the M.A.T.E. items would reflect what they shared in their interviews and the M.A.T.E. items could be used in the survey for the quantitative analysis, so the relationship between acceptance as assessed from interview content and acceptance as measured by the Likert-scaled questionnaire data was examined.

M.A.T.E. scores and evolution acceptance. Figure 21 charts the attribute values for evolution acceptance—questionnaire against the values for evolution acceptance—interview. There was a strong positive relationship between the summed Likert-scaled responses to the M.A.T.E. and an ordinal variable based on their interview attribute values, $r_s(41) = 0.63$, $p = .000$. The 35 students with a M.A.T.E. score of 24 or higher expressed acceptance of evolution in their interviews or were undecided about evolution with a preference for scientific reasoning. Of those 35, 19 said they accepted evolutionary science without invoking a supernatural explanation for the origins and diversity of life and three said they accepted evolution but had questions about it. Ten of the 35 students who scored 24 or above expressed that a supernatural being or power played some role in the origins and/or evolution of life. The majority (n = 20) of the students scoring above 24 scored between 32 and 35.

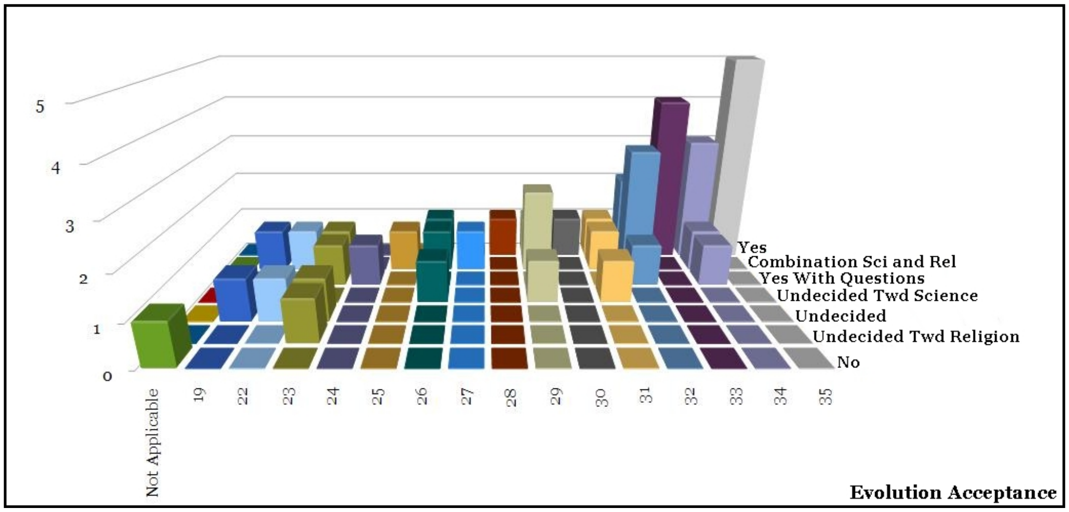

Figure 21. Distribution of the attributes *evolution acceptance – questionnaire* (X-axis) and *evolution acceptance – interview* (Z-axis; *N* = 44). One participant did not respond to all of the questionnaire questions relevant to evolution acceptance, so a score could not be calculated and *not applicable* was used for the attribute value.

For eight students, their M.A.T.E. scores ranged from 19 to 23. One additional student, as discussed earlier, did not receive a score because he did not respond to all of the M.A.T.E. items according to the instructions, but, as explained, his score could not have been higher than 24. The interview-based acceptance levels for these nine students varied. The student who did not answer all the questions properly rejected evolutionary science as a person of faith. Four of the nine students expressed indecision about evolution, and, of those four, one preferred religious viewpoints. One of these nine students accepted evolution, but said she had questions about it. Three of the nine accepted evolution, but also believed a supernatural being or power played a role. None of the students who scored a 23 or below accepted evolutionary science without invoking a supernatural explanation and none of them expressed indecision with a preference for scientific viewpoints.

Overall, despite a positive statistical correlation between the two variables, the students' responses to the M.A.T.E. items could not be used to identify the nuances in the views students expressed about evolution in their interviews (Figure 21). If a student earns a total Likert score of 24 or higher for the M.A.T.E. items, it is likely that she accepts evolutionary science as an explanation for the origins and/or diversity of life, but she may have some questions about evolutionary biology and/or be somewhat undecided about her acceptance. Additionally, a score of 24 or higher cannot predict whether a student accepts that evolution occurs without the influence of a supernatural power or being. A score of 23 or lower is indicative of either complete indecision, possible rejection of evolutionary science (based on the student who wrote-in two of his M.A.T.E. responses), or hesitant acceptance with a preference for religious views that include belief in a supernatural being that played a role in creating or diversifying life. As a result, questions were included in the survey for the quantitative analysis that better captured the variety of perspectives that students might have about evolution, including indecision and a viewpoint that integrates both acceptance of evolution and belief in a supernatural power or being. The first survey question about evolution said:

- Which comes closer to your personal view?
    - Living things have evolved over time.
    - Living things have existed in their present form since they came into being.
    - I don't know

If a student responded to this question with "Living things have evolved over time" or "I don't know," the question that followed was:

- Which comes closer to your personal view?
    - Living things have evolved solely due to natural biological processes, such as random mutations, natural selection, and genetic drift.
    - A supreme being guided the evolution of living things for the purpose of creating life in the form it exists today.
    - I don't know.

All students were then presented with the following question to determine if their views were consistent with those of most young-Earth creationists:

- Which comes closer to your personal view?
    - The age of the Earth is at least 4 billion years.
    - The age of the Earth is less than 20,000 years.
    - I don't know
    - Other ________________________________

M.A.T.E. scores and human evolution acceptance. Figure 22 charts the attribute values for human evolution acceptance questionnaire against the values for human evolution acceptance interview. As explained, one student wrote-in his responses to two questionnaire items and so *not applicable* was used for his attribute value for the human evolution acceptance questionnaire attribute. For the remaining students who expressed opinions about human evolution in their interviews, there was a strong positive relationship between their Likert-scaled responses to the M.A.T.E. item about human evolution and an ordinal variable based on their interview attribute values, $r_s(39) = 0.542$, $p = .000$. No students responded to the M.A.T.E. item about human evolution with *strongly disagree* (equivalent to 1 on the Likert scale). Two out of the 44 students disagreed with the statement (2 on the Likert scale) and in their interviews one of them rejected human evolution all together and the other was undecided, but preferred a religious or supernatural explanation for human origins. Six students responded to the M.A.T.E. item with a neutral choice of *undecided* (3 on the Likert scale). Of the six students, one was the student who did not want to answer the question of human origins in her interview, two rejected human evolutionary biology completely, one student said she did not know whether humans evolved or were created in their present form, and two students said they were undecided, but found the scientific view on the origin of humans and humans' place in nature more appealing than a religious perspective.

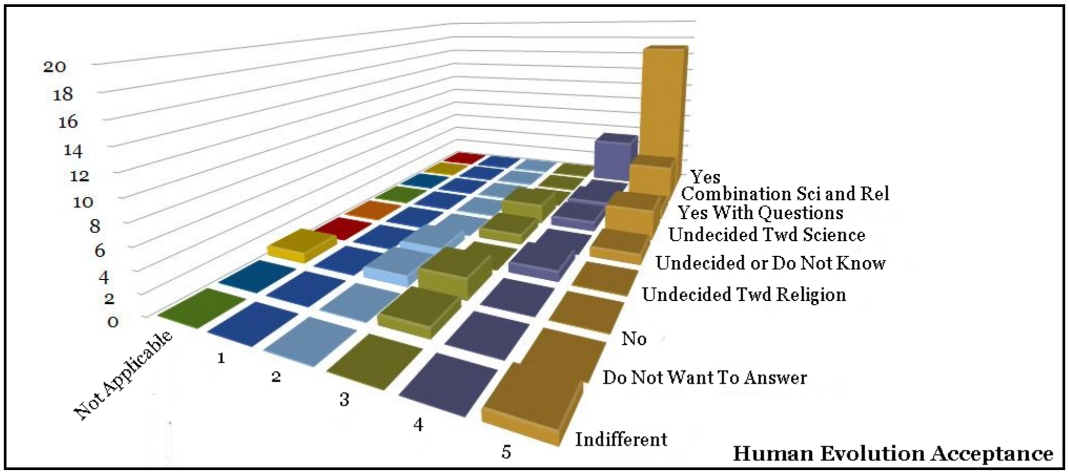

Figure 22. Distribution of the attributes *human evolution acceptance – questionnaire* (X-axis; 1 = low acceptance; 5 = high acceptance) and *human evolution acceptance – interview* (Z-axis; N = 44). One participant did not respond to the question relevant to human evolution acceptance, so *not applicable* was used for the attribute value.

Thirty-five of the 44 students agreed or strongly agreed with the statement about human evolution. Of the eight students who responded with *agree* (4 on the Likert scale), five expressed acceptance of human evolutionary biology without reference to a supernatural being or power in their interviews.

One of the eight students expressed her acceptance of human evolution, but said she had questions about it, and another student was undecided, but stated a preference for scientific explanations. One of the students who agreed with the M.A.T.E. statement on her questionnaire expressed more indecision in her interview, saying:

- Um, hmmm... I don't know [about human evolution]. It's, like, difficult for me to believe. Maybe because I grew up in a religious...with a religious background, but I don't know how they can claim that they discovered everything, like a human, and, like, with their evidence and stuff. How substantial is the evidence? (Participant 4261).

Twenty seven students responded to the human evolution statement with *strongly agree* (5 on the Likert scale). The majority (n = 17) of the 27 students accepted completely scientific explanations for the origin of humans and humans' relationship to other living organisms based on their interviews. One of the 27 students said in her interview she was indifferent about the explanation for human origins, as discussed earlier. One student who strongly agreed with human evolution based on his questionnaire response was assigned the attribute value *undecided or do not know* for human evolution acceptance based on his interview, because he said the following:

- I mean, I understand evolution from the reading I've done in college, but what still blows my mind is if we exist as humans – cognitive – why are there still monkeys and apes and primates around - why didn't they evolve as well? And it just, it leads me to ask more questions... See, I don't know [if humans have evolved or were created in their present form]. That's a tough question for me. I'll answer eventually. I don't know if I have a definitive answer there (Participant 7634).

Three of the 27 students who strongly agreed with the M.A.T.E. statement about human evolution expressed indecision in their interviews, but showed a preference for the scientific explanation for human origins and humans' relationship to other living organisms. One student expressed acceptance of human evolutionary biology in her interview, but had questions about it, saying the following:

- I definitely believed that we've evolved because it's all genetic and obviously in order to have those differences and the organisms you have to have that reproductive thing and whatnot... That's where my question lies. 'Cause I'm like, "Ok, why is there only just us? I know there's other cultures of us and there's different languages and people who speak different languages than us, but how come there's not another like, a lower, you know, the whole evolution process? Why isn't there like a primate or something that's being able to do this?" (Participant 5886)

Finally, four of the 27 students who strongly agreed with the M.A.T.E. statement spoke in their interviews about their acceptance of human evolutionary biology, but also described their belief in a supernatural being or power that was involved in humans' existence.

The conclusion that can be drawn from these data is that, despite a strong statistical correlation between scores from the single M.A.T.E. item about human evolution and students' interview-based attribute values, one cannot use the

M.A.T.E. response to predict a student's acceptance of the theory of evolution as it applies to humans and also capture the variations in the way in which that acceptance is expressed (Figure 22). When a student is restricted to one question with limited answer choices, she may indicate indecision when she truly rejects the idea, or indicate she rejects or accepts the idea when, in fact, she is undecided. It was determined, therefore, that additional questions were needed in the survey to more accurately assess students' acceptance of human evolution as well as students' awareness of the scientific evidence for human origins (see Appendix C).

The survey included the following statements and students chose a response of *completely agree, mostly agree, mostly disagree, completely disagree,* or *neutral/I don't know*:

- Divine creation is the best explanation for the existence of humans.
- Humans have always existed in the same form and have not evolved.
- Humans and other living things are the result of evolutionary processes.

These three questions were written to assess human evolution acceptance without requiring the students to have any knowledge of human evolutionary biology. Note that these questions, though similar, are not necessarily considered equivalent and were not written to test for alternate-form reliability. For example, though a student may agree that humans have always existed in the same form and have not evolved, he or she may not view divine creation as the best explanation for the existence of humans (e.g., he or she may favor explanations involving extraterrestrial life forms).

To address the issue of human evolution acceptance without using the "buzz" word evolution, two statements, to which students responded as described above, were written for the survey that dealt with explanations for modern human diversity and required little to no scientific knowledge:

- Differences in human skin color can be explained by science.
- The scattering of peoples from the Tower of Babel across the Earth is the cause for modern races of humans.

Three statements about human evolution addressed students' acceptance, but also captured students' knowledge, or awareness, of the scientific evidence for human origins:

- There is significant scientific evidence indicating that humans evolved over the course of millions of years.
- Ape-like creatures that walked upright on two legs lived millions of years ago.
- All humans on the planet today are descendants of humans who once lived in Africa.

Finally, a series of statements dealt with students' acceptance of humans' evolutionary relationship to other living organisms, specifically monkeys and apes, and students' understanding of that relationship:

- Humans have things in common (anatomy and behaviors) with monkeys and apes that they do not have in common with other animals.
- Humans and apes share a common ancestor that lived millions of years ago. (Note that this question requires a knowledge and understanding of the concept of common ancestry.)

- Scientists can learn a lot about humans by studying monkeys and apes.

Evolution acceptance vs. human evolution acceptance. Prior to finalizing the survey components dealing with acceptance, the interview data were explored to determine if general evolution acceptance predicted human evolution acceptance, or vice versa, for this study sample. A predictive relationship would be useful in the case of missing data or for identifying survey participants who do not answer questions truthfully (e.g., a respondent who randomly selects answers to complete a survey quickly). Figure 23 shows the distribution of attribute values for evolution acceptance interview and human evolution acceptance interview. A very strong positive relationship exists between

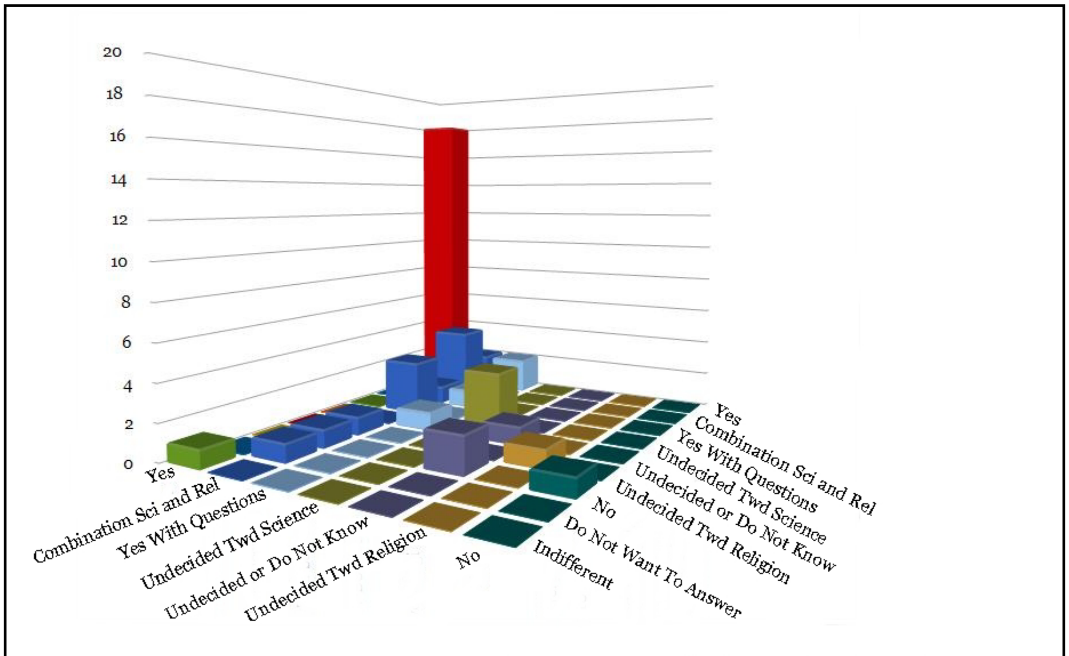

Figure 23. Distribution of the attributes *evolution acceptance – interview* (X-axis) and *human evolution acceptance – interview* (Z-axis; $N = 44$).

the attribute values for these attributes when using an ordinal scale (1 = no acceptance, 7 = acceptance; the data for students who did not want to answer and were indifferent were coded as missing data), $r_s(40) = .812$, $p = .000$.

Despite the strength of this correlation, 15 students expressed different views about general evolution than they did about human evolution. Five students who accepted general evolution and acknowledged the role of a supernatural being (combination science and religion) either rejected ($n = 1$) or were undecided about ($n = 4$) human evolution. One student who accepted general evolution, but had questions about it, did not know what to think about human evolution. Other students who had questions about general evolution expressed more confidence about their acceptance or rejection of human evolution. One student who accepted general evolution was indifferent about human evolution (this student was not included in the correlation analysis). These data demonstrate the need to consider general evolution acceptance separately from human evolution acceptance.

Acceptance by HEB exposure and religion. For summary purposes only–to compare acceptance with HEB exposure and religion (Table 12)—participants were assigned to one of three broad categories of acceptance (*high, moderate, low*) based on their Likert scores and the interview-based acceptance attributes. This shows that, within each acceptance category, all values of religion factor and HEB exposure are represented. For the purposes of theory development and hypothesis generation (see Chapter 5), the more detailed attribute values for acceptance listed in Table 10 were used.

There was a moderate negative correlation between religion factor and evolution acceptance interview, $r_s(42) = -.429$, $p = .004$, and a similar relationship between religion factor and human evolution acceptance interview, $r_s(40) = -.494$, $p = .001$. Therefore, students with relatively higher religion factors tended to have relatively lower acceptance and vice versa. It is important to remember high acceptance does not necessarily exclude belief in a supernatural power or being.

Table 12

*Summary of Acceptance, Religion Factor and HEB Exposure for Interview Participants (*N = *44)*

Participant	Acceptance	Religion Factor	Exposure
4506	High	moderate	None
7513	high	moderate	None
108	high	high	None
365	high	moderate	None
7761	high	low	None
7201	high	low	None
502	high	none	None
6006	high	low	Minimal
8124	high	moderate	Minimal
1462	high	moderate	Minimal
1214	high	high	Minimal
4262	high	low	Minimal
6004	high	low	Minimal
7634	high	high	Minimal
317	high	moderate	Minimal
913	high	moderate	Minimal
5666	high	moderate	Moderate
9008	high	moderate	Moderate
203	high	high	Moderate
2436	high	high	High
4272	high	low	High
2439	high	low	High
2206	high	moderate	High
206	high	low	High
974	moderate	low	None

Participant	Acceptance	Religion Factor	Exposure
1692	moderate	low	None
729	moderate	low	Minimal
5886	moderate	high	Minimal
7561	moderate	low	Minimal
5522	moderate	moderate	Minimal
1104	moderate	high	Minimal
4763	moderate	high	Minimal
6243	moderate	low	Minimal
8406	moderate	high	Moderate
7096	moderate	high	High
362	moderate	low	High
4261	low	moderate	None
3066	low	high	None
483	low	high	None
1123	low	high	none
7677	low	high	None
1192	low	high	Minimal
922	low	low	Moderate
7218	low	high	High

There was no relationship between evolution acceptance interview and K-12 HEB exposure, $r_s(42) = -0.093$, $p = .549$, or human evolution acceptance interview and HEB exposure, $r_s(40) = -0.106$, $p = .502$. Nor was there a relationship between religion factor and HEB exposure, $r_s(42) = 0.005$, $p = .972$. Thus, students' acceptance and religious beliefs and experiences did not predict the degree to which they were exposed to human evolutionary biology, nor did their human evolutionary biology exposure predict their acceptance or religion factor.

In the next chapter, Chapter 5: Theory Development and Hypothesis Generation, data pertaining to students' STEM enrollment, achievement, interest and motivation, and socioscientific decision-making are examined in relationship to the students' K-12 HEB exposure, with consideration given to the potential influences of religion factor and general evolution and human evolution acceptance. The hypotheses tested in the quantitative analysis are presented throughout Chapter 5.

CHAPTER 5

THEORY DEVELOPMENT AND HYPOTHESIS GENERATION

The first part of this chapter explores whether exposure to human evolutionary biology (HEB) education during K-12 schooling is correlated with students' high school STEM class enrollment, undergraduate academic achievement, interest in a STEM degree program, STEM degree success, or motivation to pursue a STEM career. In the second part of the chapter, total HEB exposure, which includes exposure to HEB during postsecondary education and from informal science education, is associated with students' socioscientific decision-making.

As described in Chapter 4: Presentation of Qualitative Data, each participant was associated with a rank for K-12 HEB exposure and religion factor, and attribute values for general evolution acceptance and for human evolution acceptance (see Tables 10 and 12). Data pertaining to students' STEM enrollment, interest, academic achievement, professional motivation, and socioscientific decision-making were examined in the context of HEB exposure with consideration given to the potential influences of religion and acceptance. Based on an analysis of the pre-interview questionnaires and interview data, inferences were made and themes emerged regarding the relationships of the variables considered. From the inferences and themes, hypotheses were generated. The hypotheses are identified throughout this chapter and are the basis for the quantitative analysis, summarized in Chapter 6: Presentation and Analysis of Quantitative Data.

HEB Exposure and STEM Enrollment, Achievement, Interest and Motivation

As discussed in Chapter 2, Maltese and Tai (2011) created a multi-block predictive model for STEM degree completion based on NELS:88 longitudinal data and showed that, at the 11th/12th grade block, enrollment in 11th grade biology could be used to predict STEM degree completion. Maltese and Tai's (2011) final (overall) model identified 8th graders' interest in STEM subject matter, 12th graders' interest in pursuing a STEM major and students' total high school science class enrollment as predictive factors for STEM degree completion. Based on Maltese and Tai's (2011) findings and other research on student interest in STEM, an inference was made that 11th grade biology enrollment can be used as a factor to predict STEM degree completion because the class content generates or fosters students' STEM interest through personally relevant content that addresses real-world issues (see Chapter 2). Among high school science classes, 11th grade biology is the class that is most likely to include human evolutionary biology. Therefore, this study investigates whether students exposed to HEB in high school find STEM more interesting (indicated by the completion of more high school science classes and/or majoring in STEM in college) and are more motivated to pursue a career in STEM (indicated by the completion of more STEM courses in their first year of college and completion of a STEM degree) than students who are not exposed to HEB.

Three years after the interviews were conducted, degree-completion data were collected from publicly accessible online resources, including the ASU Directory and LinkedIn.com. Degree-completion data were not available for nine students. Among the 35 students for whom data were available, 23 were STEM majors who were still pursuing or had completed a B.S. degree. Eleven non-STEM majors were still pursuing or completed a B.A. degree. One STEM student who completed a triple-major in Spanish, Italian and Biology earned a B.A. When completion data were not available, the combined attributes *undergraduate major* and *desire to pursue a STEM career* served as proxies for STEM degree completion as needed. The qualitative analysis looked for associations between students' HEB exposure, high school science class enrollment, interest in a STEM major, completion of a STEM degree, and motivation to pursue a STEM career.

The TEM in STEM. STEM stands for science, technology, engineering and maths. After extensive review of the qualitative data, no clear themes emerged regarding the connection between students' HEB exposure and maths achievement and goals. Among the study participants, there were few maths majors with the goal of pursuing a STEM-related career; one student majored in economics and two students majored in finance, but these degree programs at ASU did not meet the criteria to be official STEM-designated degree programs at the time of the study (U.S. Government Expands STEM Degree Program List, 2011). Degree completion data were not available for the two Finance majors. Due to the lack of data and emergent themes regarding maths, the focus of the analyses became students' science (including human health and medicine), technology, and engineering enrollment, achievement and goals. And, because no students enrolled in high school classes with technology or engineering-specific curricula, *high school science enrollment* is sometimes used in place of *high school STEM enrollment* in the remainder of this thesis. With this exception, the acronym STEM is used throughout to maintain consistency with the literature on STEM education and consistency with earlier chapters of the thesis.

HEB exposure and high school science class enrollment. Based on the pre-interview questionnaires, students were assigned attribute values (see Appendix F) for attributes pertaining to their enrollment in high school science classes. Figures 24 and 25 show the number of years of high school science classes and the number of years of high school biological science classes the participants completed, organized by HEB exposure group (note, *one year* may mean two semester-long classes, *one class* can span two years, and two or more classes could have been taken simultaneously).

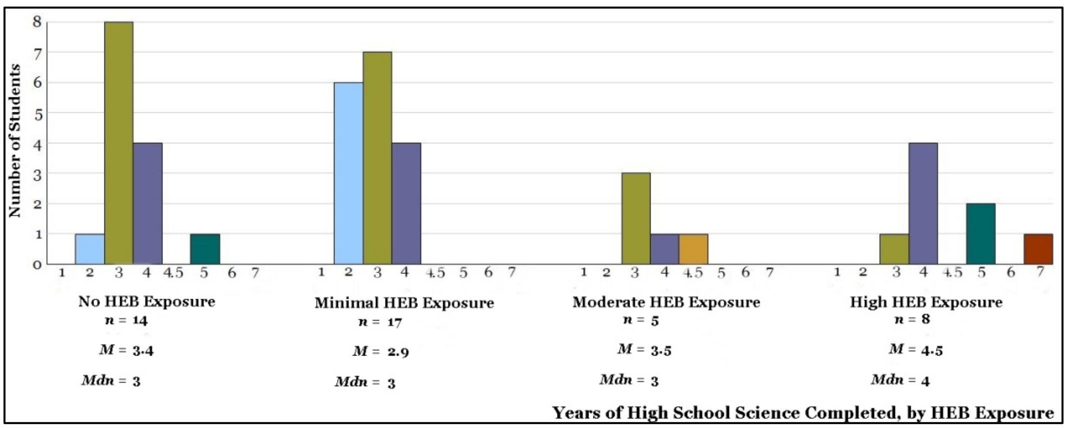

Figure 24. Years of high school science completed by the interview participants (N = 44), organized by HEB exposure.

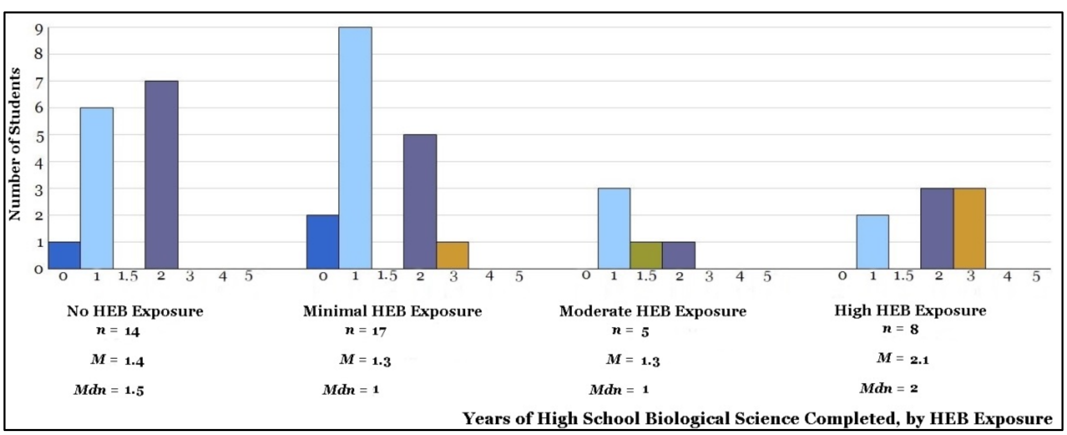

Figure 25. Years of high school biological science completed by the interview participants (N = 44), organized by HEB exposure.

Table 13 identifies the biological science classes students completed in high school. Of the 14 students with no exposure to HEB, one did not take any biological science classes, five took only one year of basic level biology, and one student took only an honors biology class. Seven of the students took two years of biological science in high school. One of the seven was home-schooled and indicated he completed Human Anatomy in addition to biology; a second student completed Human Anatomy, another student took AP Biology, one took an advanced (non-AP) course, one student took Microbiology and another took a semester each of Ecology and Human Anatomy electives. None of the students with no HEB exposure took more than two years of biological science in high school. All 14 students took chemistry and 11 of them completed a physics class.

Table 13

*Students' High School Biological Science Enrollment, University Majors and STEM Career Desires by HEB Exposure (*N *= 44)*

Participant	K-12 HEB Exposure	High School Biology Enrollment	STEM Major	Desire for STEM Career
4506	None	1	no	Maybe
7513	None	1h	yes	Yes
108	None	1+1adv[2]	yes	Yes
4261	None	1+.5E+.5HA	yes	Yes
365	None	1+HA	yes	Yes
7761	None	1	yes	Yes
974	None	0	no	No
3066	None	1+Mb	no	No
7201	None	1+HA (home)	yes	Yes
483	None	1+A&P	yes	Yes
1692	None	1	no	No
1123	None	1	yes	Yes
502	None	1+AP[3]	yes	Yes
7677	None	1	yes	Yes
6006	Minimal	1h+1adv+EP	yes	Yes

Participant	K-12 HEB Exposure	High School Biology Enrollment	STEM Major	Desire for STEM Career
8124	Minimal	1	yes	Yes
1462	Minimal	0	no	Maybe
729	Minimal	1	yes	Yes
1214	Minimal	2	yes	Yes
5886	Minimal	1+A&P	no	No
4262	Minimal	1	no	No
6004	Minimal	1	yes	Yes
7561	Minimal	1	no	No
5522	Minimal	1h	no	No
1104	Minimal	1	no	No
7634	Minimal	1	no	No
4763	Minimal	1	yes	Yes
1192	Minimal	1+ES	yes	Yes
317	Minimal	1h+AP	yes	Yes
913	Minimal	0	yes	Yes
6243	Minimal	1+A&P	no	Maybe
5666	Moderate	1	no	Maybe
9008	Moderate	1+A&P	yes	Yes
203	Moderate	1h+.5AP[3]	yes	Yes
922	Moderate	1[a]	no	No
8406	Moderate	1	yes	Yes
7096	High	1h	yes	Yes
7218	High	1h+ES	yes	Yes
2436	High	1	yes	Yes
4272	High	2IB[4]+F	yes	Yes
2439	High	1+IB	yes	Yes
2206	High	1h+AP[4]+A&P	yes	Yes
206	High	1h+ES	yes	Yes
362	High	1h+2IB[5]	yes	Yes

Note. 1 or 2 = 1 or 2 years of regular level biology classes; 1h = 1 year of honors level biology; 1adv = 1 year of advanced level (non-AP) biology; AP = Advanced Placement biology; E = Ecology; HA = Human Anatomy; A&P = Anatomy and Physiology; Mb = Microbiology; home = home school; EP = Exercise Physiology; IB = International Baccalaureate biology; F = Forensics; ES = AP Environmental Science; .5 = one semester; Numbers in brackets are scores on AP Biology or IB Higher Level Biology exams.

[a] This student completed two years of high school biology, but said in her interview the second year was a retake of the first year.

Among the 17 students with minimal HEB exposure, two students did not take any high school biological science classes, nine took only one biological science class, and six took at least one biology class in addition to regular or honors biology. Only one student in this group completed more than two years of biology, having taken honors biology, advanced honors biology and Exercise Physiology. Eleven students took at least one year of chemistry and 10 students took at least one year of physics.

The five students in the moderate HEB exposure group all took chemistry and two or fewer biology classes. Two students took physics. One student completed basic biology and Anatomy and Physiology and another student completed honors biology and one semester of AP Biology. One of the students who took only one biological science class in high school discussed having biology classes in middle school.

All eight participants assigned to the high HEB exposure group took at least one year of biological science, at least one year of chemistry and at least one additional year of science. Five of the students took at least one year of physics. One student completed seven years of high school science classes. Six of the eight students completed two or more years of biological science. One student completed regular biology and one year of IB Biology and two students completed an honors biology class as well as Environmental Science. Three students completed three years of biological science classes. One student completed two years of IB Biology and Forensics. Another student took honors biology, AP Biology and Anatomy and Physiology. And the third completed honors biology and two years of IB Biology.

The high HEB exposure group had the highest high school science enrollment (*Mdn* = 4, IQR = 1), biological science enrollment (*Mdn* = 2, IQR = 1.75), and advanced biological science enrollment (*Mdn* = 1, IQR = 1.75; see Figures 24 and 25). The minimal HEB exposure group had the lowest science enrollment (*Mdn* = 3, IQR = 1.5) and biological science enrollment (*Mdn* = 1, IQR= 1), but not the lowest advanced biological science enrollment (*Mdn* = 0, IQR = 1). The moderate HEB exposure group had the lowest advanced biological science enrollment (*Mdn* = 0, IQR = .75). Note that the moderate HEB exposure group had the smallest sample size (*n* =5).

Nonparametric statistics with bootstrapping were conducted to analyze these differences, but small sample sizes, particularly for the moderate HEB exposure group, limit the strength of some statistical tests and increase the chances of Type II error, therefore these data must be considered in the context of the interviews. Modest positive correlations between HEB exposure and science enrollment, HEB exposure and biological science enrollment, and HEB exposure and the number of advanced biological science classes students completed (i.e., any biological science classes other than a regular biology or honors biology), were not significant at $p = .05$. Note that the p-value for the correlation between HEB and science enrollment was .057.

Kruskal-Wallis tests showed that science enrollment differed significantly among the four HEB exposure groups, χ^2 (3, N = 44) = 12.822, $p < .01$, but biological science class enrollment and advanced biological science class enrollment did not. Mann-Whitney U post-hoc tests indicated that the high HEB exposure group had significantly higher science enrollment than the no HEB exposure group, $U = -12.196$, $p < .05$, and the minimal HEB exposure group, $U =$

-18.449, p <.01. The size of these differences was strong (r = 0.53 and r = 0.64, respectively). The high HEB exposure group also had significantly higher advanced biological science enrollment than the minimal HEB exposure group, U = 32.0, p < .05. The size of this difference was moderate (r = 0.47). All comparisons between the moderate HEB exposure group and the other three HEB groups were not statistically significant at p = .05, but the statistical power of these tests were low and chances of a Type II error were high. Though there were no significant differences identified among HEB groups for biological science enrollment, a strong positive correlation did exist between science enrollment and biological science enrollment, $r_s(44) = 0.821$, p < .01.

The results presented above and in Figures 24 and 25 led to the following conclusions:

- *Conclusion A*: HEB exposure is not significantly correlated with numbers of years of high school science enrollment and biological science enrollment at p = .05, though p = 0.057 for the correlation between HEB exposure and science class enrollment.
- *Conclusion B*: Among the HEB exposure groups, students with high HEB exposure completed the greatest number of science classes, biological science classes, and advanced biological science classes. The high HEB exposure group completed significantly more science classes than the no HEB and minimal HEB exposure groups and significantly more advanced biology classes than the minimal HEB exposure group.
- *Conclusion C*: Students with high HEB exposure completed at least three years of science that included one or more years of biological science.

Two alternative inferences were generated based on the conclusions above:

- *Inference A*: If a student completes more than four years of science and/or more than two years of biological science, she will have high HEB exposure.
- *Inference B*: If a student has high HEB exposure, she will enroll in at least three years of science classes that will include at least one year of biological science.

The alternative inferences, A and B, address the causal relationship between HEB exposure and enrollment. Inference A assumes that enrollment determines exposure; it predicts that a student who completes more than four years of science classes and/or more than two years of biological science will, at some point in high school science class, be exposed to a high level of HEB. Inference B assumes that exposure drives enrollment; it states that high HEB exposure during K-12 influences students to enroll in a relatively high total number of high school science classes and/or biological science classes. What follows is an examination of the questionnaire and interview data to determine if either inference is better supported than the other.

Inference A is supported by the study data with three immediately obvious exceptions: Participant 203 completed 4.5 years of science (including 1.5 years of biology) but only had moderate HEB exposure, Participant 6006 had three years of biological science (four years of science total), but only had minimal HEB exposure, and Participant 365 completed five years of science (including two years of biology), but had no HEB exposure. Participant 365's experience is consistent with the data presented in Chapter 2 showing that 20-25% of high school biology teachers do not teach about evolution in their classrooms (note that 12 other students in the no HEB exposure group took just one or two years of high school biology).

Participant 203, who completed 4.5 years of high school science and had moderate HEB exposure, took honors biology and AP Biology. She attended public high school in Utah (grade 9) and Arizona (grades 10 – 12), had a high religion factor and high general evolution and human evolution acceptance. She took honors biology in Utah and AP Biology in Arizona. In her interview, she recalled learning about general evolution in middle school in both her science and history classes and discussing evolution and intelligent design in Speech and Debate Club in high school. She also discussed learning about the australopithecine, Lucy, in Honors Biology and her teacher explaining to the class that humans are not descended from monkeys and teaching about the concept of common ancestry. Her AP Biology class, however, was only one semester and she said,

- I think in my AP Bio class, I don't even think we talked about evolution, but I think that might also be because we were on semester and our school board wouldn't let us have...since it was an AP class, the teachers wanted it to be a whole year...but it was only a semester, so we only covered half the course material and the other half we had to just learn on our own [in preparation for the AP Biology exam]. So I don't remember covering it... (Participant 203).

Possibly, if this student had formally completed a full year of AP Biology, she would have had high HEB exposure instead of moderate HEB exposure. Participant 203's experience suggests that a student who completes more than four years of science must have at least one full year of advanced biological science to have high HEB exposure.

Participant 6006, the student who completed three years of biology and had minimal HEB exposure, attended a public high school in Arizona. She had high general evolution and human evolution acceptance and a low religion factor. She took Honors Biology in 10th grade, Advanced Honors Biology (a dual-enrollment course with a local community college) in 11th grade, and Exercise Physiology in 12th grade. AP Biology may not have been offered at the school when she was in 12th grade, as it was discontinued for some time. It is offered now, but students must complete 10th and 11th grade biology before they can enroll in AP Biology. The 10th grade class included some genetics, but according to the student, the teacher "didn't talk very much about evolution" (Participant 6006). The student recounted that, in Advanced Honors Biology, which, at this public school, covers topics such as wilderness survival, as well as general biological science, the teacher "went over evolution" and the student said the teacher "had a whole class period where it was a debate between evolution and creationism" (Participant 6006). In Exercise Physiology, they "just learned about the human body" and did not do any comparative physiology or evolutionary anatomy (Participant 6006). This student's experience contradicts inference A; however, the three students with high HEB exposure who took three years of biological science all had at least one year of either AP Biology or IB Biology, which this student did not.

The third exception to inference A is Participant 365 who completed five years of science and had no HEB exposure. She completed a regular biology class, Human Anatomy, Chemistry, AP Chemistry and Physics. Like Participant 6006, she did not have an AP or IB Biology class. She attended a public high school for 1.5 years and a private high school for 2.5 years, both in California. She took regular biology in 9th grade at the public school and anatomy at the private school, which was non-denominational, but the headmasters were "very strong Catholics" and had "a huge influence on the teachers" (Participant 365). When recalling what she learned in 9th grade biology, she said,

- The only thing I can really pinpoint was, uh, you know he taught us how to do the Punnett square thing I remember, but aside from that we really focused on, you know, cell biology, things of that nature and dissecting and things like evolution were always thought of as a controversial topic of, um, of belief rather that actual science. [The teacher] didn't really teach it, he just kind of described what it was and the basic concept of it. Nothing in depth like [my professor at ASU] (Participant 365).

In this student's anatomy class, taken at the private school, the curricula included "human anatomy and body parts and its function" and no comparative anatomy (Participant 365). Based on this student's experience, an additional caveat would be that inference A only applies to students who attended public high school, but there are two participants in the high HEB exposure group who attended private (Catholic) high schools, so this was not considered when revising the inference.

Taking into account these exceptions, inference A was amended as follows:

- *Inference A(2)*: A student who completes more than four years of science and/or more than two years of biological science, including at least one full year of either AP Biology or IB Biology, will have a high level of exposure to HEB.

A closer examination of the interview data shows, however, that there are two exceptions to inference A(2). Inferences A/A(2) assume that HEB exposure only occurs in science classes and during high school, but two of the students in the high HEB exposure group were exposed to HEB primarily in history or social studies classes and/or in middle school, not only high school (see Table 14). The data, therefore, do not fully support inference A(2).

Inference B states that if a student has high HEB exposure, no matter the source of that exposure, she will choose to enroll in at least three years of high school science classes and those three years will include at least one year of biological science. This inference accommodates the two students who were primarily exposed to HEB in non-science classes. However, twenty-seven students in the no HEB to moderate HEB exposure groups, including the majority of the students with no HEB exposure (n = 13), took at least three years of science with at least one year of biological science. This does not mean that HEB does not influence students to take more science – the fact that students in the high HEB group took the most science implies that it does – but it does demonstrate that other factors, some of which may be related to HEB exposure and some which may be independent of HEB exposure, drive STEM enrollment. The timing of HEB exposure, high school graduation requirements, university admission requirements, STEM achievement and overall academic aptitude are considered as possible influencing factors.

Factor 1: Timing of HEB exposure. Support for inference B depends, in part, on the timing of HEB exposure; for example, if high HEB exposure always occurs in 12^{th} grade, then students' high school science class enrollment could not depend on HEB exposure and inference B would be false. Among the participants in the high HEB exposure group, all but one student were exposed to HEB during or prior to 11^{th} grade (Table 14); participant 362, who completed five years of science classes, primarily received HEB education in 12^{th} grade, in the

Table 14

Timing of HEB Exposure for Participants in the High HEB Exposure Group

Participant	Timing of HEB Exposure
7096	9^{th} grade biology
7218	10^{th} grade biology
2436	6^{th} grade history & 9^{th} grade biology
4272	11^{th} and 12^{th} grade biology
2439	at the zoo when he was "really little" & 9^{th} grade biology
2206	11^{th} grade social studies, 10^{th} grade biology & 12^{th}(?)[a] grade biology
206	7^{th} grade science and 9^{th} grade biology
362	12^{th} grade biology

[a] It was unclear whether this student took AP Biology in 11^{th} or 12^{th} grade, but in the interview, he implied it was in 12^{th} grade, though that is open to interpretation.

second year of a two-year IB program at his high school. Participant 4272 also completed a two-year IB Biology program, but was exposed to HEB in 11^{th} grade and completed Forensics in 12^{th} grade. With the exception of Participant 362, the data on timing of HEB exposure support inference B. This implies that high exposure to HEB increases students' interest in science classes generally, a topic that requires further exploration and is examined more closely in the *STEM Interest* section of this chapter.

Factor 2: High school graduation and university admission requirements. Though many states, like Arizona (legislation R7-2-302.01), require only two credits of science for high school graduation, school districts or high schools can establish their own policies requiring students to take three years of science to qualify for graduation. A statistical analysis report from the National Center for Education Statistics (U.S. Department of Education, 2007) showed that, in 2004, the average number of science credits for public high school graduates was 3.3, with 2.6% of students (in any school sector) not taking any science and 30% of students (in any school sector) not enrolling in any advanced-level science classes (i.e., taking only one or two years of science). The data for the 44 study participants approximate the 2004 national data, though every student in the sample completed at least two years of science classes. The students in the study took an average of 3.4 science credits and 23% of them completed only two years of science. The minimal HEB exposure group had mean science enrollment (M = 2.9, SD = 0.78) below the national average. The no HEB exposure group (M = 3.4, SD = 0.74) and the moderate HEB exposure group (M = 3.5, SD = 0.7) were slightly above the national average. The high HEB exposure group had mean science enrollment (M = 4.5, SD = 1.2) much higher than the national average. This suggests that something other than high school graduation requirements was driving STEM enrollment for the high HEB exposure group, distinguishing them from the other exposure groups.

The Arizona Tri-University Admission Standards require three units of science for assured admission, but delegated admission to Arizona universities allows for one deficiency in laboratory sciences, which accommodates the 23% of the study participants who did not meet the assured admission standard. Also, the years of science required for assured or delegated university admission do not have to include a biology class. Among the study participants, 7% did not take a biology class. These data show that graduation and/or university admission requirements may have driven STEM enrollment for some students in the sample, but are not responsible for the unusually high science and biological science enrollment that characterized the students in the high HEB exposure group.

Factor 3: STEM achievement. Participant 362, the student with high STEM enrollment and high HEB exposure who did not get exposed to HEB until 12th grade, reported that she earned As in all of her science classes in high school. This case made it evident that achievement in high school science classes may be one of the factors driving STEM enrollment. She did not grant the researcher access to her undergraduate transcript, but she indicated on her pre-interview questionnaire that she received or expected to receive As in the three undergraduate science courses she took or was taking, validating her excellent performance in science classes, generally. Later, she posted on a public website that she was on the Dean's List at ASU throughout her undergraduate career and graduated with honors. This suggests that achievement in science may drive STEM enrollment.

Another student in the high HEB exposure group, who was exposed to HEB in 6th and 9th grade, and completed four science classes in high school, when asked why he was interested in a STEM career responded, "I've always been really good at science, it's always been my favorite subject" (Participant 2436). Perhaps if a student is "good at science," regardless of, or in addition to, the content to which she is exposed, she may be more likely to enroll in a greater number of high school science classes than a student who performs less well in science classes. If the high HEB exposure group members all had higher average marks than the participants in the other exposure groups, this would weaken support for inference B and imply that achievement is the driving force behind their unusually high STEM class enrollment.

Most participants provided letter grades for their high school science classes. Table 15 includes the letter grades provided by the 13 students in the no HEB exposure group who completed three or more years of high school science that included one or more years of biological science. For about half of these students, high achievement (a letter grade of A) in some of their early high school science classes may have influenced enrollment in advanced classes, but there is not a clear positive relationship between science achievement and science enrollment based on these data, as some students earned Bs and Cs in science classes completed in 9^{th} or 10^{th} grade.

Achievement data for the high HEB exposure group suggest that a factor other than achievement drove STEM enrollment for this group. Only two of eight students earned As in all of their science classes. Three students earned As in biology class, but received at least one B or C in other science classes. One student earned a B in biology and another student earned a C in all of his science classes, including biology. The eighth student in the high HEB exposure group did not report her letter grades for high school science, but did not perform well on multiple AP and IB science exams, earning a 1 out of 5 and 2 out of 5 on AP Physics and AP Chemistry, respectively. She earned a 4 out of 7 on both her IB Biology and IB Chemistry exams. Though five of the eight students earned an A in at least one science class, it does not seem that STEM achievement was a significant contributing factor driving STEM enrollment among the high HEB exposure group.

Table 15

High School Science Performance for Participants in the No HEB Exposure Group Who Completed Three or More Years of Science Including One or More Years of Biological Science

Participant	Letter Grades for High School Science Classes
365	B, B, B, A [a]
502	A, B, A
7513	B, B, B+
4506	A, A, C
7761	A, A, A
1692	B, B, B
7677	A, A, A
4261	A, A, A, A, A [b]
3066	C+, B+, B-, A-
1123	A, B, A
483	A, B, C, B
7201	A, A, A, A
108	C, A, B, A

Note. The grades are reported in the order in which classes were completed (i.e., regular or honors classes first, advanced or AP/IB classes last).
[a] This student did not report a letter grade for one of the classes she completed.
[b] This student completed four years of science that included two one-semester classes.

Seven of the 44 participants took just two science classes in high school and their grades were compared to those of the other participants. Among the seven were two traditional students (i.e., students who entered the four-year university immediately after graduating from high school), including a participant who earned Bs in high school chemistry and physics and a participant who earned Bs in biology and physics. In addition, a 26-year-old who was a junior at ASU earned a B- in high school biology and a C in high school chemistry. The possibility that higher achievement in science classes early in high school would have influenced these students to enroll in more STEM classes cannot be ruled out. The other four participants did not provide letter grades for their science classes. Two of them misinterpreted the questionnaire question and wrote down the school year when they took their classes instead of the letter grade. One student took biology in Hong Kong and did not report her grade for that class, but indicated she earned an A in a physics class she took her senior year. A 32-year-old first-year student said in his interview that he took “a couple biologys” in high school, but on his questionnaire wrote down only one biology class and provided a grade of 100 percent (Participant 1214). Therefore, inferences cannot be made about achievement and enrollment for these four students.

It is difficult to know how letter grades should be interpreted, however, in the context of a student’s perception of her abilities and feelings of achievement. If a student earned a grade of A in a class, it is assumed that that student would perceive herself as “being good at science,” though it is impossible to know the effort that was required to achieve that grade, and how the student factors effort into her perception of performance. Additionally, one student might consider she is “good at science” if she earns a B, but another student might consider she is “bad at science” if she earns a B. Therefore, it is challenging to draw conclusions and make inferences about STEM enrollment based on achievement; it cannot be ruled out as a contributing factor for some students, but it is not the sole factor driving unusually high enrollment for students in the high HEB exposure group.

Factor 4: Academic aptitude. Participants’ letter grades from high school science classes demonstrate that science achievement does not solely or unequivocally drive STEM enrollment, but data were not collected from other (non-science) high school classes and thus, it is possible that, despite a low grade or two in science, a student might be “a good student” overall and therefore be more likely to take more advanced classes, including more advanced science classes, than a student who is not a good student. Thus, the researcher considered how students’ general academic aptitude might contribute to science enrollment. It would have been useful to collect data for high school GPA and Scholastic Aptitude Test (SAT) or ACT exams, but these were not collected from interview participants (they were collected from survey participants). Instead, undergraduate GPAs were obtained from 41 participants’ academic transcripts and were used as a scale variable to represent academic aptitude.

There was no significant correlation between university GPA scores and high school science class enrollment (Figure 26). A GPA of 3.5 to 4.0 was considered an indication of high academic aptitude. Among the 41 study participants, just more than half (51%) had a GPA of 3.5 or higher. Students with GPAs of 3.5 or higher (M = 3.6, SD = 1.2) took more STEM classes than students with GPAs less than 3.5 (M = 3.2, SD = 0.7), but this difference was not statistically significant. Participants were also placed into five achievement groups based on GPA ranges (Figure 26). For the purposes of performing statistical tests, the sole student with a GPA less than 2.5 was included as part of the next highest GPA range. There was not a significant difference between achievement groups for STEM enrollment. Thus, it was concluded that there was not a relationship between academic aptitude and high school science enrollment, such that “good students” did not complete more high school science classes.

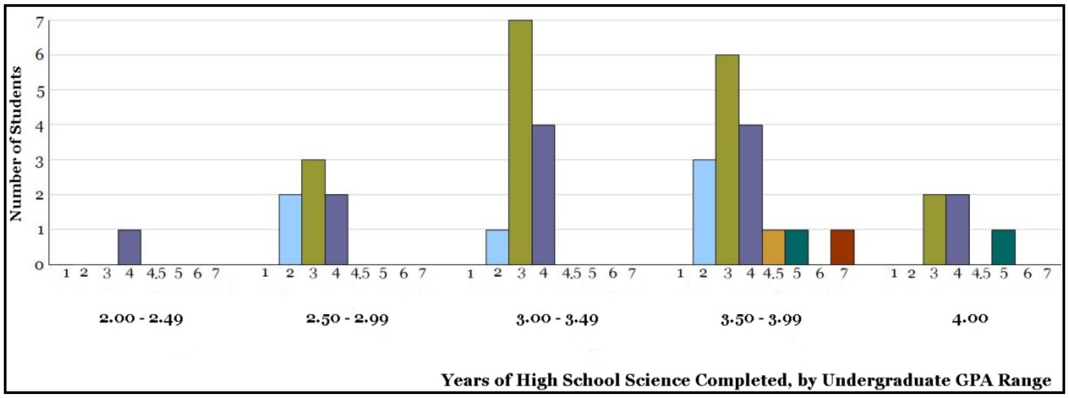

Figure 26. Enrollment in high school science classes, organized by undergraduate GPA ranges.

Students with high HEB exposure had statistically greater high school science enrollment than students with no or minimal HEB exposure and also had higher average undergraduate GPA scores than students with no or minimal HEB exposure (Figure 27). Though not a statistically significant difference, the latter

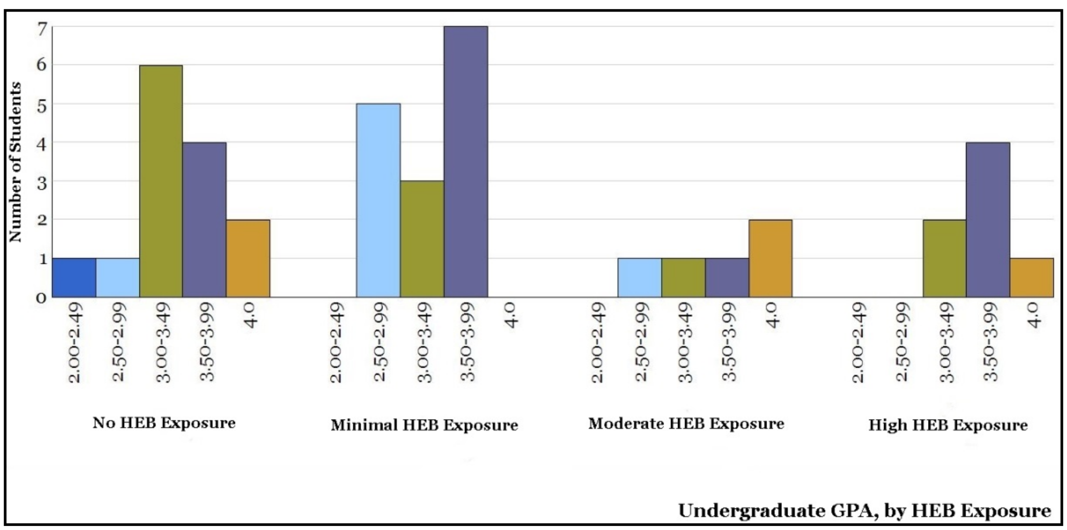

Figure 27. Undergraduate GPA ranges organized by HEB exposure groups (n = 41). (Academic transcripts were not available for three of the 44 participants.)

may be due to the fact that students with high HEB exposure are better prepared for certain undergraduate coursework that deals with HEB-related content.

At Arizona State University, the lab-based introductory level biology course that includes evolution as the primary focus of the curriculum is BIO 187, General Biology I (this class number changed to BIO 182 in 2011). BIO 187 is designed for biological science majors and pre-med students, but can be taken by non-science majors, as well, to fulfill a laboratory science requirement. The five students in the high HEB exposure group who took BIO 187 all earned As in the course. Two students in the moderate HEB exposure group completed the course and one earned an A and one earned a B. One student in the minimal HEB exposure group took the course and earned a B. Four students with no HEB exposure took BIO 187 and two of them earned As and two earned Bs. One of the students with no HEB exposure who earned an A was a 23-year-old post-baccalaureate student who completed five years of science classes in high school. The other student with no HEB exposure who earned an A was, at the time he was enrolled in the course, a 21-year-old freshman who had been out of high school for nearly four years and had transfer credits from a two-year institution.

Based on these data, traditional students with high HEB exposure perform better in undergraduate evolutionary biology courses and have higher undergraduate GPAs than students with less HEB exposure. This could be because (a) HEB content better prepares students for undergraduate coursework, (b) high HEB exposure drives high school science class enrollment, which better prepares students for undergraduate STEM coursework generally and/or (c) students in the high HEB exposure group have greater academic aptitude (e.g., better study habits and test performance) than students in other HEB exposure groups.

If only traditional students are considered, the data support any or all of these inferences with two exceptions (see Figure 26). Two students with university GPAs higher than 3.0 took only two science classes in high school and had no or minimal HEB exposure. Their individual cases were examined to see why they did not take more science classes in high school and/or why they had higher than expected undergraduate GPAs.

Participant 974, a traditional student and Finance major with a GPA of 3.16 had no HEB exposure and only took chemistry and physics in high school. As of the time of the interview, he had not taken any life or physical sciences at the university, which means the inferences above cannot be applied to his case. With regard to his general attitude toward STEM, he said,

- I think that's the biggest difference between science majors [and non-science majors] - I don't know about [another participant], but I have no interest in questioning things. I mean I think it's interesting that you guys do it, but I have no interest in... I like, you know, hard facts; I like numbers, that's why I'm in finance (Participant 974).

His low enrollment in high school science classes and lack of any biology classes were evidently due to a lack of interest in science, generally. His low high school science enrollment would not necessarily affect his performance or achievement at the undergraduate level since he was not taking science courses at ASU.

Like Participant 974, Participant 7561 was a traditional student majoring in Finance. However, she attended three years of high school in Hong Kong and took her senior year in the United States. She completed just one year of biology in Hong Kong and one year of physics in the U.S. and had minimal HEB exposure. She earned an A in her high school physics class. She said,

- I only took one year of biology in Hong Kong. In Hong Kong we don't have many choice of science, we only have Chemistry, Physics and Biology, so I

> did one year and then I felt like it was too many stuff to remember and then, I just, the senior year, in here, high school, I take Physics (Participant 7561).

As with Participant 974, this student's low enrollment in high school science classes did not affect her performance as a Finance major. She primarily took economics, business and English courses and had a GPA of 3.84. She did complete Introduction to Physical Geography (GPH 111) and earned an A.

Returning to the inferences made about achievement and academic aptitude above, and considering these two students, it seems that traditional students with high HEB exposure who have a variety of regular and advanced high school STEM classes available to them tend to enroll in more high school science classes, perform better in undergraduate science courses and have higher undergraduate GPAs than students with less HEB exposure. Again, this may be because high HEB exposure increases students' interest in science and completing more science in high school better prepares students for undergraduate coursework in the sciences. The role of interest as a factor in STEM enrollment is explored in more detail in the next section of this chapter.

Based on all four factors – timing of HEB exposure, graduation and admission requirements, achievement, and academic aptitude – the following conclusions were drawn regarding STEM enrollment:

- *Conclusion D:* High K-12 HEB exposure typically occurs during or prior to 11^{th} grade.
- *Conclusion E*: High school graduation and university admission requirements are not responsible for the high number of high school

science and biological science classes completed by students with high HEB exposure.

- *Conclusion F:* Traditional students with high K-12 HEB exposure perform better in certain undergraduate STEM courses than students with less K-12 HEB exposure.
- *Conclusion F*: Students with high K-12 HEB exposure have higher undergraduate GPAs than students with no K-12 HEB exposure or minimal K-12 HEB exposure, though the difference is not statistically significant in this sample.

These conclusions generated the following inference:

- *Inference C*: Traditional students majoring in STEM who have high K-12 HEB exposure perform better in certain undergraduate STEM courses and thus will have higher GPAs than traditional students in the no HEB exposure and minimal HEB exposure groups who are also STEM majors.

Inferences B and C were the basis for generating the following hypotheses:

- A high school student with high K-12 HEB exposure will complete at least three years of high school science classes that will include at least one year of biological science.
- Among traditional students majoring in STEM, students with high K-12 HEB exposure will have higher university GPAs than students with less HEB exposure.

To test these hypotheses, survey data were collected from students ages 18 to 22 (inclusive). The survey included the following questions:

- How old are you?
    - under 18 [Terminate survey]
    - 18

- 19
- 20
- 21
- 22
- 23 or older [Terminate survey]

- Please indicate which of the following science courses you took in high school. (Check all that apply.)
  - Integrated Science
  - Earth Science/Earth and Space Science
  - Astronomy
  - Environmental Science
  - Physics
  - Honors Physics
  - AP or IB Physics
  - Chemistry
  - Honors Chemistry
  - AP or IB Chemistry
  - Biology
  - Honors Biology
  - AP or IB Biology
  - Plant Biology/Botany
  - Zoology
  - Forensics
  - Anatomy and Physiology
  - Exercise Physiology
  - Historical Geology
  - Other ____
- Have you officially declared your major?
  - Yes
  - No
- What do you think your major will be? (If you don't know the answer, you can leave this blank.)
- What is your approximate GPA at ASU?
  - less than 2.0
  - 2.0 - 2.49
  - 2.5 - 2.99
  - 3.0 - 3.49
  - 3.5 - 3.99
  - 4.0
  - I don't know

To assess general academic aptitude, data were also collected on students' SAT/ACT performance with the following questions:

- Did you take the SAT?
  - Yes [view next question]
  - No

- I don't know

- What was your highest score on the reading and math sections combined? (This should be the score you used to apply to ASU. Do not count the recently added writing section of the SAT.)
  - less than 1000
  - 1000 to 1099
  - 1100 to 1199
  - 1200 to 1299
  - 1300 to 1399
  - 1400 to 1499
  - 1500 to 1600
- Did you take the ACT?
  - Yes [view next question]
  - No
  - I don't know
- What was your highest total score on the ACT?
  - less than 20
  - 20-22
  - 23-25
  - 26-28
  - 29-31
  - 32-34
  - 35-36

HEB exposure and STEM interest. It is possible that the high HEB exposure group had unusually high enrollment in high school science classes in part due to their relatively high interest in STEM content. Not all high schools offer AP and IB courses, so it is also possible that the students in the high HEB exposure group had greater access to advanced science classes than did the other participants. There was no commonality, however, in the type (public, private, denominational) or location (state) of high school attended by the participants in the high HEB exposure group when contrasted with the schools attended by the other participants, and therefore no reason to think that they had greater or lesser access to advanced classes. Additionally, all of the students in the high HEB exposure group were enrolled in STEM degree programs at ASU (see Table 13 and Table 16) which implies that their high secondary STEM class enrollment was, at least in part, associated with their interest in STEM.

Data from the interviews and pre-interview questionnaires support the idea that the students in the high HEB exposure group were generally more interested in STEM subjects than other students, and/or were interested in STEM for different reasons than the other students. The *STEM appeal* node in NVivo had a coding density of 267 references. Thirty-six daughter nodes were created to capture the diversity of students' views about STEM, particularly science, and why they did or did not find STEM appealing. These included daughter nodes such as *science as a calling*, *science as important*, *science as understanding how things works, science brings meaning*, *science good at it, science coursework*, *science as natural inclination* and *motivated by illness*, among many others.

Table 16

*Percentage of STEM Majors in Each HEB Exposure Group (*N = 44*)*

HEB exposure group	STEM Majors
no HEB (n = 14)	71.4%
minimal HEB (n = 17)	52.9%
moderate HEB (n = 5)	60%
high HEB (n = 8)	100%

The daughter node *science as interesting* had a coding density of 28 references. Students in the high HEB exposure group made broad statements about their interest in STEM and reflected on science content and activities they had learned or done in the past, such as:

- I've always been really good at science, it's always been my favorite subject... (Participant 2436).
- I find science extremely interesting and enlightening (Participant 2206).
- I believe that [science] is very interesting (Participant 362).

- I’ve always enjoyed science. Science fair was always the best time of year for me; it was so much fun (Participant 7218).
- I know for me, like, I’ve always been interested in different science things. Like I had a microscope when I was little and I like had little samples of random things in our backyard and like looked at them (Participant 4272).
- Discovering something that no one has ever seen before, like it’s exciting to me. And I think it’s just generally interesting and kind of like awe inspiring. I think I like, yeah, it’s just me and just, definitely my [6th grade] teacher, ‘cause I think that’s when I really decided that like, stuff is like really cool and really interesting... also my honors biology teacher was really cool ‘cause he was kind of the one who like allowed me to see like...how many, how just interesting and diverse [biology] is (Participant 2006).

For most of these students, science was identified as a discipline in which they were interested prior to high school and that remained interesting to them during and after high school or was an area of study that became more interesting to them during high school.

For students with no or minimal exposure to HEB, most statements describing their STEM interest focused on their desire for *continued* STEM learning or the acquisition of specific new knowledge, rather than on their prior K-12 learning experiences. Some also emphasized the direct relationship between science and a particular career they wanted and a few included reflections upon what other people wanted for their futures or thought of their STEM aptitude:

- I would look at [having a career in] anthropology or archaeology. It interests me (Participant 4506, no HEB exposure).
- I enjoy biology in all aspects, so I want a career that serves my interest and lets me continue learning (Participant 108, no HEB exposure).
- I am interested in science. I think it's fascinating to explore...even know about, the human body (Participant 4261, no HEB exposure).
- [Science] is the subject that interested me the most and is related to the dental industry (Participant 1214, minimal HEB exposure).
- There was nothing in my social or personal life that inspired me to study what I am today and be interested in science... And then my [biology teachers] were both very inspiring. And both kind of pointed out to me that I excelled really well in their biology classes and had a really strong interest in it (Participant 108, no HEB exposure).
- [Science is] somewhat appealing. I really didn't like it [in high school]...I'm definitely not a "science person" and I just, like, now I have to take two classes and that's just because I have to...I definitely like more like the anatomy and physiology, how the body works because it's something, you know I'm a human, all these functions are a part of me. I'm definitely more interested in that, as opposed to the chemical compounds of molecules and stuff like that. I like the more anatomy and learning about my muscles and how this works and what chemicals make your body do this and that. Definitely I'm more interested in that (Participant 5886, minimal HEB exposure).
- So I learned a lot in that [nursing] class, like health class was so much fun. Like I learned the heart, all the different diseases and after that I was like,

"Oh my god, I want to be a doctor" (Participant 1192, minimal HEB exposure).

- I think it's the family. Like, the fact that my Dad works with science and that made me want to have an interested in science when I was younger (Participant 913, minimal HEB exposure).
- My Dad actually wanted me to do engineering because he's an engineer and I was interested in it... I was just interested in science and I knew it would captivate my attention for a long time (Participant 317, minimal HEB exposure).

The primary theme that emerged from all of these interest data involved intrinsically-inspired versus extrinsically-inspired STEM interest. Students with high K-12 HEB exposure were generally characterized by a broad, long-term intrinsic interest in STEM and had positive memories of K-12 STEM learning or activities. Students with no or minimal K-12 HEB exposure had a more extrinsically-inspired interest in STEM; they were more likely to equate their STEM interest to a desire for a specific career or say something about how their affinity for STEM was pointed out to them by someone else. Note that, among the quotes from students with no or minimal HEB exposure, a number of them include references to some particular aspect of science that they found interesting and that motivated them to learn science, and for most of them it was a topic related to human biology.

Students' interest in STEM does not appear to be influenced by their religion factor. In fact, a greater percentage of students majored in STEM among the moderate and high religion factor groups than did students in the low religion factor group (see Figure 28). Among the high HEB exposure students, who all majored in STEM, religion factor ranged from low to high.

An interesting relationship was found between STEM interest and general evolution and human evolution acceptance (Figures 29 and 30). Though there were STEM majors in all general evolution acceptance groups (Figure 29), the non-STEM majors all accepted general evolution. And the only students who completely rejected human evolution were STEM majors (Figure 30). These data imply that evolution and human evolution acceptance cannot predict whether a student will enroll in a STEM degree program.

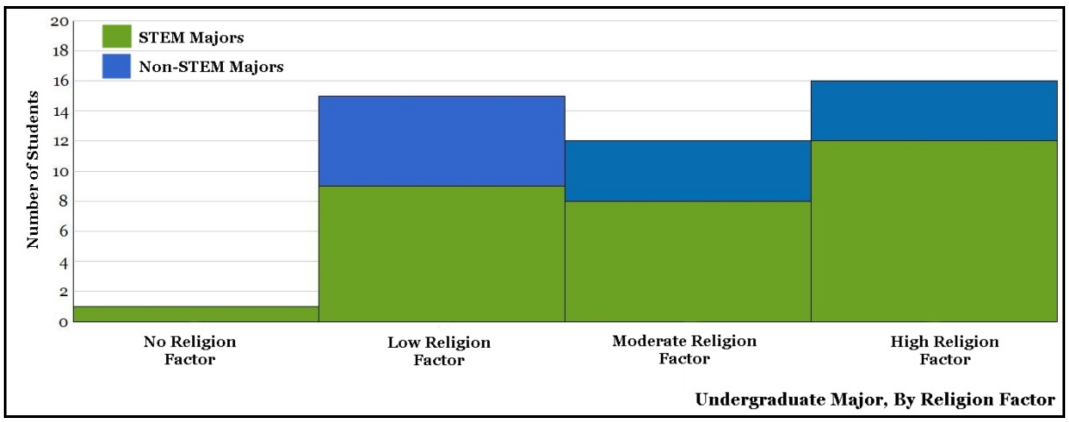

Figure 28. STEM and non-STEM majors by *religion factor* (N = 44).

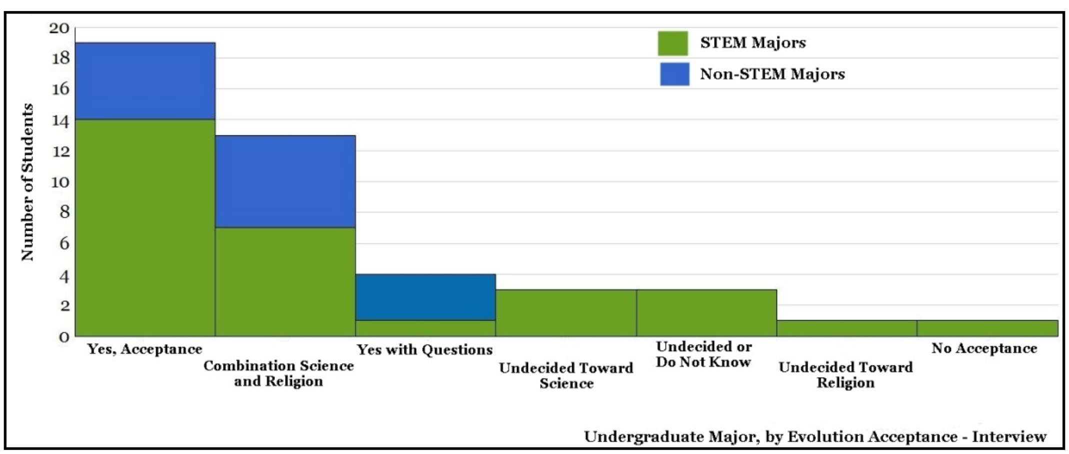

Figure 29. STEM and non-STEM majors by *evolution acceptance – interview* (N = 44).

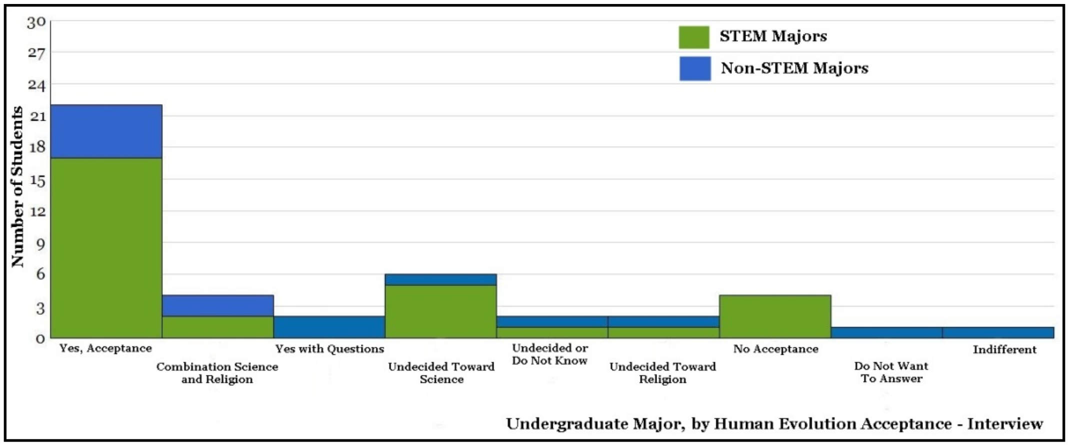

Figure 30. STEM and non-STEM majors by *human evolution acceptance - interview* (N = 44).

Based on the questionnaire and interview data, a theme emerged that multiple factors seem to influence students' interest in a STEM major. The high HEB exposure group had the highest percentage of students enrolled in STEM degree programs at ASU (100%). This group also had the highest average high school science class enrollment and the highest average biological science and advanced biological science class enrollment. Therefore, there is a relationship of some sort between HEB exposure, high school science class enrollment and interest in STEM. Other factors that were discussed during the interviews may correlate with STEM degree enrollment, as well. Students' talked about their intrinsically and extrinsically-inspired interest in STEM, including their life-long curiosity about the world, a parent's career, a family member's or personal illness, an inspirational classroom teacher or course instructor, and/or their enjoyment of participation in science fairs. The students in the high HEB exposure group tended to be the students who were most likely to have an intrinsically-inspired interest in STEM.

The moderator also asked participants how often they visited zoos and museums as children and if this had any influence on their interest in science. A few students in different HEB exposure groups remarked that informal science experiences did influence them; for example, Participant 6006, an Anthropology major with minimal K-12 HEB exposure who took 3 years of high school biology said,

- If I hadn't been exposed to all of that [at zoos], I wouldn't have had the interest in animals that I have, and I wouldn't have had the interest in how things work and where they come from that I've got.

Participant 2436, an Ecology and Evolutionary Biology major with high HEB exposure who took just one high school biology class was heavily influenced by a visit to Sea World as a child:

- And then my parents took me to Sea World and we saw seals and sea lions and penguins and orcas and I was like, "What?!," and so I never lost that and I've always said I'm gonna be a marine mammal scientist.

Based on this feedback from participants, it was necessary to consider all possible intrinsic and extrinsic factors that may have influenced students to pursue a STEM degree program to better understand the impact of HEB exposure on STEM interest.

The following hypotheses were generated regarding students' interest in STEM:

- Students with high K-12 HEB exposure are more likely to be interested in a STEM degree program than students with less K-12 HEB exposure.
- Religion factor and general evolution acceptance and human evolution acceptance cannot be used to predict if a student is interested in a STEM degree program.

- STEM interest and persistence are influenced by factors including both formal and informal education experiences, such as visits to zoos and museums, participation in science fairs, or an influential teacher or faculty member, or personal experiences and desires, including, but not limited to, illnesses, a curiosity about the world, or a desire to help other people or animals.
    - Among STEM majors with high K-12 HEB exposure, motivation to pursue a STEM career is associated with intrinsic motivating factors more than with extrinsic motivating factors.

To test these hypotheses, the survey included the following questions:

- Have you officially declared your major?
    - Yes
    - No
- What do you think your major will be? (If you don't know the answer, you can leave this blank.) (Students were provided with an open-ended box in which to type.)

And, the following addressed STEM career motivation among STEM majors, which is discussed in the next section of this chapter:

- To what degree did each of the following influence your interest in a science, technology, or engineering-related career (including medical, teaching, research or industry jobs)? (Response options included *a lot of influence*, *some influence*, and *no influence*.)
    - Your parents/guardians careers
    - Your parents/guardians hobbies
    - Elementary, middle or high school class
    - Elementary, middle or high school teacher
    - Participation in science fairs
    - Visits to hands-on style science centers/museums
    - Visits to natural history museums
    - Visits to zoo, aquaria or wildlife parks
    - Illness or death of a family member
    - Personal illness
    - A college/university professor
    - A college/university course
    - An internship or job
    - Books

- Movies
- Documentary/Nonfiction television programs
- Fiction television programs (primetime dramas/sitcoms)
- Print or online news media (newspapers, magazines)
- Personal interest in or curiosity about the world
- A desire to help other people
- A desire to help animals
- This survey
- Other (see next question)

▪ If you indicated "other" in the previous question as having "some" or "a lot" of influence, please explain. (If you chose "no influence" you may skip this question.) (Students were provided with an open-ended box in which to type.)

HEB exposure and STEM career motivation. As discussed in Chapter 2: Review of Literature and Research, interest in STEM subject matter (taking STEM classes or pursuing a STEM degree) is not mutually exclusive from students' motivation to pursue STEM careers. Table 13 includes data on the interview participants' undergraduate major and desire for a STEM career. Thirty of the 44 participants intended to declare or had declared a STEM major at the time of the interviews and all 30 planned to pursue a STEM career (Figure 31). The percentages of STEM versus non-STEM majors in the study sample is

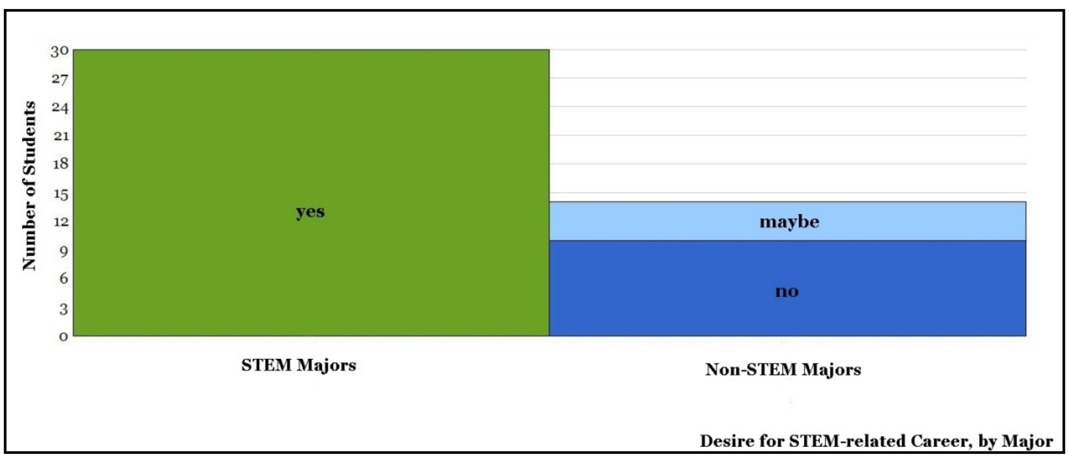

Figure 31. Students' desire (*yes, no* or *maybe*) for a STEM-related career, by undergraduate major (*STEM* or *not STEM*).

most likely a result of heavy recruiting efforts in introductory-level STEM courses at ASU and it is possible that STEM majors were more attracted to a study about science learning than non-STEM majors were. Four students, all non-STEM majors, said they “maybe” wanted a career in STEM, and 10 students, all non-STEM majors, did not want to have a STEM-related career.

Of the fourteen non-STEM majors, 12 of them were in the no HEB exposure or minimal HEB exposure groups (see Table 13). The other two non-STEM majors were in the moderate HEB exposure group and one of those students, a theater major, said he would possibly consider a STEM-related career. This student was interested in science and enjoyed science in high school, describing high school biology as “really awesome, especially when we got into phenotypes and genotypes; that was my favorite” (Participant 5666). He noted, however, that his biology class was “taught by this highly Christian woman” who, when teaching about evolutionary biology, “said ‘this is just a theory’ a lot” (Participant 5666). The student also stated that his high school did not offer AP classes. His acceptance of evolution was high and his religion factor was moderate. Three years after the interviews, this student was working as a theater technician. The other non-STEM major with moderate HEB exposure, a sophomore journalism student, was questioning her choice of major at the time of the interview. She said, “I don’t know anymore, I’m kind of lost” (Participant 922). Degree completion and career data were not available for this student. Her acceptance of evolution was low, but her religion factor was low, as well. Though her HEB exposure was moderate, she described her confusion over how evolution affects humans and presented misconceptions based on her memory of what she learned in high school biology:

- Yeah, with the [evolution of] animals and the birds and stuff, I was like, "Ok, I totally get this," and what [my teacher] said about humans is, "We used to have five fingers," I mean, "six fingers, so that's why some people are still born with six fingers," and I, we, were like [to the teacher], "Well, some people are born with four fingers on one hand, or three fingers" and then, like, so then she left us all confused in our mind, and so we couldn't - it's like, "Ok, she's trippin'." I couldn't necessarily believe her. (Participant 922).

Three STEM majors were in the moderate HEB exposure group. Two of them took AP biological science classes in high school. They had high evolution acceptance and moderate and high religion factors. The third student did not take AP courses, but took four years of science in high school and discussed taking biology classes in middle school:

- So they were labeled biology courses [in middle school], but I mean [in 7th grade] we would learn about the physiology and slightly touch upon the chemistry of certain things. Eighth grade was just a continuation of that. We learned about the human body. We learned about small differences in the human body and the body of plants, I mean, specifically the physiology processes and those and how they used energy, energy conversions (Participant 8406).

This student's acceptance level was moderate and his religion factor was high.

Within the no HEB exposure group, there were 10 STEM majors who desired a STEM career and 4 non-STEM majors. One of the non-STEM majors said she was possibly interested in a STEM career. At three years after the interviews were conducted, she had earned her B.A. and was working as an accounting assistant. In this group, the distinction between STEM and non-STEM majors, and thus students who did or did not desire a STEM career, was not determined by acceptance or religion factor, but rather associated with a lack of exposure to informal and/or formal science education.

One of the non-STEM majors in the no HEB exposure group did express a lot of interest in science, particularly in astronomy and biology, but she said she was deterred from astronomy in middle school because she "did some research on how much math they needed and [thought] 'I'm not doing that!'" (Participant 3066). She took basic biology and Microbiology in high school, and thought about majoring in biology at ASU, but said:

- I was actually on a[n athletics] recruiting trip [to ASU during high school] and I told them, "I don't know really what I want to do, I'm gonna be a biology major, but I'm not sure" and they're like, "What do you think about sports management?" and I'm like "I could do that!" (Participant 3066).

This student completed a B.A. in Communications.

A shared characteristic of the other non-STEM majors with no HEB exposure who did not intend to pursue a STEM-related career was a limited exposure to either formal or informal science. One of the three students did not take any biology courses in high school and took only two years of high school science – a basic chemistry class and a basic physics class. He was quoted earlier and described his attitude toward STEM and his science-related interactions with his parents as follows:

- I think that's the biggest difference between science majors or maybe research-based [majors and non-STEM majors]...I don't know about [the other participant], but I have no interest in questioning things. I mean, I think it's interesting that you guys do it, but I have no interest in [it]. I like, you know, hard facts. I like numbers. That's why I'm in finance. And I think [the other participants] both talked about [how] their parents, growing up, kind of helped them lead them that way. I didn't have that. Both of my parents, they never asked me why or had me ask why (Participant 974).

Of the thirty STEM majors who wanted to pursue a STEM career, good degree completion and career data were available for 24 of them. All 24 remained in STEM; some of them were still pursuing their B.S. degree, some had earned their B.S. and were working in STEM jobs, and others were enrolled in STEM graduate degree programs.

Based on the data presented above and the fact that all of the students who were pursuing or planned to pursue a STEM degree also wanted a STEM career, the hypotheses regarding STEM motivation were the same as for STEM degree interest (see p. 155). Data regarding the interview participants' STEM degree completion and careers were not collected until after the hypotheses were generated, so were not a factor when developing the questions for the online survey, but they were used to reflect on Maltese and Tai's (2010) findings that enrollment in high school biology and total high school science class enrollment can be used to predict STEM degree completion. In addition, the survey participants were asked:

- Are you interested in pursuing a science, technology or engineering-related career (including medical, teaching, research or industry jobs)?
  - Yes
  - No
  - I don't know

- Do you have a specific career in mind?
  - Yes (If students responded with “Yes,” they were asked “What is it?” and given an open-ended box in which to type.)
  - No

HEB Exposure and Socioscientific Decision-Making

The interview data were used to explore students’ views and decision-making about socioscientific issues. For this part of the analysis, it was necessary to consider if students were exposed to human evolutionary biology at any time prior to the interview, including during their postsecondary education. Therefore, the students who had completed or were enrolled in the ASU course ASM 104: Bones, Stones and Human Evolution, an introduction to biological anthropology, were added to the high HEB exposure group. Four students took ASM 104 – participant 4506 had no K-12 HEB exposure, participants 6006 and 8124 had minimal K-12 HEB exposure and participant 5666 had moderate K-12 HEB exposure. As a result, there were 12 students in the high HEB exposure group instead of eight for this part of the study.

The students were asked a number of questions pertaining to socioscientific issues, such as the environment (e.g., climate change, biodiversity conservation, recycling) and human skin color diversity (“race”). Many of the participants were also asked if they vote in elections and whether they watched, read or listened to news media at the time of the interview. Not all participants were asked all of the questions due to occasional time constraints and the semi-structured format of the interviews. Transcripts were coded in NVivo to the nodes *news-voting-current events*, *environment*, and *diversity*. Some of the participants raised concerns about other socioscientific issues, such as human health (e.g., stem cell research) and sexuality, vegetarianism, poverty, famine, hunger, green energy, pollution, animal testing, and drug resistance; these statements were coded to the node *sociosci*. In all, 553 references were coded to these nodes. Comparisons and contrasts were primarily made between students in the no HEB exposure group and the students in the moderate and high HEB exposure groups to maximize the likelihood that HEB exposure contributed to any differences in students' decision-making and science literacy.

News engagement, current event awareness, and voting behavior. There were 62 references coded to the news-voting-current events node.

News and current events. Participants were asked if they followed current events via various forms of news media. Nine of the students in the no HEB exposure group commented on this. A common theme for these students was that they were either (a) interested in current events and the news, but did not have enough time to listen to, watch or read it to be aware of or fully understand the current events, or (b) they purposefully avoided the news media and were not particularly concerned with current events. For example, one student, a Family and Human Development and Sociology dual-major, who was asked if she was interested in current events pertaining to human health said,

- Um, actually, yeah, with the whole swine flu thing, I was like "Oh, it's so weird." Yeah. And I was kind of interested in why it hadn't hit Arizona that bad, but it hit some other state that was completely far away, whereas we're next to Mexico, so that's...yeah, I definitely was interested in that (Participant 483).

Two other students, a female Ecology and Evolutionary Biology major (Participant 108) and a male Microbiology major (Participant 7761) said:

- I have BBC news tagged in my bookmarks, but um, I can't say I read it every day and I watch local news, but I hardly ever watch national news like CNN or Fox. It's really stressful and it kind of just stresses me out and bogs me down, so I kind of try to stay away from news sources as much as possible (Participant 108).
- I just like the weird news, um, and, like, every now and then I'll read a ticker running across a TV show but, I try to...it's depressing most of the time, so I don't like to look at it (Participant 7761).

Half of the students in the high HEB exposure group talked about their interactions with news media. None of them spoke of an aversion to the news or to learning about current events, but Participant 7218, the male pre-med student who wrote-in two M.A.T.E. responses on his pre-interview questionnaire saying, "Religiously, I disagree, but I accept [evolution and human evolution] scientifically," indicated:

- I am a little [conscientious about issues in the news], I mean, like, there was a plane crash at an airport that killed 19 people including children, but I don't go actively searching for information about global issues, much less national or state (Participant 7218).

Participant 2436, an Ecology and Evolutionary Biology major with high HEB exposure, was very interested in science news and current events and said,

- I have a couple subscriptions to magazines, National Geographic and Scientific American. I check out NPR every morning just for headline news and then, I don't know, I'll read a newspaper if I have time.

Overall, the students in the high HEB exposure group were more likely to say that they deliberately sought out news than the participants with no HEB exposure.

Religion factor and evolution acceptance were not associated with one behavior or the other. The two students in the no HEB exposure group who were stressed by and avoided news media differed in their religion factor, but both of them had high evolution acceptance overall. The group of students who purposefully sought out news of current events and regularly watched CNN or read a newspaper in print or online included individuals of both genders and all acceptance levels and religion factors.

The following hypothesis was generated from these data:

- Students with high HEB exposure are more likely to seek out information about current events via news media outlets including television, print journalism and online news, than are students with no HEB exposure and will therefore be more aware of socioscientific issues and events.

To test this hypothesis, the following questions were included in the survey:

- Would you say you follow what is going on in government and public affairs?
  - Most of the time
  - Some of the time
  - Only now and then
  - Hardly at all
  - I don't know
- Are you aware of last year's major oil leak in the Gulf of Mexico?
  - Yes
  - No
- Do you regularly read the newspaper, check news websites, and/or listen to the news on the radio?
  - Yes, regularly
  - No, not regularly
  - I don't know
- Do you regularly watch television programs or channels about science (e.g., NOVA or Discovery Channel)?
  - Yes, regularly
  - No, not regularly
  - I don't know
- Do you regularly visit science web sites and blogs (e.g., the National Geographic web site or ScienceDaily.com)?
  - Yes, regularly

- No, not regularly
- I don't know

- Do you regularly read science magazines (e.g., Scientific American or Popular Science)?
  - Yes, regularly
  - No, not regularly
  - I don't know

Voting. Of the nine students in the no HEB exposure group who were asked about their voting behaviors, seven of them said they voted in the 2008 Presidential election and two of them said they did not vote even though they could have voted. A few of the participants talked about the issues that were important to them when considering a Presidential nominee; these included the economy, health, education, and the candidate's "competency," intentions and open-mindedness. One student in the no HEB exposure group – the female Ecology and Evolutionary Biology major (quoted previously) – said,

- I think yes, definitely, learning science [is related to how I vote], but being just a well-rounded person with a knowledge of a lot of different issues kind of, for me, decides who I vote for. But, yeah, when you get, like, in-depth with science and things like stem cell research – hot topic issues like that – that can definitely decide who you vote for along the lines of science (Participant 108).

Five students in the high HEB exposure group reported that they voted or tried to vote in the 2008 election (one student had "paperwork issues"). Participant 6006, an Anthropology major, specifically stated that her choice of candidate was not dependent on her science education and that she simply wanted to pick the best candidate for the job. Participant 7096, a Secondary Education and Biological Sciences dual-major, said that she probably made voting decisions “separate from” biology and evolution, and instead made them based on how she was raised by her parents, but then she said,

- Some of [how I vote] has to do with [science]. Some parts are different from my parents, whereas biology taught me a lot about global warming. I'm a strong believer in global warming, whereas my parents don't.

Though the data on voting behaviors were limited—and there were similarities across HEB exposure groups regarding the role of science literacy in decision-making—one theme that stood out was, among students who could vote, students in the high HEB exposure group were more likely to vote than students in the no HEB exposure group.

Voting behavior did not vary with acceptance or religion factor. The two students in the no HEB exposure group who could have voted in 2008, but did not, differed in both factors: Participant 7201 had a low religion factor and high acceptance and Participant 483 had a high religion factor and was undecided about general evolution and rejected human evolution. Both of the students quoted above – Participants 108 and 7096 – had high religion factors, but they differed in their levels of evolution acceptance.

The interview data generated the following hypothesis:

- Among individuals who are eligible to vote in the United States, individuals with high HEB exposure are more likely to vote than individuals with no HEB exposure.

To test this hypothesis, the online survey included the following question:

- Are you now, or have you ever been, registered to vote?
    - Yes
    - I can register, but I haven’t
    - I cannot legally register to vote in the U.S.
    - I don’t know

If a student responded with “yes,” he or she was asked:

- Did you vote in the 2008 United States presidential election?
    - Yes
    - No, though I could have voted
    - No, I was too young to vote at the time
    - Other ______________________

Environment. The majority of the time spent talking about socioscientific issues during the interviews was focused on environmental issues and human skin color diversity (“race”). One hundred twenty two references were coded to the environment node. Within the scope of environmental issues were students’ recycling behaviors, their concerns about climate change, the preservation and conservation of forests and of endangered species, and, in general, students’ opinions about stewardship (humans’ place in nature and responsibility toward protecting the natural world). Some of these discussions focused on humans’ roles and responsibilities and if those differ depending on whether humans are a product of divine creation or of biological evolution. As mentioned earlier, some students discussed other socioscientific issues about which the moderator did not specifically inquire, such as vegetarianism, energy use, and pollution.

The students with no HEB exposure group expressed a variety of views on humans’ place in nature and responsibility toward the planet, but, overall, the students favored stewardship behaviors and felt that efforts should be made to maintain or improve the Earth’s environmental conditions. A majority of the students in the no HEB exposure group thought that humans were separate from other living organisms and/or that the natural world was specifically designed for humans’ benefit. Among this group, most said that humans had a responsibility to care for the Earth and, for example, “not abuse what we have” and to “respect our surroundings” (Participant 1123). Some also said things such as “I don’t know if I would go so far as to call myself an environmentalist” (Participant 108) or “I’m not, like, a big advocate for [the environment]” (Participant 4261).

Participant 4261, a female Biological Sciences major with no HEB exposure who thought the world was “designed for humans,” said:

- I think humans can help, I don’t think it’s entirely up to them [to fix environmental problems]. Um, ‘cause, I don’t think it’s entirely, um, humans’ fault. It might just be, like, evolution or be how, like, the Earth is supposed to progress or some people don’t do it intentionally...so I don’t think it’s entirely up to the humans to fix everything. I think if you can respect [nature], it’s fine. I think if you are just immature or disrespectful towards the environment and the animals, then I don’t think it’s right.

Participant 1123, a female Chemical Engineering major, said:

- I think that humans are the purpose of the world. I think everything else is here to aid us, somewhat, but I don’t think that means we should abuse what we have. I think we should take care of the Earth and we should, um, like, respect our surroundings, like, animals and other things, but, like, just because we’re superior doesn’t mean that we should, I don’t know...I think we should still respect other things and take care of them.

Some of the students in the no HEB exposure group were less sure about humans’ place in nature and our contributions to environmental conditions. Participant 365, a post-baccalaureate student studying biochemistry who had a moderate religion factor and high general and human evolution acceptance said,

- When [my professor] brings up, you know, ecology and everything, I think it's fascinating, humans' roles in it, because I think we're really changing, um, I mean, we're manifesting our own...are manipulating everything to make our own resources, and our own environment and ecology. I think...and I do kind of wonder the fact of it. I don't know enough to really put any conclusion on it, but I do think it's an interesting factor.

When asked if humans have a responsibility to protect endangered species from extinction, she said,

- Yes and no. I mean, it would be nice to allow, you know, all the species to be what they are, but then, I think at the same time, um, you know, it is what it is, you know? I think it's just, uh, kind of a result of um, our own evolved nature. So I'm kind of, actually, I really am a little bit torn on that (Participant 365).

Participant 483, a female student studying Family and Human Development and Sociology with a high religion factor who was undecided about general evolution and rejected human evolution, included a bit more science when articulating her views. She was one of the students in the no HEB exposure group who did not vote in the 2008 Presidential election though she could have voted. She expressed concern about pollution and talked about the importance of carpooling and turning off lights to save money and conserve energy, but was unsure about global warming:

- But global warming I don't know much about. But I know there's lots of people trying to make it known, but then again, they're doing everything against what they're saying...but then they gather trying to promote it all they can. So, it's a difficult thing to think about. So, are they saying that, like, um, the global warming really won't have an effect on...? I don't know. Global warming I'm not too...I don't really know much about it, actually, like, what actually causes it and what can be done, really? Is it just energy? I really don't know.

Other students in the no HEB exposure group articulated that humans do contribute to environmental conditions and can take action to address issues of concern. Participant 502, a female student dual-majoring in Mathematics and Biology, who had no religion factor and high general and human evolution acceptance said,

- Well, like, we kind of have to, like, fix the problems that we've created. Like, species are endangered because we've endangered them and global warming is probably from us. But, you know, like...I guess we have to work to fix those problems since we've created them.

Participant 108, the female Ecology and Evolutionary biology major (quoted previously) with a high religion factor and high acceptance of general and human evolution said,

- I recycle, I do buy things that are environmentally friendly and I try to cut back on waste and stuff. And I definitely believe in cutting back waste in industry and stuff like that, but I don't know if I would go so far as to call myself an environmentalist. Definitely [learning about evolution has changed the way I view global issues]. I try to look at everything as on the same playing field and we're no better than, you know, any other thing, so to cut down forests and build highways where, you know, like, fields of wildflowers once were, isn't really our natural right to be able to do that...I want the future generations to see all the beauty this planet has, so I don't want to destroy it...

Three students in the no HEB exposure group considered whether stewardship is a particularly faith-based concept or whether it is more rooted in science. Participant 3066, a female Communications major who accepted general evolution (she did not share her views on human evolution), but also believed in divine creation said,

- I definitely think that we should take care of the planet if we want it to be here for, like, future generations, so it's a good thing to, like, pay attention to stuff.

And when asked about the basis for her opinions she said,

- I don't know, I guess just hearing stuff on the news especially, um, eh, I guess with my faith, I mean, you want to take care of all living things. That's what I've been brought up to do... I would say faith, but also science, too, just because, like, seeing on TV, um, scientists have, like, seen, like, how global warming is kind of taking...taking...coming and stuff, I guess. A little of both, I guess, but you just want to take care of it... (Participant 3066).

Participant 974, a male Finance major with a low religion factor who accepted general and human evolution was in the same focus group as Participant 3066. He said,

- I think it's just the human nature in us or, I don't think it's even science, I just think it's...we all care about others and we all [in the focus group] mentioned that we want to, you know, help each other. I think that that might just be an idea that's been fostered from our parents or just being brought up in this society. It's not an individualistic society, I think we all, for whatever reasons, care about others. I don't think it's religious or scientific to be honest with you (Participant 974).

Participant 7677, a female Biology and Psychology dual-major with a high religion factor who was undecided about evolution and human evolution thought,

- I think we were put here along with everything else to work in harmony, it's like a full circle, but since we think that we're all about the circle, then we kind of take it that we can use animals or plants to whatever we want them to be, but I don't think it works that way. I think you have to work with them, not on them. [This perspective is] just something I developed along the way, all from different perspectives from different people.

Overall, the statements made by students with no HEB exposure did not demonstrate a sophisticated knowledge of scientific evidence regarding environmental issues and generally were not based on scientific reasoning. In contrast, the participants in the high HEB exposure group had much stronger opinions and were more confident about their views on humans' place in nature and stewardship than were the students in the no HEB exposure group and/or they were more likely to weigh scientific evidence as part of their decision-making process. They were also more likely to weigh potential future consequences of human action or inaction.

Participant 4506, a female English Literature major who completed ASM 104, the introduction to biological anthropology course at ASU, shared her views on why she made the choice to become a vegetarian:

- My Mom doesn't get it. My little funny bit is that I'm doing it so there will be less production of meat so there will be fewer cows, so they'll stop emitting carbon dioxide and then I'm saving the planet because I'm reducing greenhouse gases.

When asked if she would have made this decision had she not taken biological science courses at ASU, she said,

- Probably not. You also learn about the enzymes it takes to, like, break down...you learn a lot more about what actually happens in your body... Anyway, I think it's just like, I think taking those classes and learning about it just slowly made me that kind of person. And the more I take, the more I'm like, "Yeah, I'm right. I'm glad I'm doing it this way" (Participant 4506).

Later in the interview she added,

- I feel strongly about environmental things. I recycle. I try not to use plastic. Being vegetarian...I try to clean up. I try to do something (Participant 4506).

Participant 2206, a Biological Sciences major with high HEB exposure and a high religion factor and high acceptance of evolution and human evolution assessed humans' place in nature in biological terms:

- We're just another piece in the puzzle, like part of the food chain, as well, so, even if we don't have...I think we have population limits, essentially, so we're not really helping our niche, I suppose, like we're consuming faster than we can do our part to, like, give back to the rest of it, you know, so, like, global warming stuff, or, like, er, you know, not using very green things, so... Yeah, I think [stewardship] is important because if we destroy our environment, there there's not going to be anything to give back to us, essentially.

Participant 2439, a Biological Sciences and French dual-major, and Participant 4272, a Biochemistry major, who both had low religion factors and high acceptance of general and human evolution, shared the sentiment of Participant 2206:

- I think my views are probably slightly more toward scientific, but I think more out of necessity that, like, it's just clear that regardless of what your religion or beliefs are, that if we continue on the path that we're at that it's not gonna end well for us. If we wanna stay around, yeah, we gotta change (Participant 2439).
- I believe just as humans – as they developed – since we can think, like, our purpose should be to help out more with the planet, try to make it better for our future, so hopefully we can have this planet last longer by not destroying it as quickly as supposedly some scientists say we are now (Participant 4272).

Participants 206 and 362, both in the high HEB exposure group, identified specific environmental issues about which they were concerned and that they thought humans should address. Participant 206, a Biochemistry major with a low religion factor who believed in divine creation but accepted general and human evolution said,

- Yeah, we do [have an obligation toward the planet]. I'm all for that. Like, my phone, it's made from all recycled material and I just got it. Like, I'm vegetarian, I eat, um, locally grown things and it's like, I feel like if everybody did something for their planet, then it could last a little bit longer. Because you know...they say that a person lives and uses the resources of this Earth about five times what the Earth can handle...And, it's like, you know, if you can do something to, you know, preserve a tree or preserve something for someone in the future... And there's a lot of health problems, too, because of the pollution and I have asthma because of that...if everybody did what they could, then, or tried to do some things for this Earth, then I think...that everybody would live healthier and it would last longer and there would be something there for the future generations.

Participant 362, an Animal Physiology and Behavior major with a low religion factor who was undecided about, but leaning toward scientific explanations for general and human evolution said,

- Well, from a lot of what I've read and, like, heard, we are a lot of the cause of why all of this is happening, you know, like cutting down rainforests, you know, for industrial purposes, um, in Africa they are, like, killing off species, well, in particular the elephants, just to name some stuff, so, I think we definitely have an obligation to try to correct what we've done, but maybe it's too late, that's what a lot of people are saying. I think that if you, the thing is, I don't, ok...if you just start trying, then maybe you'll make progress – maybe you'll get further than if you just continue...the ways they are now with cars that emit methane, you know, different gases into the atmosphere. So, it's worth it to try to save what we can of the Earth. We're not the only organisms here – it's not just us, there's so many different forms of life – so with that comes, you know, you have to be respectful of them, too.

Two other students in the high HEB exposure group had opinions that closely reflected those of some students in the no HEB exposure group, but when articulating their views, the students with high HEB exposure relied more on scientific evidence. The first was Participant 7218 (quoted previously) who indicated on his questionnaire, "Religiously, I disagree, but I accept [evolution and human evolution] scientifically." With regard to stewardship he said,

- I recycle, but I mean, I took Physical Geography as a freshman [at ASU] and my professor was very anti-human involvement in global climate change. He felt there wasn't enough evidence to support that. [He said] that, um, solar flares or anything else can cause it. I'd read some studies that refuted him, but he could argue against it. It was just interesting to have that opinion since most people generally don't go that route.

When asked about humans' place in nature and responsibility toward protecting other species, he said,

- I view [humans] separate [from other living organisms], a little bit separate, but yet, part of the biosphere. What we do affects it...we have to protect it, but also, the same point, I believe that God created the world for us, so we can use it. I think we should protect [endangered species] to a point; I mean, I don't agree that we should set apart 10,000 square miles of rain forest just for 10 bullfrogs that are endangered. I think there has to be some benefit to us, but at the same time, it's a creation, it's a life, whether or not it's the same quality – the same worth – as a human life, we have some responsibility to care for it (Participant 7218).

Participant 2436 (quoted previously), an Ecology and Evolutionary Biology major with a high religion factor who believed in divine creation and accepted general evolution, but was undecided and leaning toward scientific explanations for human evolution, shared some of the same views as Participant 7218 about endangered species. He also considered the scientific information to which he was previously exposed when expressing his views. Regarding recycling and humans' role in the environment, he said,

- As far as something like recycling goes, I actually used to live really close to a recycling plant and I've seen the waste those things put out. But, at the same time, I guess I'm more interested in learning about what I wasn't told initially. When you're told about recycling, you're told, "Ok, this is the way to go," you're told about electric cars and all those things and, you know, biofuels and ethanol. But I am more interested in getting an objective look at each of these solutions and figuring out what really is the best. I don't know...it's a good idea to try and – as far as we know how things were before people were around – leave it as it was so when we're not here, it won't be too screwed up... So, yeah, as far as saving endangered species, that's a little more tricky. I mean, so like, keeping waste out of our oceans and out of our...trying to prevent waste as much as possible is pretty important...but saving endangered species, I don't know, that's a little more tricky, just because things are - especially if you accept evolution as fact, right – it's difficult to determine how people are, how much people affect, whether species are dying off or not. I wouldn't say I think [other species are] here to benefit people as much as the fact that they are there and, as humans, we have the ability to take advantage of them or to do as we see fit most of the time (Participant 2436).

When asked about the foundation for his views, he said,

- I think it's a combination [of spiritual belief and scientific knowledge], but probably more scientific. [Regarding preventing species extinction, for

> example], there's got to be a point. And I'm not saying that it's just from a human standpoint that there's a point to it, but a point to the system as a whole. So…you have to establish that scientifically and I don't know if you can – but that's how you would go about doing that is scientifically (Participant 2436).

To summarize, the students in the high HEB exposure group were more likely to consider or weigh scientific evidence when expressing their views on stewardship and humans' place in nature. They used terms such as "enzymes," "food chain," "niche," "methane," and "biofuels," to describe the issues, whereas the students in the no HEB exposure group used terms such as "surroundings," "things," "nature," "waste," "beauty," and "stuff." The high HEB exposure group was also more likely to think about the future of the planet and the consequences of human action or inaction. Additionally, they were more assured in their views about biodiversity and habitat conservation and the scientific evidence behind the need for stewardship.

A theme emerged among the 17 participants quoted above; students in the no HEB exposure group who shared their views on environmental issues primarily had moderate to high religion factors and those in the high HEB exposure group who contributed their opinions primarily had low to moderate religion factors. The two students in the high HEB exposure group with high religion factors were both unsure about humans' responsibility toward endangered species and their opinions were generally more similar to those of the students in the no HEB exposure group. The two students in the no HEB exposure group with no religion factor and a low religion factor were more confident than their peers with no HEB exposure that humans must be pro-active in preserving and conserving the environment. It seems as though religion factor influences students' decision-making about environment-related socioscientific issues, but HEB exposure is related to students' science literacy and also contributes to their decision-making processes.

Based on these data, three hypotheses were generated:

- When holding religion factor constant, students with high HEB exposure are more likely than other students to think that human behaviors contribute to global climate change.
- When holding religion factor constant, students with high HEB exposure are more likely than other students to identify, favor and engage in specific activities that, based on sound scientific evidence, minimize humans' contribution to global climate change.
- When holding religion factor constant, students with high HEB exposure are more likely than other students to favor human efforts to conserve biodiversity and natural spaces, such as rain forests.

To test these hypotheses, the following questions were included in the online survey:

- Which comes closer to your personal view?
  - The earth is getting warmer mostly because of natural changes in the atmosphere.
  - The earth is getting warmer mostly because of human activity such as burning fossil fuels.
  - The earth is not getting warmer.
  - I don't know.
- Indicate the degree to which you think global warming is a problem.
  - A very serious problem.
  - A somewhat serious problem.
  - Not too serious of a problem
  - Not a problem
  - I don't know

- How likely are you to make a special effort to do each of the following actions? (The response options were *extremely likely*, *very likely*, *moderately likely*, *somewhat likely*, and *not at all likely*.)
    - Reuse water bottles
    - Carpool or take public transportation
    - Buy recycled paper products
    - Bring your own shopping bags to stores
    - Adjust thermostats by two degrees
    - Wash laundry in cold water
    - Recycle bottles and cans

Among a series of questions related to human evolution and humans' relationship to other great apes, the following question was included:

- It is important to preserve the forests where chimpanzees, gorillas and orangutans live.
    - Completely agree
    - Mostly agree
    - Mostly disagree
    - Completely disagree
    - I don't know/Neutral

Diversity. The interviewed students were asked a number of questions related to human diversity, specifically about variation in human skin color and racism. One hundred forty nine references were coded to the diversity node in NVivo. As was the case for the students' responses about environmental issues, there was some variation in the students' views and experiences, within HEB exposure groups. Students talked about their experiences with racism, revealed whether anyone in their families behaved in a racist manner or had racist opinions, and many of them provided an explanation, to the best of their abilities, for modern human skin color diversity. The students who tried to give an explanation commonly related differences in skin color to some form of geographic, climatological or genetic difference, but their levels of understanding of the evolutionary mechanisms involved in the generation of diversity varied. In addition, some students gave faith-based explanations or a combination of faith and science-based explanations.

The students in the no HEB exposure group had no formal education in the science of human skin color variation, nor did one of the students in the high HEB exposure group. None of the participants expressed a viewpoint that could be considered racist in nature; however two students identified some of their own thought processes and behaviors as a form of stereotyping. About one-third of all of the students who discussed the topic of human diversity in their interviews said they had been the target of racism or had a family member (typically a member of an older generation) who occasionally behaved in a racist manner or expressed racist opinions. For some, this personal experience with racism was the primary motivating factor for them to accept or embrace peoples of skin colors, ethnicities or cultures different than their own and to reject racist agendas. Other students said that they were taught in school that humans are all equal and thus should treat others as such. Only a few participants said that it made sense to treat people equally based on what they knew about evolution.

There were obvious contrasts between the no HEB exposure and high HEB exposure groups in the explanations they gave for human skin color diversity and their knowledge structures regarding evolution of human populations generally. There were also some differences between the moderate HEB exposure group and the high HEB exposure group. Most of the students in the high HEB exposure group tended to explain aspects of human diversity using specific scientific concepts for which they demonstrated a basic to moderate level of understanding; for example, the biological species concept, the relationship between skin pigmentation and UV radiation, and the idea that traits develop over time. The students in the no HEB exposure group struggled to explain differences in human skin color in scientific terms and/or provided faith-based explanations. Participant 7218, the student in the high HEB exposure group who wrote-in his responses to two M.A.T.E. questions saying he accepted evolution scientifically but not religiously, also provided faith and science-based explanations for skin color diversity.

Students in the high HEB exposure group used terms such as “traits,” “equator,” “migration,” “pigment,” “melanin,” and “wavelengths (of light),” that the students with no HEB exposure did not. Some of the students in the no HEB exposure group were able to make a connection between what they knew about non-human animal adaptations and apply those concepts to humans, although they lacked confidence in their answers. The differences between HEB exposure groups in the students’ use of scientific terminology, the weighing of scientific evidence, and the articulation of scientific explanations, were similar to the differences identified earlier regarding environmental issues.

Students who were less confident than their peers about the scientific reasons for human skin color diversity tended to express curiosity about the science and even stated that they wished they could learn more about it for a particular reason, regardless of their HEB exposure. For example, Participant 974, who was in the no HEB exposure group, was a male, Caucasian Finance major with a low religion factor and high general and human evolution acceptance who did not take any biological science classes in high school and had never learned about the science of human skin color diversity. He said,

- It would have been nice for elementary school [to understand the reasons for human diversity]. I lived on, like, a reservation area and so it was just

Indians versus white boys all the time and I was kind of like, oh my gosh, I was kind of like stuck in the middle ‘cause I liked playing basketball (Participant 974).

A few other students in the no HEB exposure group said that they would like to know more about the science of human skin color diversity. Two of them provided faith-based explanations for diversity. Participant 7761 (quoted previously), a Microbiology major with a low religion factor and very high acceptance of general and human evolution who had one year of high school biology, said he learned why humans have different skin colors “really early in church” and what they told him was the story of the scattering of peoples from the Tower of Babel. He said he would like to have formal science education regarding skin color diversity and specified that he would like to have that knowledge so he could say to his relatives who he categorized as racist, “You’re no different” and “Haha, you think this for no reason” (Participant 7761).

Participant 483 (quoted twice previously), a Family and Human Development and Sociology dual-major with a high religion factor who was undecided about general evolution and rejected human evolution and completed two years of biological science in high school said,

- Yeah, um, that’s like really hard to answer [why there is human diversity]. I think it’s...in an evolutionary kind of aspect they would say, “Oh, you’re in this area, your skin’s darker because of the sun or whatever.” I don’t know. That’s really interesting to think about because...hmmm...like, I don’t know if it’s actually...I don’t know. I think that they’ve basically, because...well, my personal opinion is, like, a religious kind of view, um, I think that God created different types of ethnicities and whatnot. That way people could learn to accept other things about themselves. I don't know, I think he made everyone the same, just maybe different colors and different physical attributes and that kind of thing...I don't know exact reasons.

When asked if she would like to learn more about the scientific evidence for human skin color diversity and why people should learn about the topic, she responded,

- Yeah, definitely. I think if people would learn that, you know, no one is this perfect person and there is other variations, you know, tall people, short people, I think it would help in their understanding that not everyone is the same or should be the same. That way they aren't sort of discriminatory against people with different characteristics and whatnot (Participant 483).

Here, this student is appropriately equating skin color to another continuous biological trait – height. She also uses the term "evolutionary," though not in a strictly scientific manner and vaguely alludes to the scientists who study evolutionary biology as "they." She does not provide a scientific explanation for diversity, however, and relies on a theistic explanation. Similarly, Participant 1123 (quoted twice previously), a Chemical Engineering major with a high religion factor who believed in divine creation but accepted general evolution and rejected human evolution and took one year of high school biology said,

- See, like, I do understand, like, the view, like, that does make sense that due to evolution your skin color changed, but, then I also, um, believe my religious views that, like, um – that the wicked people – God turned their skin darker color to be able to tell the difference between, like, the righteous people and the wicked people, so, like, I don't know, because I do believe...I believe both? I don't know how that really works, but...I don't think I'm really biased in any way because I realize it was a long time ago, they're not the same people, just because, like, I don't think I really, like, am biased in any way.

A number of the students with no HEB exposure provided thoughtful responses that incorporated biological concepts into their explanations, even though their understanding of those concepts may have been limited. Some of them also transferred their existing knowledge of adaptation in non-human animals to the issue of human diversity, though with some misconceptions or Lamarckian perspectives. For example, Participant 7513 was a Computer Systems Engineering major with a moderate religion factor and the highest possible general evolution and human evolution acceptance who had no HEB exposure and completed one year of biological science in high school. He was not able to provide an accurate scientific explanation for human skin color diversity, but he incorporated some aspects of human evolutionary biology knowledge – the genetic similarity of humans to chimpanzees - into his response when asked about human diversity (though this may have been influenced by discussions earlier in the interview):

- It's weird to think about [human diversity], though, I mean, for me, because we...racism is seen as such a bad thing these days – and I'm not saying it's not – it's just, you know, you realize you have so much genetic material in common with a chimp and you're so little like a chimp you wonder how, for example, people in different places in the world have different skin colors. But we know how evolution happens, you know, at a decent rate…you wonder what other differences you have, you know, like if me and some guy from Africa were compared, I don't know, like, in every category, I wonder if we think differently because of the way that, essentially, our ancestors have grown up in different environments or essentially lived in different places for so long. So, yeah, the diversity makes me wonder if we're not more diverse in areas we don't even know about because we're not always measuring them all the time.

This student's answer, though thoughtful, lacks scientific rigor; for example, he uses "grown up" instead of "evolved" or "adapted" and does not use "genes" or "traits," but instead uses "category," when speaking about differences between two humans.

Participant 7201 did not have a solid grasp of evolutionary concepts as evidenced by a number of statements in his interview, but succeeded in identifying a relationship between human diversity and geographic and environmental conditions. He was a home-schooled student majoring in Applied Computing who had a low religion factor and high general and human evolution acceptance. Regarding human skin color diversity he said,

- It depends on, uh, it was evolution and it obviously was, this person was developing in this part of the world, so obviously their eyes closed more because the sun was brighter, or their skin darkened because the sun was hotter and it was just human evolution immediately changed your surroundings and the environment or whatever was happening around you (Participant 7201).

This student's thoughts on human diversity are Lamarckian in nature, rely on the plasticity of human features that have a genetic basis, and demonstrate a general lack of understanding of evolutionary mechanisms.

One student seemed uncomfortable applying her knowledge of evolutionary biology to the concept of human skin color diversity. Participant 108 (quoted thrice previously), an Ecology and Evolutionary Biology major with no HEB exposure, who had a high religion factor and high acceptance of both general and human evolution and completed two years of high school biological science, spoke about genetics when discussing human variation, but did so in the context of human disease and appeared uncomfortable talking about human variation and skin color:

- Oh yeah, definitely [learning about evolution has changed the way I view diversity or global issues]. Especially along the lines of, like, genetics and things like sickle cell anemia and how people are more prone to getting certain, like, diseases than others. Like, genetics-wise, yeah, like evolution plays a big part in how genetic diseases affect people. I don't know about race and skin color too much. I don't know. I feel like there's a really fine line there that has to do with race that I don't really hang around it too much.

When asked if learning about biology and general evolution in high school and at ASU had affected her opinion about the differences between groups of humans globally, she said,

- I guess I really don't know. I guess I've probably always just kept the same opinion (Participant 108).

Either this student was unable to apply what she had learned and what she knew about the link between genetics and disease to human skin color, or her discomfort with the topic of "race" prevented her from articulating that she had made that connection. Therefore, it was not clear to what degree she understood the scientific explanations for human skin color diversity.

When explaining human diversity, a few students in the no HEB exposure group did use terms such as "adapt" or "adaptation," but were unsure about whether their answers were correct or said they have never thought about the issue previously and were only "assuming" that their explanations were truly how human skin color diversified. One student in the no HEB exposure explained that diversity is due to "genetic mutations over time:"

- I've never really questioned [the reason for human skin color diversity] because, like, people are different, personalities are different, eyes are different. It doesn't matter to me, it's just genetic mutations over time. Um, but I never really thought about it, never was taught about it or anything (Participant 1692).

This student was a Film major with high general and human evolution acceptance, but with M.A.T.E. scores of only 28/35 and 4/5, respectively. She had a low religion factor and took one year of high school biology. It should be noted that there were 12 uses of the word "genetic" during her interview prior to her making this statement, including three instances in the three minutes prior to the statement.

Four students in the moderate HEB exposure group talked about human skin color diversity. They were not as confident in their explanations as the students in the high HEB exposure group, but their use of scientific terminology was more frequent and technical than that of the no HEB exposure group. Participant 922 was a Journalism major who had to repeat her high school biology class. She had a low religion factor and accepted evolution generally, but believed in a supernatural being and was undecided, leaning toward religious explanations, regarding human evolution. She described her “mixed” family as “not at all racist” and explained that she had been the target of racism on occasion (Participant 922). She said about modern human skin color diversity:

- I don’t know if you ever heard about this, but it’s different [from what I think the other participant said]. I was taught sometimes, like, in high school that everything originated in Africa and everyone was dark and then, when they migrated north, that’s when the noses got smaller and that’s when the pigment got lighter, so it’s not the opposite way around that everyone got darker, it’s like everyone got lighter, so that’s what I was taught and I never really heard...like, I hear, like, a lot of [explanations.] I don’t know which one is true, but that’s what I always...that’s what I was raised [to think] (Participant 922).

Most everything that this student said about human evolution, migrations, and changes in skin color was accurate, but she was clearly lacking confidence when explaining what she had learned in high school. Participant 8406 also lacked some confidence in his explanation:

- From what I've learned and from the way...from what I've also done in my genetic engineering courses, things just look the way, under, you know... when exposed to different stimuli. And this is only from what I've learned in genetics, but it makes sense after doing it in genetic engineering...but, they say that, um, you know, black people are black because the

> wavelengths or whatever of the sun, were so high in energy and would, you know...basically, they could burn after long periods of time in that area...that eventually, over time, they started getting darker and darker pigments of skin... It's an extremely small difference that is stimulated, as far as they know – you know? – and from small experiments on, like, phenotypic variations, that it's just from the small stimuli. I've come to believe that different stimuli...and Asian people, they say, like, a lot of the brightness of the sun – you know? – didn't need, like, the eyeballs to be as dilated, or as open, so, you know, the whole squinty kind of look comes in. And, yeah, I think that that's the biggest reason why people are different. And just showing that it's on the outside (Participant 8406).

This student was a Molecular Biosciences and Biotechnology major who was taught biology in middle school and completed one year of high school biology. He accepted general and human evolution, but also believed in a divine, supernatural being. His explanation comprises some misconceptions, but he draws a connection between genes and phenotype and integrates appropriate use of technical biological terms such as “wavelength” and “pigments.”

The students in the high HEB exposure group provided the most accurate explanations for human skin color diversity and did so with the most confidence, even when they admitted that their explanation was just their “opinion” and did not know for certain if what they were saying was true. Some of the explanations did include misconceptions, though most of the students suggested diversity was a result of some combination of genetics, pigmentation, and geographic or climatological conditions. Two students referred to what they were taught in the introductory biological anthropology course at ASU and a few students referred to what they learned in school. A couple of the students made the observation that there are larger cultural differences between some ethnic groups than there are physical differences. Multiple students in the high HEB exposure group said the topic was very interesting to them.

Participant 2206 (quoted previously) was a Biological Sciences major in the high HEB exposure group who completed honors high school biology, AP Biology (he earned a 4 out of 5 on the AP Biology exam) and high school Anatomy and Physiology. He had a moderate religion factor and high acceptance of general and human evolution. He said,

- All through school I was just taught that everyone's equal, so skin color, you know, religion, anything, doesn't change anything... I think [human skin color diversity] is the result of evolution, like, depending on, like, where you are, like, it makes sense for people around the equator, like in Africa, to have darker skin because they have more melanin – or is it melatonin? – in their skin [that] just helps like, um, ward off...like, you don't get burned as easily, they can just stay in the sun. But, people in, like, northern, like stuff... they don't. They...it's just not very sunny ever, so fair skin just works for them. It's fine, so... (Participant 2206).

This student does an excellent job of recognizing that humans living closer to the equator have more darkly pigmented skin compared to humans living at northern latitudes and conveys a basic understanding of the concept of adaptation; however, he erroneously uses the phrase "ward off," implying that dark-skinned people are immune to the effects of UV radiation. He also seems to have a misconception that the sun does not shine as much in the northern latitudes and this allows for less skin pigmentation, as opposed to the more accurate conception that lighter skin tones are an adaptation to regions with less UV radiation.

Participant 206 (quoted previously) was a Biochemistry major in the high HEB exposure group who completed honors biology and AP Environmental Science in high school. She accepted general and human evolution, held traditional Buddhist beliefs, and questioned the existence of a supernatural being. No one in her family was described as racist or prejudice. She said,

- ...everyone [in my family is] really open to everything and, like, I think because we've all been exposed to evolution in some way, so, like, I feel like if schools don't teach that, then why are you holding it back?... [Human skin color diversity] is due to genetics. I just think it's raised by your genes and your cells that, you know, you're made of so...It's because we change – we keep changing – like, things split out – I mean peoples – these species split away from each other in different areas and stuff and according to, um, Darwin's theory, like, things change over time to survive and then features of the body change, so... (Participant 206).

This student clearly has a basic understanding of adaptation—that populations change over time in response to the environment and individuals' need to survive—and correctly correlates adaptation and changes in morphology. She expresses some possible misconceptions, though, by implying that genes are separate from cells and that different populations of people are different species.

One of the students in the high HEB exposure group, when asked about skin color diversity simply said, "genetic variability" (Participant 362; quoted previously) and another said "genetics and skin pigmentation" (Participant 4272; quoted previously). The former was an Animal Physiology and Behavior major who was undecided about, but leaning toward scientific explanations for, general and human evolution. The latter, a Biochemistry major, had high general and human evolution acceptance, but no formal education in the topic of skin color diversity. Both of these students completed IB Biology in high school and had low religion factors. Participant 4272 also completed a high school forensics class.

Based on these data, a theme emerged that the students with moderate to high HEB exposure have a superior knowledge structure regarding evolutionary concepts that allows them to better articulate scientific explanations for modern human skin color diversity than students with no HEB exposure. For some students in the moderate and high HEB exposure group, their ability to explain this evidence was directly related to information they were taught in school or in a university course. Students with high religion factors, in any HEB exposure group, were more likely to provided theistic explanations for the origins of modern human diversity, but the students in the high HEB exposure group with high religion factors also supported the scientific explanations for diversity. Acceptance did not determine whether students acknowledged and articulated scientific explanations for skin color diversity. The HEB exposure variable could not be associated with racist or prejudice attitudes, as none of the students in the study sample expressed views that could be characterized as racist or prejudice.

Based on these themes, the following hypotheses were generated:

- Students with high HEB exposure are more likely to have been exposed to the scientific evidence that explains modern human skin color diversity.
- Students with high HEB exposure have a better basic knowledge structure of evolutionary biology concepts than students with less HEB exposure.

- Students with high HEB exposure were more likely to state that human skin color diversity can be explained by science, rather than by faith-based explanations, and do so with more confidence, regardless of their religion factor.

To test the hypotheses, the following questions were included in the survey:

- Can you recall being taught about any of the following concepts or topics in your middle school or high school science classes or as part of your official home schooling in science? (Response options included *yes*, *no*, and *I don't know*.)
    - Explanations for variation in human skin color
- Can you recall being taught about any of the following concepts or topics in your middle school or high school non-science classes, such as a social studies/history class or a religious studies class, or as part of your official home schooling in non-science subject areas? (Response options included *yes*, *no*, and *I don't know*.)
    - Explanations for variation in human skin color

- Do you agree or disagree with the following statements? (Response options included *agree*, *disagree*, and *I don't know*.)
    - Children resemble their parents because the children inherited their parents' genetic material (DNA).
    - All DNA mutations are harmful.

- Please indicate your level of agreement with the following statements. (Response options included *completely agree, mostly agree, mostly disagree*, *completely disagree*, and *I don't know/neutral.*)
    - Differences in human skin color can be explained by science.
    - The scattering of peoples from the tower of Babel across the earth is the cause of modern races of humans.

Other socioscientific issues. As mentioned earlier, some of the students raised issues about which the moderator did not specifically inquire; these included human health, stem cell research, human sexuality, global hunger, animal testing and drug resistance. There were not enough interview data to generate hypotheses about these topics, but questions were included in the survey to test whether there is an association between students' decision-making about matters related to these topics and their HEB exposure, in the context of religion factor and acceptance of general and human evolution. These questions included:

- Please indicate your level of agreement with the following statements. (Response options included *completely agree, mostly agree, mostly disagree, completely disagree, I don't know/neutral*.)
    - Homosexuality is a way of life that should be accepted by society.
    - Same-sex couples should not be allowed to adopt children.
    - People who are openly gay or homosexual should be allowed to serve in the United States military.
    - It should be illegal for same sex couples to marry.
    - Scientists should not use chimpanzees for drug testing.
    - It is wrong for humans to poach (hunt) and eat monkeys and apes.
    - Immigrants to the U.S. today strengthen our country because of their hard work and talents.
    - Immigrants today are a burden on our country because they take our jobs, housing and health care.
- The technology now exists to clone or genetically alter animals. How much do you favor or oppose allowing the same thing to be done in humans?
    - Strongly favor
    - Somewhat favor
    - Somewhat oppose
    - Strongly oppose
    - I don't know/Neutral
- All in all, do you favor or oppose the following? (Response options included *favor, oppose, I don't know/neutral*.)
    - Federal funding for embryonic stem cell research.
    - Required vaccinations for all children.
- Do antibiotics kill viruses as well as bacteria?
    - Yes
    - No
    - I don't know
- Indicate the degree to which you think human overpopulation is a problem.
    - A very serious problem
    - A somewhat serious problem
    - Not too serious of a problem
    - Not a problem
    - I don't know
- Which comes closer to your personal view?
    - Birth control should be used to prevent unwanted pregnancies.
    - It is wrong to use birth control.
    - I don't know.

CHAPTER 6

PRESENTATION AND ANALYSIS OF QUANTITATIVE DATA

The goal of the quantitative analyses is to explore the survey data and test hypotheses about the relationships between human evolutionary biology exposure and American students' STEM enrollment, academic achievement, interest, and motivation, and their socioscientific decision-making. The data collection instrument was a survey distributed electronically to Arizona State University undergraduates enrolled in the Fall 2010 and Spring 2011 semesters. This chapter presents the response data, demographic data for the research sample, exploratory data, and the results of hypothesis testing. The presentation of results is organized to reflect that of the previous chapter, beginning with factors associated with STEM class enrollment and academic achievement, followed by an analysis of students' interest in STEM degree programs and motivation to pursue a STEM career, and concluding with an assessment of variables that correlate with and models that predict students' socioscientific decision-making.

Response data

Seven hundred forty two individuals started the online survey (i.e., responded to one or more questions). Among those who started the survey, some individuals' questionnaires automatically terminated because one of their responses alerted the software that they did not meet the inclusion criteria (e.g., age or enrollment status). A dropout analysis revealed the highest percentage of dropouts comprised those who did so at or immediately after the consent page and the second highest percentage did so at questions pertaining to the age of the earth and religion[1].

Average time to complete the survey was 20.5 minutes. QuestionPro reported that 570 of the individuals who started the survey completed it (a 76 % completion rate); however, six cases were dropped due to duplications in IP addresses that QuestionPro did not identify as duplicate attempts by the same individual. A review of the item responses for these cases, and the high rate of missing data for each, indicated that two individuals had each attempted to complete the survey three times, possibly with different email addresses each time. Another case was dropped because the respondent provided problematic responses to questions about his university major and desire for a STEM career by writing “none of your concern” in the open-ended “other” box.

Thirteen respondents’ cases were dropped because they graduated from high schools outside the United States and two students were dropped because they were home-schooled in high school. Sixty-two respondents graduated from non-public (charter, private, or magnet) high schools in the United States. Due to the low sample sizes for those groups, they were also dropped from the study. The final study sample comprised 486 Arizona State University undergraduate students between the ages of 18 and 22 (inclusive) who graduated from public high schools in the United States—a response rate of 65.5%.

Variables

Appendix G lists the variables for the quantitative analysis (“final variables”), and the label, values and measure for each. As explained in Chapter 3: Research Design and Methodology, some final variables are composite variables based on a set of single-question responses regarding a student’s knowledge, belief, acceptance, opinions or behavior. For example, the scores for the final variables *religion factor* (RELFACT) and *K-12 human evolutionary* *biology exposure* (HEBEXP) were generated in Excel using complex IF formulas. Religion factor was based on students' self-reported religion, their parents' religions, whether students attended religious services, and how often they attended religious services. HEBEXP was based on students' responses to questions about their K-12 academic exposure to scientific explanations for the origin of humans and variation in modern human skin color and whether they remembered learning about primates and the fossil hominin specimen Lucy. HEBEXP accounted for students' responses to questions about their science and non-science classes. For composite variables to be computed, students had to respond to all of the survey questions on which the final variables were based.

Other final variables were computed in SPSS based on sums or mean values of multiple single-question based variables and then those scores were recoded into categorical variables as needed; these included *human evolution acceptance* (HEACCEPT), *acceptance of humans' relationship to great apes* (APES4), *views on same-sex relationships* (SAMESEX), *pro-environmental behaviors* (ENVIRO), *engagement with science news and media* (SCIAWARE), *views on immigration* (IMMIG), and *basic science knowledge* (SCIKNOW; this variable ultimately was not included for reasons explained later in the chapter).

Before calculating scores for composite variables in SPSS, the single-question based variables thought to reflect a particular issue were subject to factor analysis and internal consistency reliability analysis and the total number of single-question based variables used to compute the composite scores was reduced as needed. For example, when assessing students' views on same-sex relationships, four variables (WAYLIFE, ADOPT, SERVE, MARRY) were subject to factor analysis (see Appendix B). Three of the variables (WAYLIFE, ADOPT, MARRY) contributed to one factor and the fourth variable (SERVE) represented a second factor. An internal consistency reliability analysis (Cronbach's alpha, standardized = .853) confirmed that WAYLIFE, ADOPT, and MARRY consistently measured the same outcome, thus a composite variable based on these three variables was used to assess students' support for same-sex relationships. A score was generated from the mean of the values of WAYLIFE, ADOPT, and MARRY and the score was used for the composite scale variable SAMESEX, which was then recoded into an ordinal final variable with the same label. Similar results were obtained when determining the final variables HEACCEPT, APES4, and ENVIRO, in that at least one single-question based variable was ultimately excluded from the score calculation due to the results of factor analysis or reliability analysis. In the case of the variable SCIKNOW, intended to reflect students' scientific knowledge, the results of the factor analysis and an extremely low Cronbach's alpha value indicated that none of four single-question based variables could be combined to create a composite score reflecting basic science knowledge; therefore, the variables were maintained separately.

Summary data for the study sample

Sex ratio. The ratio of females (n = 342) to males (n = 144) in the sample was 2.375 (Table 17). The ratio of females to males in the sample of students interviewed for the qualitative analysis was 1.933. In the 2010-2011 academic year, the ratio of females to males enrolled as degree-seeking undergraduates with part- or full-time status was 1.04; however this statistic comprises students from all ASU campuses and of all ages (ASU Common Data Set, 2011; 18.4% of these students were 25 or older). The ratio of females to males enrolled as undergraduates in the College of Liberal Arts and Sciences (CLAS), which better reflects the population from which the research participants were recruited, was 1.23 (ASU Enrollment Summary, 2010). The research sample therefore has a higher proportion of females than did the population from which the sample was derived. To account for this difference, bootstrapping of the sample data was employed when appropriate.

Age and class year. The study sample comprised more freshmen (n = 192) than students from other classes; seniors were least well represented (n = 58). Eighteen to 20-year-olds each represented 20-30% of the sample (Table 17). In 2010, enrollment of undergraduates in CLAS was 16.2% Freshmen, 20% Sophomores, 29.3% Juniors, and 33.1% Seniors (ASU Enrollment Summary); therefore, the study sample over-represents Freshmen and under-represents Seniors compared to the total CLAS population. Again, to account for this difference, bootstrapping of the sample data was employed when appropriate.

Table 17

*Self-reported Characteristics of Students Who Completed the Online Survey (*N *= 486)*

Characteristic	Category	Frequency	Percent
Biological sex	Female	342	70.4
	Male	144	29.6
Age (years)	18	111	22.8
	19	141	29.0
	20	102	21.0
	21	84	17.3
	22	48	9.9
Class year	Freshman	192	39.5
	Sophomore	101	20.8
	Junior	135	27.8
	Senior	58	11.9

State of high school graduation. The majority of students (73.5%) graduated from a public high school in Arizona; students who graduated in

California composed 6.6% of the sample, and students from Colorado and Illinois each composed approximately 2% of the sample. The remaining 26 states represented by the participants each composed less than 2% of the sample; 20 states were not represented.

Ethnicity. Approximately 62% of the participants identified as White or Caucasian, 11.3% of students were mixed ethnicities, with some Caucasian background, 8.6% were Mexican, Mexican American or Chicano, 3.5% identified as mixed ethnicity not including a Caucasian background and 2.5% identified as Black or African American. Students of other ethnicities each represented 2.1% or less of the total sample. Five students did not provide data regarding their ethnicity.

Academic aptitude and GPA. The categorical variable for *academic aptitude* (ACADAPT) is based on a student's SAT or ACT score (1 = lowest aptitude, 7 = highest aptitude); if a student took both achievement tests, then the test result that placed the student in a higher aptitude category was used, though the two test scores most often aligned to the same category. Students also reported their approximate *grade point average* (GPA) at ASU and this was converted to an ordinal variable, as well (1 = lowest GPA category, 6 = highest GPA category). Tables 18 and 19 summarize the data for ACADAPT and GPA for the study sample. The distribution for both variables resembled a normal distribution.

Undergraduate major and STEM career motivation. Just more than half of the students in the sample (52.7%) were majoring in or wanted to major in a STEM degree program at ASU. Forty-three percent of the students were not interested in a STEM major (45.3%) and a small percentage of the

Table 18

Academic aptitude (ACADAPT)

		Frequency	Valid Percent	Cumulative Percent
Academic aptitude	1=Lowest academic aptitude	16	3.5	3.5
	2	42	9.2	12.6
	3	74	16.1	28.8
	4	116	25.3	54.0
	5	127	27.7	81.7
	6	70	15.3	96.9
	7=Highest academic aptitude	14	3.1	100.0
Missing	-1	7		
	999	20		
Total		486	100.0	

Note. Scores are based on students' performance on the SAT or ACT. If students reported not taking either test, data are coded as -1. For valid cases, μ = 4.22 ± 1.4 (n = 459); a score of 4 represents a 1200-1299 on the SAT or a 26-28 on the ACT.

Table 19

Undergraduate grade point average (GPA)

	Score (GPA)	Frequency	Valid Percent	Cumulative Percent
GPA	1 (<2.0)	4	.9	.9
	2 (2.0-2.49)	26	5.6	6.5
	3 (2.5-2.99)	61	13.2	19.7
	4 (3.0-3.49)	156	33.8	53.6
	5 (3.5-3.99)	164	35.6	89.2
	6 (4.0)	50	10.8	100.0
	999 (I don't know)	25		
Total		486	100.0	

Note. Scores are based on students' self-reported grade point averages. For valid cases, μ score = 4.3 ± 1.1 (n=461); a score of 4 represents a GPA of 3.0-3.49.

students (2.1%) were still undecided. Similar results were obtained for STEM career motivation; 54.1% of participants desired a STEM career, 37% desired a non-STEM career, and 8.8% did not know what type of career they wanted. Table 20 summarizes these results, showing the percentage of students in each undergraduate major category who were or were not motivated to pursue a STEM career. There was a statistically significant relationship with a strong effect between *interest in a STEM degree* (STEMDEG) and *motivation to pursue a STEM career* (STEMCAR), χ^2 (1, N = 434) = 315.972, p < .001, r = .853.

Table 20

Students' declared or desired undergraduate major (STEMDEG) and motivation to pursue a STEM Career (STEMCAR)

		Career Motivation			
		STEM	Not STEM	I don't know	Total
Major	STEM	239	12	5	256
		93.4%	4.7%	2.0%	100.0%
	Not STEM	19	164	37	220
		8.6%	74.5%	16.8%	100.0%
	I don't know	5	4	1	10
		50.0%	40.0%	10.0%	100.0%
Total		263	180	43	486
		54.1%	37.0%	8.8%	100.0%

χ^2 (1, N = 434) = 315.972, p < .001, r = .853

Religion factor. The participants' *religion factor* (RELFACT) was scored as *none*, *low*, *moderate*, or *high* based on their responses to questions about their own religion, their parents' religion, and their attendance at religious services (Table 21). Five students did not answer all of the religion-related questions so they did not receive a RELFACT score. Approximately 36% of students had a high religion factor, 26.2% had a moderate religion factor and

30.6% had a low religion factor. Approximately 7% of students had no religion factor.

Table 21

Religion factor (RELFACT)

		Frequency	Valid Percent
Religion factor	None	32	6.7
	Low	147	30.6
	Moderate	126	26.2
	High	176	36.6
	Missing	5	
Total		486	100.0

General evolution and human evolution acceptance. *General evolution acceptance* (GENACCEP) is a categorical variable based on students' agreement with the statement, *Living things have evolved over time,* or the statement, *Living things have existed in their present form since they came into being.* Students also had the option to respond with "I don't know." The majority of students (83.1%) accepted that living things have evolved over time (Table 22). Among the students who accepted general evolution, 69.3% thought that living things have evolved due to natural processes, 21.5% thought that a supreme being guided the evolution of living things, and 9.2% responded they did not know what the role of a supernatural being was in the phenomenon of evolution (Table 23).

Students' *human evolution acceptance* (HEACCEP) was a scale score based on responses to four survey questions as described earlier. A factor analysis and internal consistency reliability analysis confirmed that the four single-question variables adequately measured human evolution acceptance. The scale scores were categorized and HEACCEP was recoded into an ordinal variable with the same name (Table 24). More than half of students (59.7%) scored at the highest level of human evolution acceptance.

Table 22

Acceptance of general evolution (GENACCEP)

	Frequency	Percent
Living things have existed in their present form since they came into being.	54	11.1
I don't know.	28	5.8
Living things have evolved over time.	404	83.1
Total	486	100.0

Table 23

Views on the role of a supreme being in general evolution, among students who accept general evolution (GODINVOL)

	Frequency	Percent
A supreme being guided the evolution of living things.	87	21.5
I don't know.	37	9.2
Living things have evolved due to natural processes.	280	69.3
Total	404	100.0

Table 24

Acceptance of human evolution (HEACCEP)

	Frequency	Percent
1=Lowest acceptance	32	6.6
2	47	9.7
3	117	24.1
4=Highest acceptance	290	59.7
Total	486	100.0

A Mann-Whitney *U* test was conducted to compare human evolution acceptance between students who accepted that living things have evolved over time and students who thought that living things have existed in their present form since they came into being (Table 25). A moderate to strong significant difference in median acceptance between the two groups was identified, $U = 2566$, $p < .001$, $r = 0.493$. A chi-square analysis identified a significant association between GENACCEP and HEACCEP, χ^2 (3, N = 486) = 170.453, $p < .001$, Cramer's V = .592, 95% CI [.489, .697]. The value of lambda (λ) when GENACCEP was the dependent variable, $\lambda = .185$, 95% CI [.000, .364], was higher than lambda when HEACCEP was the dependent variable, $\lambda = .077$, 95% CI [.043, .130], indicating that human evolution acceptance predicts general evolution acceptance better than general evolution acceptance predicts human

Table 25

*GENACCEP * HEACCEP cross-tabulation*

		Acceptance of Human Evolution				
		1=Lowest Acceptance	2	3	4=Highest Acceptance	Total
Acceptance of general evolution	*Living things have existed in their present form since they came into being.*	21	20	7	6	54
		38.9%	37.0%	13.0%	11.1%	100.0%
	Living things have evolved over time.	7	22	97	278	404
		1.7%	5.4%	24.0%	68.8%	100.0%
Total		28	42	104	284	458
		6.1%	9.2%	22.7%	62.0%	100.0%

Note. Students who responded I don't know" to the question about acceptance of general evolution were excluded. χ^2 (3, N = 486) = 170.453, $p < .001$, Cramer's V = .592, 95% CI [.489, .697].

evolution acceptance. Using HEACCEP to predict GENACCEP yields a 36.1% reduction in prediction error for GENACCEP over a null model (i.e., a model based just on student survey responses for GENACCEP); 95% CI [25.5, 49.4].

Though there was a statistically significant association between general evolution acceptance and human evolution acceptance, of the 54 students who agreed living things have existed in their present form since they came into being, 33 of them expressed a level of acceptance of human evolution greater than or equal to two (minimal to high acceptance) and six of those 33 students were scored as having the highest level of human evolution acceptance (Table 25). This finding implies some students may have misunderstood the survey questions or, possibly, were inclined to respond to questions in a way that both honored their faith and appealed to their logic. Among the 404 students who accepted general evolution, seven scored at the lowest level of acceptance of human evolution, demonstrating that some students view humans separately from other living organisms in the light of evolution (Table 25).

Table 26 compares students' acceptance of human evolution and their views on the role of a supreme being in the phenomenon of general evolution (for those students who accept general evolution). A Kruskal-Wallis test confirmed that there were significant differences among the groups being compared, χ^2 (3, N = 404) = 56.021, $p < 0.001$. Students who had higher levels of human evolution acceptance were more likely to also accept that living things have evolved due to natural processes. Students with lower levels of human evolution acceptance were more likely to also believe that a supreme being guided the evolution of living organisms. When responses of "I do not know" for the variable GODINVOL were excluded from the analysis, there was a significant difference between those who identified a role for a supreme being in the process of general evolution and those who did not, $U = 7505.5$, $p < 0.001$, $r = 0.352$.

Table 26

Students' views on the role of a supreme being in evolution (GODINVOL) for levels of acceptance of human evolution (HEACCEP)

		The role of the supernatural in general evolution			
		A supreme being guided the evolution of living things.	*I don't know*	*Living things have evolved due to natural processes.*	Total
Human evolution acceptance	1=Lowest Acceptance	5	1	1	7
		71.4%	14.3%	14.3%	100.0%
	2	15	2	5	22
		68.2%	9.1%	22.7%	100.0%
	3	29	13	55	97
		29.9%	13.4%	56.7%	100.0%
	4=Highest Acceptance	38	21	219	278
		13.7%	7.6%	78.8%	100.0%
Total		87	37	280	404
		21.5%	9.2%	69.3%	100.0%

Note. χ^2 (3, $N = 404$) = 56.021, $p < 0.001$.

These findings reflect what was shared by some of the ASU students who participated in the interview portion of this study. For example, Participant 1104 believed in a supernatural creator, but was able to accept the idea of general evolution. She was less sure about human evolution, though it made more sense to her than did the particular religious explanation for the origin of humans with which she was familiar. She was a Junior Communications major at ASU who graduated from a public high school in Minnesota and had a high religion factor. She said:

- I really, really feel that if there is a God, which I'm pretty sure there is, there just can't be nothing, you know...why couldn't evolution have come from God? I mean, it takes a lot of the circumstances to be right to even have Earth, so there's got to be something there, maybe to put it all together, and then, along with free will, you know, there could also be the right to evolve, you know, the right to higher education, the right to happiness, and stuff like that. [Regarding human evolution,] I'm still completely undecided, but I tend to take the evolutionary side a little more because there's a little more logic behind [the idea that] we came from monkeys and evolved than we came out of the dirt [as I have been taught] (Participant 1104).

Participant 922 was a second year Journalism major who graduated from high school in Arizona and acknowledged that her lack of formal human evolutionary biology education may have contributed to her personal views and beliefs. She had a low religion factor, but believed in a supernatural power that was not a Christian God. When asked how she reconciles her beliefs with the science of evolutionary biology, she said:

- I really don't know, maybe because I haven't taken a lot of biology classes, but it's still not something...I don't know...it feels like I can believe it more in animals. Like, I can see, ok, maybe the animal, it's like this and it was put in this environment, so it's evolved, but because we never really elaborate on humans, I can't...it's not like something I can actually [say in regards to], "Ok, I believe this." You know, we're always told, "There's a lot of evidence, there's a lot of evidence [for human evolution]," and then I never see the reasons. I've always felt like—[regarding the statement],

> "Well, if God created this, then it shouldn't evolve,"—why can't it? You know, I've always felt like, maybe things didn't just come from one cell and everything multiplied. I couldn't–I can't–grasp that because of my level of knowledge, so how I cope with it is, [I think] "Ok, God created things but then everything's flourished and everything's evolved." [Moderator: It's a little bit harder for you to accept for humans, you would say?] Mmm-hmm [agreement]. Maybe if I would learn more, I could totally understand, but I just, I'm like, mmm-mmm [doubting noise]. (Participant 922).

Religion factor and acceptance. Clearly, religious beliefs were associated with some students' views about evolution and human evolution. Table 27 includes the results of a comparison of the surveyed students' religion factors and acceptance of general evolution. A Kruskal-Wallis test identified a significant difference between RELFACT groups for GENACCEP, χ^2 (3, N = 481) = 48.722, $p < 0.001$. As religion factor increased, the proportion of students who agreed with, *Living things have existed in their present form since the came into being*, increased.

Table 28 compares students' religion factor and acceptance of human evolution. A Spearman rank correlation test identified a moderate correlation, $r_s(479) = -.406$, $p < 0.01$, between RELFACT and HEACCEP; the two ordinal variables share 16.5% of their variation in common. As religion factor increased, the percentage of students with the lowest, and second lowest, levels of acceptance of human evolution increased.

Table 27

Acceptance of general evolution (GENACCEP) by religion factor (RELFACT)

		Acceptance of general evolution			
		Living things have existed in their present form since they came into being.	*I don't know.*	*Living things have evolved over time.*	Total
Religion factor	None	0	1	31	32
		.0%	3.1%	96.9%	100.0%
	Low	5	3	139	147
		3.4%	2.0%	94.6%	100.0%
	Moderate	7	10	109	126
		5.6%	7.9%	86.5%	100.0%
	High	42	14	120	176
		23.9%	8.0%	68.2%	100.0%
Total		54	28	399	481
		11.2%	5.8%	83.0%	100.0%

χ^2 (3, N = 481) = 48.722, $p < 0.001$

Table 28

Acceptance of human evolution (HEACCEP) by religion factor (RELFACT)

		Acceptance of Human Evolution				
		1=Lowest Acceptance	2	3	4=Highest Acceptance	Total
Religion factor	None	0	0	7	25	32
		.0%	.0%	21.9%	78.1%	100.0%
	Low	1	5	20	121	147
		.7%	3.4%	13.6%	82.3%	100.0%
	Moderate	3	10	38	75	126
		2.4%	7.9%	30.2%	59.5%	100.0%
	High	28	32	48	68	176
		15.9%	18.2%	27.3%	38.6%	100.0%
Total		32	47	113	289	481
		6.7%	9.8%	23.5%	60.1%	100.0%

$r_s(479) = -.406$, $p < 0.01$

Human evolutionary biology exposure. As described earlier in this chapter, the survey participants' *K-12 human evolutionary biology exposure* (HEBEXP) was categorized as *none*, *low*, *moderate*, or *high* (Table 29). HEBEXP was a composite variable based on students' responses to seven survey questions. The HEBEXP categories are relative for the study, meaning, for example, the students in the high HEBEXP group had the highest HEB exposure of all the participants. Forty-two percent of participants had high HEB exposure, 18.3% had moderate exposure, 23.5% had low exposure, and 15.8% had no exposure to human evolutionary biology prior to college. K-12 human evolutionary biology exposure was used in analyses involving STEM class enrollment, STEM interest and motivation, and pre-collegiate and undergraduate academic achievement.

Table 29

K-12 human evolutionary biology exposure (HEBEXP)

	Frequency	Percent
None	77	15.8
Low	114	23.5
Moderate	89	18.3
High	206	42.4
Total	486	100.0

A composite variable for *total HEB exposure* (TOTALHEB) was used in the analyses of students' socioscientific decision-making because students' exposure to HEB at the university level had to be considered with regard to the thoughts, opinions, and behaviors they expressed at the time they completed the online survey. TOTALHEB was also categorized as *none, low, moderate,* or *high* based on students' K-12 HEB exposure and their *exposure to HEB in undergraduate coursework* (UNDHUEV). Fifty-eight percent of students had high total HEB exposure, 14.6% had moderate total HEB exposure, and 27% had no or minimal total HEB exposure (Table 30).

Table 30

Total human evolutionary biology exposure (TOTALHEB)

	Frequency	Percent
None	45	9.3
Minimal	86	17.7
Moderate	71	14.6
High	284	58.4
Total	486	100.0

K-12 human evolutionary biology exposure and STEM enrollment, achievement, interest and motivation

HEB exposure and potential predictor variables. Table 31 summarizes the relationship between students' K-12 human evolutionary biology exposure and the demographic and descriptive variables presented above. There was not a significant relationship between HEB exposure and students' sex or ethnicity. There was a weak negative correlation between HEBEXP and AGE, but this relationship was not significant at the .05 level. The states where students graduated high school were used to code a variable representing *high school region* (HSREGION; West, Midwest, Northeast and South) and HEB exposure did not differ significantly by region. There was no statistically significant relationship between students' religion factor and HEB exposure, nor their general evolution acceptance and HEB exposure. There was a weak positive correlation between HEBEXP and human evolution acceptance, but it was not significant at the .05 level. Though *interest in a STEM degree program* (STEMDEG) and *STEM career motivation* (STEMCAR) were significantly associated with each other, there was only a significant relationship between HEB exposure and students' interest in a STEM degree, and not between HEB exposure and students' STEM career motivation, when responses of "I don't know" for STEMDEG and STEMCAR were excluded (these relationships are explored in greater detail later in the chapter).

Table 31

Summary of relationships between K-12 human evolutionary biology exposure (HEBEXP) and potential cofactors or covariates in the study

Variable	Statistical Test Result	Significant relationship with HEBEXP
Sex	U = 22,948.00, p = .212	No
Age	$r_s(486) = -.083$, p = .068	No
Ethnicity	χ^2 (14, N = 481) = 18.973, p = .166	No
State of H.S. graduation (by region)	χ^2 (3, N = 486) = .326, p = .955	No
Academic aptitude	$r_s(486) = .078$, p = .094	No
Religion factor	$r_s(486) = .060$, p = .185	No
General evolution acceptance	U = 10,808.50, p = .909	No
Human evolution acceptance	$r_s(486) = .078$, p = .085	No
Interest in a STEM degree program	χ^2 (3, N = 443) = 8.564, p = .036, r = .134	**Yes** [a]
STEM career motivation	χ^2 (3, N = 443) = 7.280, p = .063	No

[a] This relationship is significant when responses of "I don't know" regarding interest in a STEM degree are excluded from the analysis.

HEB exposure and high school science class enrollment. Table 32 includes descriptions of the six variables that were used to reflect high school science class enrollment (also see Appendix G). SCIENCE, BIOSCI, and ADVBIO were scale variables accounting for *the number of classes students completed in science, biological science* and *advanced biological science*, respectively (Table

33). These variables were not normally distributed (Figures 32, 34, and 36). HSSCI, HSSCIHI and BIOLOGY were nominal variables summarizing students' overall class enrollment. Every participant in the study completed at least one high school science class, but 3.9% did not take any biological science classes and 49% did not take any advanced biological science classes.

Table 32

High school science class enrollment variables

Variable	Label
SCIENCE	Number of high school science classes completed
BIOSCI	Number of biological science classes completed
ADVBIO	Number of advanced biological science classes completed
HSSCI	If students completed at least 3 science classes including 1 or more biological science classes (yes/no)
HSSCIHI	If students completed more than 4 years of science including 1 or more advanced biological science classes (yes/no).
BIOLOGY	If students completed more than 2 biological science classes including one or more advanced biological science classes (yes/no)

Table 33

Descriptive statistics for scale variables related to students' high school science class enrollment

Variable	Range	*Mdn*	IQR
SCIENCE	1-10	3	1
BIOSCI	0-5	2	1
ADVBIO	0-4	1	1

The number of science classes, biological science classes, and advanced biological science classes students completed in high school were compared among and between HEBEXP groups (Figures 33, 35, and 37). Though class enrollment data within each HEBEXP group were not normally distributed for any of the three scale variables, SCIENCE and BIOSCI exhibited homogeneity of variance among the groups, based on nonparametric Levene's F-Tests (Nordstokke et al., 2011), $F(3, 482) = 1.1$, $p > .05$ for SCIENCE and $F(3, 482) = .981$, $p > .05$ for BIOSCI, which permitted testing via nonparametric methods. The data for ADVBIO were heteroscedastic; root transformation and base-10 log transformation did not result in homoscedasticity, so these data were not subject to nonparametric statistical analyses. A comparison of ADVBIO among HEBEXP groups was limited to a boxplot (Figure 37). Table 34 reports the medians for science class enrollment for each HEBEXP group. The moderate and high HEBEXP groups completed a higher median number of science, biological science and advanced biological science classes than the groups with no or minimal HEB exposure.

Table 34

High school science class enrollment by HEB exposure (Median, Interquartile range)

	HEB Exposure			
Variable	None	Low	Moderate	High
SCIENCE	*Mdn* = 3	*Mdn* = 3	*Mdn* = 3	*Mdn* = 4
	IQR = 1	IQR = 1	IQR = 1	IQR = 2
BIOSCI	*Mdn* = 1	*Mdn* = 1	*Mdn* = 2	*Mdn* = 2
	IQR = 1	IQR = 1	IQR = 1	IQR = 1
ADVBIO	*Mdn* = 0	*Mdn* = 0	*Mdn* = 1	*Mdn* = 1
	IQR = 1	IQR = 1	IQR = 1	IQR = 1

There was a weak positive correlation between the number of high school science classes students completed and their HEB exposure based on a Spearman rank correlation, $r_s(486) = .155$, $p < .01$ (Table 34 and Figure 33). A Kruskal-

Wallis test confirmed there was a significant difference in the number of science classes completed between HEBEXP groups, χ^2 (3, N = 486) = 12.737, $p < .01$, with a weak effect size, $r = .026$, indicating that 2.6% of the variation in SCIENCE is due to HEBEXP. A series of Mann-Whitney U post-hoc pairwise comparisons showed that the differences in SCIENCE between the high HEBEXP group and the no HEB exposure and low HEBEXP groups were significant, $U = 6442$, $p < .05$, $r = .15$, and $U = 9385$, $p < .01$, $r = .17$, respectively.

There was a weak positive correlation between the number of biological science classes students completed and their HEB exposure, $r_s(486) = .211$, $p < .001$ (Table 34 and Figure 35). And there was a significant difference between HEBEXP groups for BIOSCI, χ^2 (3, N = 486) = 25.124, $p < .001$, $r = .052$. Post-hoc pairwise comparisons showed that there was a significant difference between the high HEBEXP group and the no HEBEXP and low HEBEXP groups, $U = 5984$, $p < .01$, $r = .20$, and $U = 8542.5$, $p < .001$, $r = .24$, respectively, in the number of biological science classes they completed. And there was a significant difference between the moderate HEBEXP group and the no HEBEXP and low HEBEXP groups, $U = 2760.5$, $p < .05$, $r = .18$, and $U = 3964.5$, $p < .01$, $r = .20$, respectively.

As mentioned earlier, 49% of students (n = 238) did not complete an advanced biological science class (Table 34 and Figure 36). The boxplot in Figure 37 shows the differences in ADVBIO between HEBEXP groups. Students who completed 3 or 4 advanced biological science classes were in the moderate or high HEBEXP groups only.

In sum, all participants completed at least one science class and the median number of high school science classes completed by participants was three—the minimum number of science classes required for graduation by most U.S. high schools. The median number of biology classes completed was two, but approximately 4% of students did not take any biology. And the median number of advanced biological science classes completed was one, but nearly half of the participants did not take any advanced biological science. Among the HEBEXP groups, the students with high HEB exposure completed a statistically greater number of science and biological science classes than students with no or low HEB exposure and, on average, a greater number of advanced biological science classes.

Enrollment: Hypothesis testing. The null hypothesis regarding high school science class enrollment and human evolutionary biology exposure states:

- H_0 = There is no association between completing at least three years of high school science classes that include at least one year of biological science and K-12 HEB exposure.

To test the hypothesis, the data for the variables SCIENCE and BIOSCI were recoded into the nominal variable, HSSCI, which identified *whether students completed at least three years of high school science classes that included at least one year of biological science* (see Table 32). Among all of the participants, 88.3% completed at least three years of high school science classes including at least one year of biological science; this subsample comprised at least 83% of students in any given HEBEXP group (Table 35). Among students with high HEB exposure, 90.3% completed at least 3 years of high school science classes that included at least one year of biological science classes, which was the highest proportion within any HEBEXP group. Twenty students (9.7%) in the high

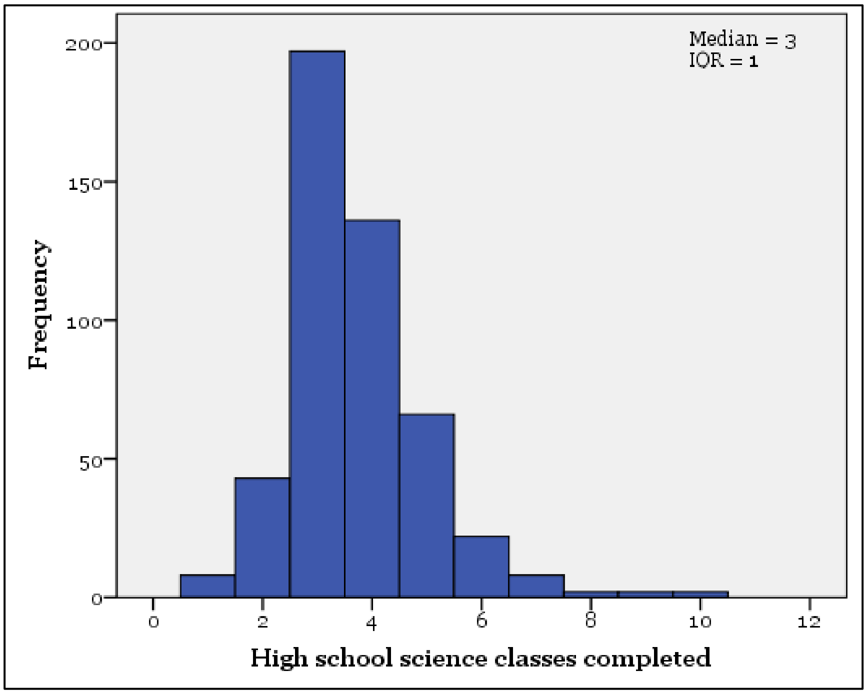

Figure 32. Students' enrollment in high school science classes (N = 486).

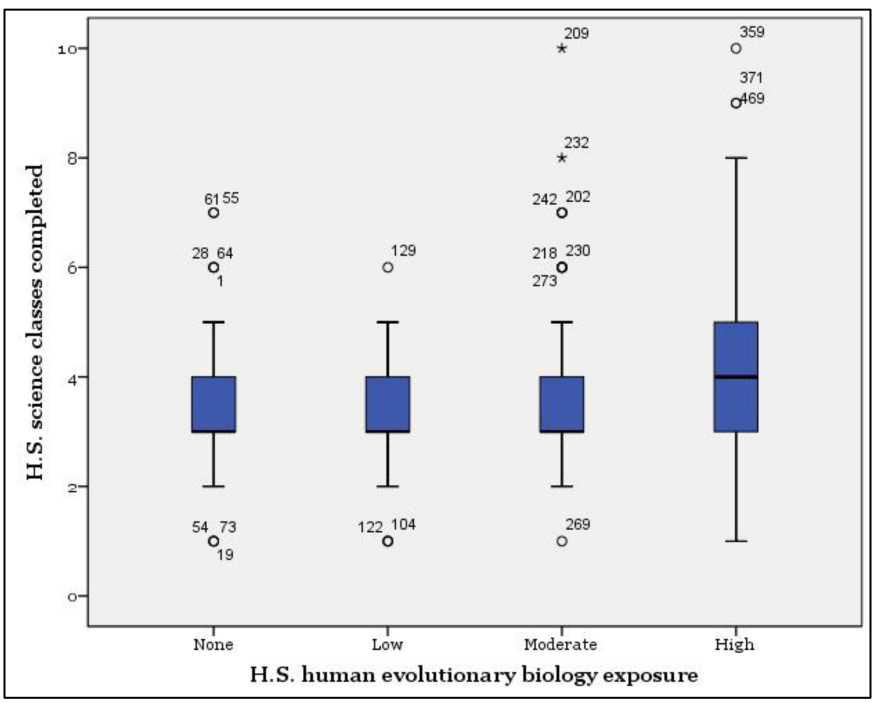

Figure 33. Comparison of high school science class enrollment for human evolutionary biology exposure groups.

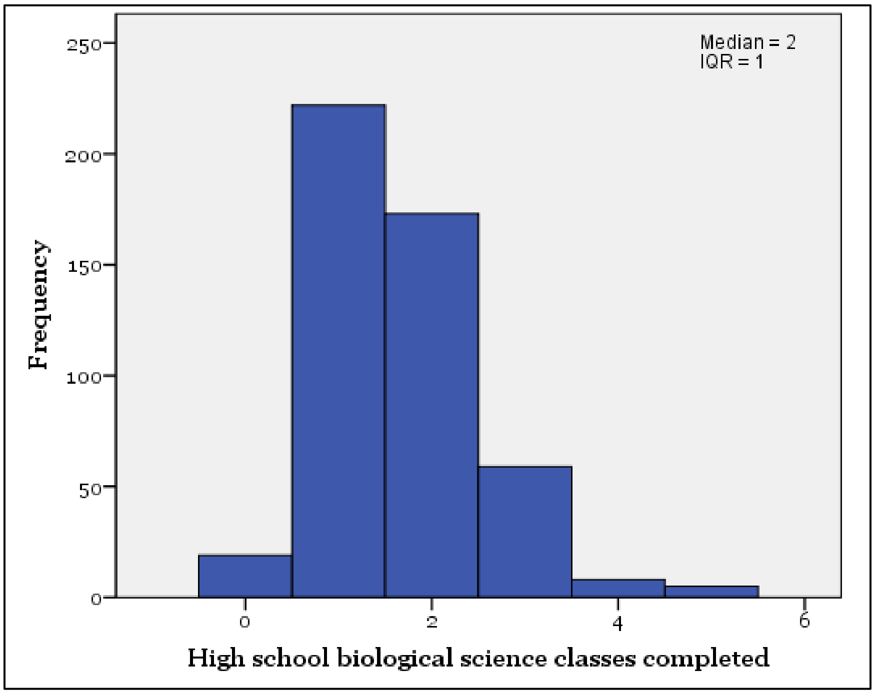

Figure 34. Students' enrollment in high school biological science classes (N = 486).

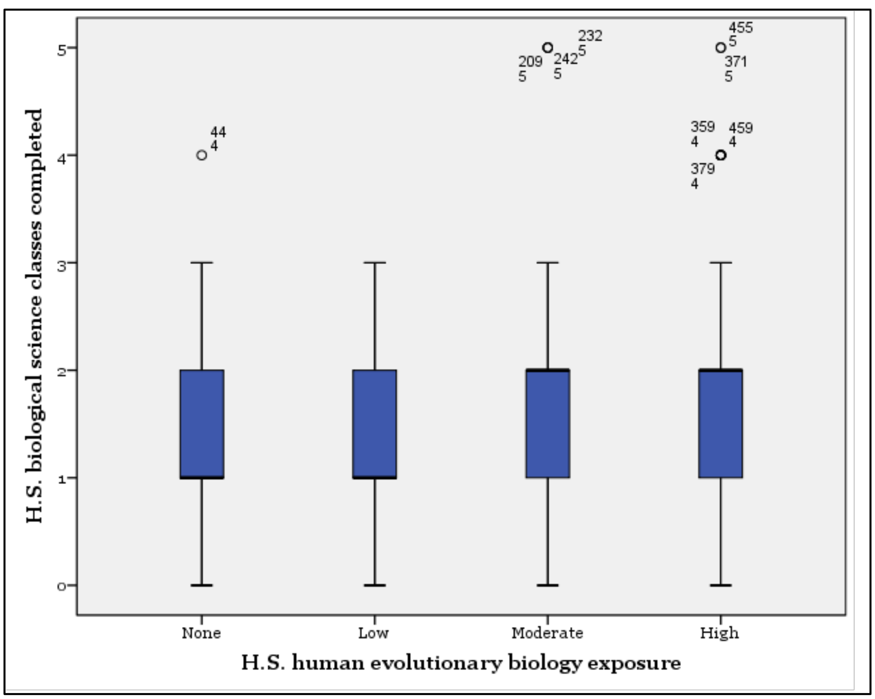

Figure 35. Comparison of high school biological science class enrollment for human evolutionary biology exposure groups.

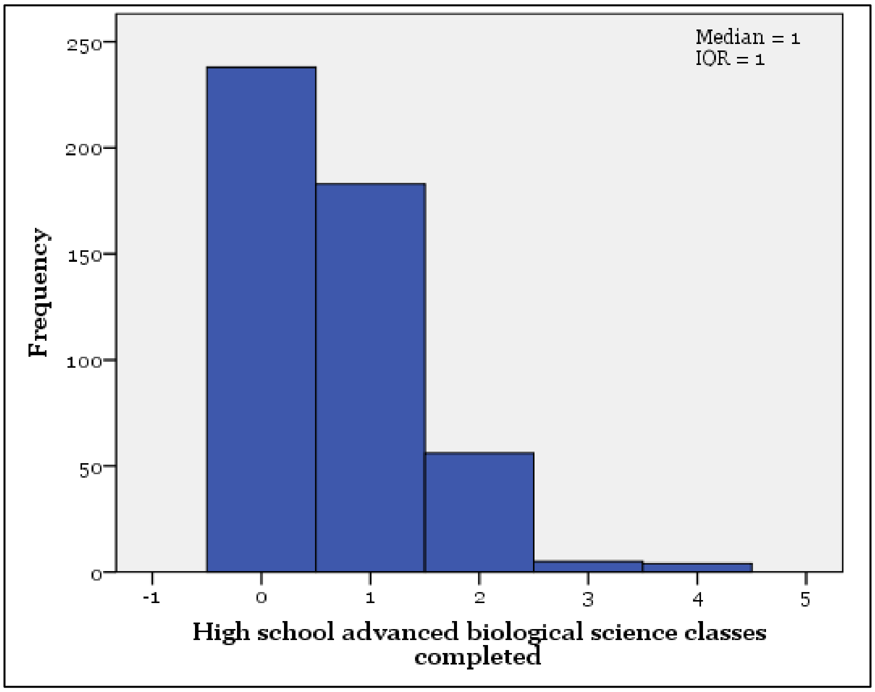

Figure 36. Students' enrollment in high school advanced biological science classes (N = 486).

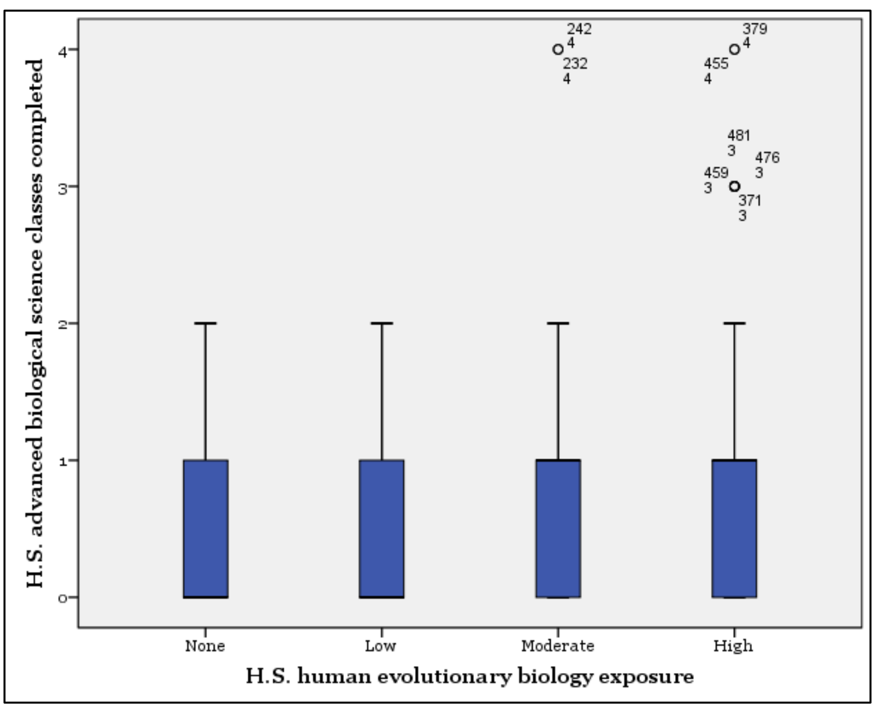

Figure 37. Comparison of high school advanced biological science class enrollment for human evolutionary biology exposure groups.

HEBEXP group did not complete this combination of classes. Of those 20 students, 17 took only two science classes in high school. Eighteen of the 20 reported learning about scientific explanations for the origin of humans in science class and 13 reported learning about scientific explanations for the origin of humans in a non-science class.

The relative proportion of students who completed at least 3 years of high school science with one or more years of biological science was higher for the moderate (92.1%) and high (90.3%) HEBEXP groups than for the no (83.1%) and low (85.1%) HEBEXP groups; however, a Kruskal-Wallis test showed there was not a significant difference among the four HEBEXP groups for the variable HSSCI (Table 35).

Given the statistical similarity of enrollment for the groups with no or low HEB exposure and the similarity of enrollment for the groups with moderate and high HEB exposure, the no and low HEBEXP groups were combined and recoded into a new (*lower*) exposure group and the moderate and high HEBEXP groups were combined into a new (*higher*) exposure group to generate a new variable, HEBEXP2. The association between HSSCI and HEBEXP2 was statistically significant, though weak, χ^2 (1, N = 486) = 4.811, $p < .05$, Cramer's V = 0.99, 95% CI [.016, .191] (Table 36). A student in the higher HEBEXP2 group was 1.08 times as likely to complete 3 years of high school science including one year of biological science than a student in the lower HEBEXP2 group. A student who completed at least 3 years of high school science including one or more years of biological science was 1.67 times more likely to be in the higher HEBEXP2 group than the lower HEBEXP2 group. In other words, enrollment was a better predictor of HEB exposure than HEB exposure was of enrollment.

Table 35

*HSSCI * HEBEXP cross-tabulation*

		Human evolutionary biology exposure				
		None	Low	Moderate	High	Total
Completed 3 or more H.S. science classes including 1 or more biological sciences	*No*	13 16.9%	17 14.9%	7 7.9%	20 9.7%	57 11.7%
	Yes	64 83.1%	97 85.1%	82 92.1%	186 90.3%	429 88.3%
Total		77 100.0%	114 100.0%	89 100.0%	206 100.0%	486 100.0%

χ^2 (3, N = 486) = 5.176, p = .159

Table 36

*HSSCI * HEBEXP2 cross-tabulation*

		Human evolutionary biology exposure (recoded)		
		lower	higher	Total
Completed 3 or more science classes including 1 or more biological science	*No*	30 15.7%	27 9.2%	57 11.7%
	Yes	161 84.3%	268 90.8%	429 88.3%
Total		191 100.0%	295 100.0%	486 100.0%

χ^2 (1, N = 486) = 4.811, $p < .05$, Cramer's V = 0.99, 95% CI [.016, .191]

A binary logistic regression analysis incorporating the variables listed in Table 37 was performed to predict HSSCI membership. The final model had low predictive capacity, explaining just 13.5% of the variance in HSSCI (Nagelkerke R^2), and did not increase the percentage of correct classifications from the null model. The lack of sensitivity and specificity of the model was in part due to the large percentage of students in the sample who did complete at least three years of science including one or more years of biological science (88.3%; thus, the models predict that 100% of students do). Additionally, as demonstrated earlier in this chapter, some of the variables in Table 37 were associated with one another; as a result, the initial binary logistic regression model did not satisfy the assumption of a lack of multicollinearity. To account for this, a reduced model was generated; the variables for evolution acceptance (GENACCEP and HEACCEP) were removed and the variable for students' religion factor, RELFACT, was maintained. Likewise, the variable for STEM career motivation, STEMCAR, was removed and the variable for interest in a STEM degree program, STEMDEG, was maintained.

The new model met the assumption of logistic regression that it not exhibit perfect multicollinearity; however, the predictive capacity of the model was still low and it explained a low percentage (10.7%) of the variation in the dependent variable, HSSCI, $\chi^2(13) = 24.750$, $p < .05$. Age was a significant predictor of HSSCI membership in this model. The contribution of HEBEXP to the model was not statistically significant, but had a greater effect than any of the remaining factors/covariates, except for some categories of ethnicity.

When the binary logistic regression model was reduced via the backwards stepwise likelihood ratio (LR) method in SPSS, age, ethnicity and HEB exposure were the variables remaining in the final significant model, $\chi^2(6) = 13.255$, $p < .05$, which explained 5.8% of the variation in HSSCI. Age was the only statistically significant contributor, $p < .05$; a one year increase in age was correlated with a decreased likelihood (.814x) of students' completing 3 years of high school science including at least one year of biological science (i.e., younger undergraduate students were more likely to have completed this combination of

Table 37

Summary of relationships between high school science class enrollment (SCIENCE and HSSCI) and factors or covariates used in regression

Variable	Statistical Test Result	Significant relationship
Sex & SCIENCE	$U = 21{,}978.50$, $p = .050$, $r = .09$	No*
Sex & HSSCI	χ^2 (1, $N = 486$) = .075, $p = .784$	No
Age & SCIENCE	$r_s(486) = -.026$, $p = .561$	No
Age & HSSCI	$U = 10{,}330.5$, $p = .051$, $r = .09$	No**
Ethnicity & SCIENCE	χ^2 (4, $N = 481$) = 12.610, $p < .05$	**Yes**
Ethnicity & HSSCI	χ^2 (4, $N = 481$) = 4.999, $p = .287$	No
State of H.S. graduation (by region) & SCIENCE	χ^2 (3, $N = 486$) = 25.236, $p < .01$	**Yes**
State of H.S. graduation (by region) & HSSCI	χ^2 (3, $N = 486$) = 4.432, $p = .218$	No
Academic aptitude & SCIENCE	$r_s(486) = .085$, $p = .069$	No
Academic aptitude & HSSCI	$U = 9662.0$, $p = .155$	No
Religion factor & SCIENCE	$r_s(486) = .014$, $p = .751$	No
Religion factor & HSSCI	$U = 11{,}218.0$, $p = .463$	No
General evolution acceptance & SCIENCE	$U = 10105.00$, $p = .357$	No
General evolution acceptance & HSSCI	χ^2 (1, $N = 458$) = .320, $p = .572$	No
Human evolution acceptance & SCIENCE	$r_s(486) = .079$, $p = .082$	No
Human evolution acceptance & HSSCI	χ^2 (3, $N = 458$) = 1.551, $p = .670$	No
Interest in a STEM degree program & SCIENCE	$U = 21{,}926.50$, $p < .001$, $r = .20$	**Yes**
Interest in a STEM degree program & HSSCI	χ^2 (1, $N = 476$) = 1.735, $p = .188$	No
STEM career motivation & SCIENCE	$U = 19{,}144.00$, $p < .001$, $r = .16$	**Yes**
STEM career motivation & HSSCI	χ^2 (1, $N = 443$) = 1.771, $p = .183$	No
HEB exposure (binomial) & SCIENCE	χ^2 (1, $N = 486$) = 11.976, $p < .01$	**Yes**
HEB exposure (binomial) & HSSCI	χ^2 (1, $N = 486$) = 4.811, $p < .05$	**Yes**

Note. *$p = .05$ **$p = .051$

high school classes than older undergraduates). In this model, as HEB exposure increased, there was a positive increase (1.6x) in the likelihood of students' completing 3 years of high school science including at least one year of biological science, however this result was not significant at p = .05. Sex, high school region, religion factor, enrollment in a STEM degree program, and academic aptitude were the variables excluded by SPSS from the final model.

In addition to testing the formal hypothesis involving the variable HSSCI, the inferences regarding high school science enrollment described in Chapter 5 were also explored. The inferences were:

- A student who *completes more than four years of high school science classes that include one or more years of advanced biological science* (HSSCIHI = yes) will also have high HEB exposure.
- A student who *completes more than two years of high school biological science classes that include one or more years of advanced biological science* (BIOLOGY = yes) will also have high HEB exposure.

Eighty-two percent of the total participants completed more than four years of high school science classes that included one or more years of advanced biological science. There was a significant difference in students' HEB exposure between HSSCIHI groups; the students who completed more than four years of science including one or more years of advanced biological science had a higher mean rank, and thus a relatively higher exposure to HEB than the other group, U = 13,911.00, $p < .01$, r = .12 (Table 38). The association between HEBEXP and HSSCIHI was weak to modest, χ^2 (3, N = 486) = 10.136, $p < .05$, Cramer's V = 0.144, 95% CI [.077, .234]; but, just 46 of 206 (22%) students in the high

HEBEXP group completed more than four high school science classes including one or more biological sciences.

Table 38

*HEBEXP * HSSCIHI cross-tabulation*

		More than 4 science classes including 1 or more advanced biological science classes		
		No	Yes	Total
HEB exposure	None	66	11	77
		85.7%	14.3%	100.0%
	Low	104	10	114
		91.2%	8.8%	100.0%
	Moderate	72	17	89
		80.9%	19.1%	100.0%
	High	160	46	206
		77.7%	22.3%	100.0%
Total		402	84	486
		82.7%	17.3%	100.0%

χ^2 (3, N = 486) = 10.136, p < .05, Cramer's V = 0.144, 95% CI [.077, .234]

A similar, but slightly stronger association was identified for students' HEB exposure and BIOLOGY membership (Table 39). Students who completed more than two years of biological science classes that included at least one year of advanced biological science had higher relative HEB exposure than those who did not, χ^2 (3, N = 486) = 16.187, p < .01, Cramer's V = 0.182, 95% CI [.123, .265]. Approximately 20% of students with high HEB exposure completed more than two years of biological science including at least one year of advanced biological science, compared to only 5-9% in the no or low HEBEXP groups. However, since not all students with high HEB exposure completed this combination of classes, the second inference was not fully supported.

Table 39

*HEBEXP * BIOLOGY cross-tabulation*

		More than 2 biological science classes including 1 or more advanced biology classes		
		No	Yes	Total
HEB exposure	None	70	7	77
		90.9%	9.1%	100.0%
	Low	108	6	114
		94.7%	5.3%	100.0%
	Moderate	73	16	89
		82.0%	18.0%	100.0%
	High	164	42	206
		79.6%	20.4%	100.0%
Total		415	71	486
		85.4%	14.6%	100.0%

χ^2 (3, N = 486) = 16.187, p < .01, Cramer's V = 0.182, 95% CI [.123, .265]

As Table 37 on page 225 showed, there was a significant relationship between the total number of high school science classes students completed (SCIENCE) and five variables: ethnicity, high school region, interest in a STEM major, motivation to pursue a STEM career, and HEB exposure. A cumulative odds ordinal logistic regression with proportional odds was run to determine the effect of these factors on the total number of high school science classes students completed (multiple regression was not appropriate due to a lack of independence of the residuals and heteroscedasticity). The non-normally distributed scale variable SCIENCE (range = 0-10) was recoded into the ordinal variable SCICAT, with 5 categories. The data met the assumptions for ordinal logistic regression; no perfect multicollinearity and proportional odds. The assumption of proportional odds was assessed by a full likelihood ratio test comparing the residual of the fitted location model to a model with varying location parameters, χ^2 (48, 405) = 38.679, p = .829. The deviance goodness-of-fit test indicated that the model was a good fit to the observed data, χ^2 (1544, N = 405) = 695.420, p = 1.00; however, due to a large number of cells with zero frequencies, the goodness-of-fit result should be treated with suspicion. The final model did statistically significantly predict the dependent variable over and above the intercept-only model, χ^2(16, 405) = 55.868, p < .001.

Based on the results of the ordinal logistic regression, the overall effects for three categorical variables were statistically significant for predicting SCICAT: academic aptitude, high school region (Wald χ^2(3) = 20.246, p < .001), and HEB exposure (Table 40). Unlike in the binary logistic regression model used to predict HSSCI, age was not a significant predictor of the dependent variable. The odds of taking two more science classes (i.e., being in a higher category of SCICAT) for students with higher academic aptitude (i.e., a one unit increase in SAT and/or ACT scores) was 1.216, 95% CI [1.039 to 1.422], Wald χ^2(1) = 5.954, p < .05. The odds of taking more science classes for students who graduated from high schools in the Northeast region of the United States compared to students who graduated from high schools in the West was 4.970, 95% CI [1.939 to 12.739], Wald χ^2(1) = 11.146, p < .01. The odds of taking more science classes for students who graduated from high schools in the Midwest region of the United States compared to students who graduated from high schools in the West was 4.956 95% CI [1.930 to 12.730], Wald χ^2(1) = 11.061, p < .01. The West region was used as the reference category for this variable since the majority of students in the study graduated from high school in Arizona. And, lastly, the odds of a one

Table 40

Parameter estimates for the ordinal logistic regression of high school science class enrollment (SCICAT)

Parameter		Est	Std. Error	Wald	df	Sig.	Exp(β)	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Threshold	[SCICAT=1]	-2.814	1.8319	2.359	1	.125	.060	.002	2.175
	[SCICAT=2]	.999	1.8252	.300	1	.584	2.716	.076	97.164
	[SCICAT=3]	3.294	1.8439	3.192	1	.074	26.956	.726	1000.368
	[SCICAT=4]	4.791	1.9122	6.276	1	.012	120.378	2.837	5107.939
[SEX=Female]		-.455	.2396	3.600	1	*.058*	.635	.397	1.015
[SEX=Male]			.	.	.	.	1	.	.
[GENACCEP=No]		.195	.4049	.231	1	.631	1.215	.549	2.686
[GENACCEP=Yes]			.	.	.	.	1	.	.
[ETHNIC=1][a]		.408	.5813	.492	1	.483	1.503	.481	4.697
[ETHNIC=2][a]		.612	.3769	2.637	1	.104	1.844	.881	3.860
[ETHNIC=3][a]		.334	.3729	.800	1	.371	1.396	.672	2.899
[ETHNIC=4][a]		-.254	.3240	.614	1	.433	.776	.411	1.464
[ETHNIC=5][a]			.	.	.	.	1	.	.
[HSREGION=South]		-.236	.6073	.151	1	.698	.790	.240	2.597
[HSREGION=NE]		1.603	.4803	11.146	1	**.001**	4.970	1.939	12.739
[HSREGION=Midwest]		1.601	.4813	11.061	1	**.001**	4.956	1.930	12.730
[HSREGION=West]			.	.	.	.	1	.	.
[STEMDEGREE=No]		-.726	.4178	3.017	1	*.082*	.484	.213	1.098

Parameter	Est	Std. Error	Wald	df	Sig.	Exp(β)	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
[STEMDEGREE=Yes]		.	.	.	.	1	.	.
[STEMCAREER=Yes]	.092	.4180	.049	1	.825	1.097	.483	2.488
[STEMCAREER=No]		.	.	.	.	1	.	.
Age	-.051	.0847	.361	1	.548	.950	.805	1.122
Academic aptitude	.195	.0801	5.954	1	**.015**	1.216	1.039	1.422
Religion factor	-.039	.1275	.094	1	.759	.962	.749	1.235
Human evolution acceptance	-.043	.1530	.078	1	.780	.958	.710	1.293
HEB exposure	.214	.0999	4.588	1	**.032**	1.239	1.018	1.507

Note. Link function: Logit
. This parameter is set to zero because it is the reference category (redundant).
[a] Ethnicity categories: 1=Non-white, non-Hispanic, non-Asian; 2=Asian; 3=Hispanic/Latino/Spanish/Mexican/Chicano; 4=Mixed; 5=Caucasian

unit increase in SCICAT for students with higher HEB exposure compared to students with lower HEB exposure was 1.239, 95% CI [1.018 to 1.507], Wald $\chi^2(1) = 4.488$, $p < .05$.

A deeper exploration of the assumption of proportional odds for the cumulative odds ordinal logistic regression showed that the assumption of proportional odds, though met for the overall model, was not met for some independent variables when analyzing higher cumulative categories of the SCICAT variable. This is presumably due to the fact that so few students completed seven or more science classes in high school (n = 14). This is evident from the threshold values in the parameter estimates table (Table 40). To determine if excluding those 14 students from the analysis altered the model, the ordinal regression analysis was rerun excluding the two highest categories of SCICAT (i.e., students who completed seven to 10 science classes). The results of this analysis were the same as the previous model with regard to significance; however, the likelihood ratios, Exp(β), increased greatly for students who graduated high school in the Northeast (8.003) and Midwest (7.523). Likelihood ratios for academic aptitude and HEB exposure were essentially unchanged.

Though the causal relationship between K-12 human evolutionary biology exposure and high school science enrollment would need to be tested via a randomized controlled study, there are adequate data presented here on which to make inferences about it. There is strong evidence that enrollment in more science classes, especially biological science classes, increases the likelihood that a student will be exposed to the science of human evolutionary biology. There is also evidence to suggest that moderate to high exposure to human evolutionary biology may contribute—though to a lesser degree—to students' enrolling in more science classes, specifically advanced biological science classes, than does low or no exposure to HEB.

Of the 161 students who had moderate to high HEB exposure and completed 4 or more high school science classes, 15 of them reported learning about the scientific explanations for the origin of humans only in non-science classes (e.g., social studies), demonstrating that enrollment in science classes is not always the variable determining HEB exposure. Likewise, of the 172 students who had moderate to high HEB exposure and completed at least one advanced biological science class, 11 of them reported learning about scientific explanations for the origin of humans only in non-science classes, demonstrating that enrollment in advanced biological science classes does not always determine HEB exposure.

Data from the survey suggest that the potential relationship between HEB education and science class enrollment varies for different types of students. For example, a correlation analysis of HEB exposure and absolute science class enrollment controlling for high school region was conducted and revealed that the relationship between HEB exposure and enrollment is modest, and more significant, when controlling for high school region, $r_s(486) = .162$, $p < .001$. Similar results were obtained when controlling for academic aptitude, $r_s(486) = .139$, $p < .01$, or both high school region and aptitude, $r_s(486) = .143$, $p < .01$.

The strongest significant correlation between HEB exposure and science class enrollment was for students who graduated high school in the West and scored between 1000 and 1999 on the SAT or 20 and 22 on the ACT, $r_s(60) = .282$, $p < .05$. For these students, Somer's d indicated a somewhat stronger association with HEB exposure as the dependent variable (.314) than with science enrollment as the dependent variable (.212). The majority of these students (72%) learned about the scientific explanations for the origin of humans in science class versus non-science class. Thirty-two (53%) of the 60 students did not take advanced biological science classes, 21 (35%) completed one advanced biological science class, six (10%) completed two advanced biological science classes and one student completed four advanced biological science classes. The students who completed two or four advanced classes all had moderate or high HEB exposure. Eight of the 10 students with no HEB exposure took no advanced biological science classes. A partial correlation between HEB exposure and total science class enrollment controlling for advanced biological science class enrollment showed that advanced biological science class enrollment is responsible for the significance of the association in this case.

For students in the South who earned between 1300 and 1399 on the SAT or 29 and 31 on the ACT (n = 5), a positive Spearman rank correlation between HEB exposure and total science class enrollment was not significant at p = .05, but Somer's d was significant at p = .01 and indicated that HEB exposure was a better predictor of science class enrollment (.833) than was enrollment of HEB exposure (.625) for these students, though this result should be considered with caution due to the small sample size. Four of the five students completed at least one advanced biological science course and had low to moderate HEB exposure.

The information interview participants shared also suggest that the relationship between total science class enrollment, biological science class enrollment, and human evolutionary biology exposure is different for different students and affected by factors such as the timing of exposure and students' perceived abilities in STEM disciplines. An interview participant with moderate

K-12 HEB exposure expressed that her biology education in high school, particularly one semester of AP Biology, influenced her to enroll in more high school science classes. However, her exposure to HEB occurred primarily during middle school and 9th grade; she did not recall learning about evolution in AP Biology. At the time of the interview, she was a freshman at ASU planning to major in Biology. She graduated from a public high school in Arizona and completed 4.5 years of high school science classes, including the semester of AP Biology. This student's evolution and human evolution acceptance were high, as was her religion factor; she was raised in the Hindu tradition, but described herself as an atheist. Regarding high school science class enrollment, she said:

- For me, my AP Biology course was like, really, I think it set me on the right track for all of high school, because I did really well in that class and I felt like I understood everything and things made so much sense and that's why I'm a biology major because I feel like with biology things can really make sense, as opposed to English, where things can get subjective, and I'm not good with math, so physics and chemistry were kind of like abstract for me. It really geared me toward science and then I think because I took AP Biology first and I could understand it and do well is the only reason I would even try to take AP Chemistry and Physics because I've always just since day one, I've just been like, I've really liked biology (Participant 203).

This student's experience demonstrates that high school biology and, furthermore, success in high school biology, can influence students to enroll in classes in other STEM subject areas, increasing their total high school STEM enrollment. This case does not lend support to, nor does it necessarily refute, the idea that the science of human evolutionary biology is what makes K-12 biology interesting and relevant, as it is unclear whether the student was referring to her previous academic experiences when she said "since day one," or if she was implying that there was something about her nature that made biology naturally appealing to her.

Another interviewed student discussed what appealed and did not appeal to her about her high school science classes. She completed a freshman science class, which included a minimal amount of evolutionary biology, a chemistry class, and AP Anatomy and Physiology. At the time of the interview, Participant 5886 was a sophomore at ASU, majoring in Business Management. Her religion factor was high, and she was a practicing Catholic. She expressed confusion over explanations for the origin of life and humans, but said that she found scientific explanations more logical than religious explanations. She graduated from a public high school in Arizona. Regarding her high school science classes and undergraduate course requirements, she said:

- [Science was] somewhat appealing. I really didn't like it. I took chemistry and I hated it. I never was interested in physics at all. I'm definitely not a "science person" and I just, like, now I have to take two [science] classes [at ASU] and that's just because I have to. If I didn't have to, I wouldn't. I mean, it's interesting once I'm in the class, but if it were my choice, I definitely would not go with those classes, like a science class, as opposed to a different class. [Moderator: What did you hate about your chemistry class?] Um, it was hard learning all those different elements and formulas and I wasn't good at it, no matter how hard I tried, no matter how much I saw my teacher. Something was not clicking. And then it was opposite for

> when I took a human anatomy class. It was an AP class. And I totally loved that better. So, it was, I did well in that, I got an A in that, as opposed to a C in chemistry. I definitely like more, like, the anatomy and physiology and how the body works because it's something, you know, I'm a human, all these functions are a part of me. I'm definitely more interested in that, as opposed to the chemical compounds of molecules and stuff like that. I like more the anatomy and learning about my muscles and how this works and what chemicals make your body do this and that. Definitely I'm more interested in that. I learned about [evolution and human evolution] when I took my anatomy class, which was my senior year in high school, and we went to Body Worlds. It was all body functions [and] that was very awesome (Participant 5886).

This student provides an example of how human biology can be viewed by students—even those who generally find science unappealing—as a personally relevant subject. Her exposure to the subject was in 12th grade, however, so one cannot assess whether her exposure to human biology would have influenced her to take more high school science classes. Perhaps, had she completed AP Anatomy and Physiology prior to the chemistry class, she may have felt more inclined to identify herself as a "science person" and enroll in more high school science classes.

Another interviewee, Participant 2206, discussed how his middle school and high school life science education stimulated his interest in science. His middle school education included a 6th grade class with a science component that involved dissections, a 7th grade life science class and an 8th grade earth science class. He completed five high school science classes, including honors biology, AP

Biology, and Anatomy and Physiology, and two chemistry classes. He graduated from a public high school in Arizona and had high K-12 HEB exposure which occurred primarily in his 10th grade honors biology and 11th grade social studies classes. At the time of the interview, he was a 20 year old sophomore at ASU majoring in Biology. He had high evolution and human evolution acceptance and a moderate religion factor; he identified himself as an atheist and said he had been an atheist for about three years. Regarding what influenced his interest in science, he said:

- Just, like, discovering something that no one has ever seen before, like, it's exciting to me. Like, all that, and I think it's just generally interesting and kind of like awe inspiring, I suppose. It was about the same time [my brother] decided he wanted to do neurosurgery [that], in 6th grade, my teacher really pushed science a lot and I hadn't really been exposed to so many things at once. Some, like, history and art and everything and science were... real big things, like, she would push and I find that... really interesting and that's about when I decided [I liked science]. [Moderator: What most influences the fact that you're going into science?] I think...it's just me and just, definitely my [6th grade] teacher, because I think that's when I really decided that...stuff is...really cool and really interesting. That and also my [10th grade] honors biology teacher was really cool because he was kind of the one who...allowed me to see...all the stuff that is going on, essentially in the biological perspective, like, how...just interesting and diverse it is, too (Participant 2206).

Regarding his honors biology teacher and his thoughts about evolution, he said:

- I had to...make a decision for myself, based on what I was taught, because at first, I was almost, like, kind of standoffish...as my teachers were trying to kinda introduce it, because where I was from was a really conservative area. At first I shut down, and then, when it was...introduced, my sophomore honors teacher, he was a really huge Mendel and Darwin fan, so we talked about...all the finches and everything, so you could see, definitely, how change was occurring and that kind of made me...reevaluate my stance on it, I suppose. ...and then seeing...comparative biology, like, we'd look at the fetuses from...whales and...how the development is similar and then...actually...in the social sciences [in 11^{th} grade], we talked about Lucy and Neandertals, also, and that kind of made me think. [And] I think it's kind of hard for [me and the other interview participant] to disagree that we aren't changing a little bit, like, our genes are evolving. [The honors biology teacher] didn't delve too much into the...common ancestor...from you know, primates and humans as much. [He] did discuss common ancestors and stuff, but he mostly focused on animal evolution, I'd say (Participant 2206).

When asked if the science of human evolution was something he would like to learn more about, he said:

- Yeah. I think [human evolution] is interesting because it's always kind of...a curiosity, where we came from, essentially, how similar are the other [living] things, for me, at least. [And] just to see that we've evolved from...conditions that...we see as much more extreme and to...our present form and our ability to think and interpret, I think that's really cool (Participant 2206).

This student does not explicitly attribute his enrollment in three high school biological science classes to his exposure to evolutionary biology, or human evolutionary biology, but he identifies “the biological perspective” as interesting and specifically identifies human evolutionary biology as interesting and “cool” to him personally. Based on this student’s interview, it can be inferred that his enrollment in Advanced Placement Biology and Anatomy and Physiology were, at least in part, influenced or otherwise undeterred by his general life science education. Perhaps his exposure to evolutionary biology in middle school and 10^{th} grade honors biology and to human evolutionary biology in 11^{th} grade social studies class contributed to this, as well. The relationship between HEB exposure and students’ interest in STEM is discussed in more detail below.

Academic achievement: Hypothesis testing. The results of the qualitative analysis led to the following null hypothesis regarding STEM achievement:

- H_0 = For traditional students interested in a STEM degree, there is no relationship between K-12 HEB exposure and university GPA.

The idea behind the alternative hypothesis was that students with higher K-12 HEB exposure would be better prepared for science coursework, and would therefore achieve higher grades and have a higher GPA than students with less or no K-12 HEB exposure. Undergraduate GPA was coded as an ordinal variable with six categories. A response of “I don’t know” was coded as missing data. A Spearman rank correlation found no relationship between HEB exposure and GPA for STEM majors, $r_s(241) = .037$, $p = .570$, and a Kruskal-Wallis test found no difference between HEBEXP groups for GPA, $\chi^2(3, N = 241) = .874$, $p = .832$. Therefore, the null hypothesis was supported.

The researcher questioned whether perceived performance—considered by the researcher to be an aspect of achievement—would have a different relationship to human evolutionary biology education than grade point average. STEM majors who completed the online survey were asked (a) *how easy they perceived their undergraduate science coursework to be* (SCIEASE) and (b) *how well prepared they felt for their undergraduate science coursework* (SCIPREP).

There was not a significant association between K-12 HEB exposure and students' perceptions of the ease of their coursework; only four of 238 STEM majors said their coursework was "extremely easy" and the majority found their coursework to be "somewhat challenging," regardless of their HEB exposure. The relationship between STEM majors' HEB exposure and perceived preparation for science coursework was weakly positive, but not significant at the $p = .05$ level, though it was stronger and more significant than the association between HEB exposure and students' perceptions of the ease of their coursework.

Among STEM majors with high HEB exposure, a relatively higher proportion (37.0%) of students felt "extremely prepared" compared to the proportion of students with no HEB exposure (24.1%) who felt extremely prepared. Likewise, a relatively lower proportion of students (9.0%) in the high HEB exposure group felt "extremely unprepared" than in the no HEB exposure group (13.8%). The relationship between K-12 HEB exposure and students' perceived preparedness for undergraduate science coursework was found to be significant for STEM majors who had completed two or more undergraduate courses related to evolution, $r_s(132) = .188$, $p < .05$, but K-12 HEB exposure was not correlated with GPA, even for this group.

Some of the interviewed students discussed whether they felt prepared for their undergraduate science coursework and their statements also suggested there is a relationship between K-12 evolution education and perceived preparedness for science coursework. Participant 108 was a Junior and a Biology major at ASU who graduated from a public high school in Wisconsin where she completed four science classes, including a regular biology class and an AP Biology class. She transferred to ASU from the University of Wisconsin where she had completed one biology course. She had a high religion factor and high evolution and human evolution acceptance. Though she had high exposure to general evolutionary biology education in K-12, she had no formal K-12 exposure to HEB. At the time of the interview, she was enrolled in BIO188: General Biology II at ASU, for which she ultimately earned a C. Her transcript indicated that she earned a C or C+ in all of her undergraduate courses that semester and in the following semester. She said:

- My major is biological sciences, but specializing in ecology and evolution and obviously evolution played a big part in what I want to do, more from the stand point of evolution of bacteria and how it's evolved into what it is today and how it affected the evolution of other things. I actually find that my advanced biology class my senior year [of high school] has been much more in depth and specific than my general biology courses in college have been. So, yeah, I think I was definitely prepared (Participant 108).

This is an example of a student who had a relatively low GPA, but who perceived herself as well-prepared for her undergraduate coursework. At the time of the interview, she reported, “I enjoy biology in all aspects, so I want a career that serves my interest and lets me continue learning” (Participant 108). Three years after the interview, she had graduated with a B.S. in Biology and was enrolled in a master's degree program in Geosciences. This student demonstrates that success in the STEM pipeline is not solely contingent on letter grades, but on students' interest and perceived preparation for study in a STEM discipline.

Participant 7096 was a first-year student at ASU with transfer credits from a community college and was dual-majoring in Secondary Education and Biology. She graduated from a public high school in Arizona where she completed four science classes including one year each of biology, chemistry, physics and astrophysics. She had high K-12 HEB exposure in her biology class; she said "I think that was the biggest topic we covered in evolution and, obviously, you know, just change and different species, as well" (Participant 7096). She had a high religion factor and moderate evolution and human evolution acceptance, saying, "At this point, I'm still kind of undecided" regarding her acceptance of human evolution (Participant 7096). Regarding her preparation for undergraduate coursework in biology, she said:

- I felt really prepared. My bio teacher in high school was great. All the topics we're covering in BIO 187 [General Biology I] we covered in high school, just not as in as great detail. So, I felt very comfortable coming into college and taking these courses. I think [introductory level courses at ASU] are appropriately challenging for people who have taken biology before. Having biology freshman year [in high school] prepared me very well. But for someone who hasn't taken biology before, they certainly shouldn't be in that class. The concepts are introduced so fast and in such depth that you have to have some idea of what you're going into...unless you're going to stay up every night reading the textbook and a lot of students don't have time for that with all their classes. I believe it's challenging for students coming in who haven't taken it before. (Participant 7096).

This student earned a grade of A in General Biology I and, in the following semester, a C in General Biology II. General Biology I, at the time of the interviews, was the introductory biology course at ASU that had evolutionary biology as its focus. General Biology II focused on human physiology and cell biology. She earned As or Bs in her other science courses those semesters. One year after the interview, she was enrolled in Organic Evolution, Biology of Microorganisms, and Fundamentals of Ecology (grades were not available for these courses). This participant's experience supports the idea that, for some students, exposure to evolutionary biology in high school can better prepare them for introductory level science coursework that specifically addresses evolutionary biology, which would contribute to the students' actual and/or perceived academic achievement, which, in turn, might encourage them to persist in the STEM pipeline.

Participant 365 felt unprepared for her undergraduate course in biology. At the time of the interview, she was a 23 year old post-baccalaureate student. After attending a public high school for 1.5 years, she enrolled in and graduated from a private high school in California. She completed five years of high school science, including biology, human anatomy, physics, chemistry and AP Chemistry. She had a moderate religion factor and high acceptance of general and human evolution. She had no formal K-12 HEB exposure and minimal general evolutionary biology exposure. During the final year of her Bachelor's degree program at the University of Arizona (as a dual-major in English and Political

Science) she took an astronomy course to meet a general science requirement. The astronomy course included some discussion of evolution; this course "sparked" her interest in science and she was returning to school at ASU to take pre-requisite coursework for medical school or pharmacy school. Regarding her preparation for biology coursework at ASU, she said:

- … I do find myself struggling a lot with the biology class because I'm not … used to this type of thought process yet and it's always kind of a struggle for me to study. But … I think I enjoy it enough that I propel myself to do it, at least; but definitely [high school] didn't prepare me at all, I think (Participant 365).

Despite her feeling that she was unprepared for the course, this student earned an A in General Biology I. She also earned an A in General Biology II and no less than a B in her other science coursework. For this student, a lack of evolutionary biology education in high school made her college coursework more challenging, but did not noticeably affect her grade-based achievement or deter her from pursuing a STEM degree; she graduated from ASU with a Bachelor of Science three years after the interview. This suggests that STEM persistence might depend more on letter grades for those students who perceive challenges to learning than for the students who feel well-prepared for coursework.

STEM interest and motivation: Hypothesis testing. The results of the qualitative analysis led to the following null hypotheses regarding students' interest in STEM:

- H_0 = There is no relationship between K-12 HEB exposure and interest in a STEM degree program.

- H_0 = Religion factor, general evolution acceptance and human evolution acceptance do not predict interest in a STEM degree program.
- H_0 = For students interested in a STEM degree program and motivated to pursue a STEM career, HEB exposure was not associated with intrinsic motivating factors (e.g., self-identified curiosity or compassion for animals or other people).

Due to the statistically significant relationship with a strong effect between students' interest in a STEM degree and motivation to pursue a STEM career, χ^2 (1, N = 434) = 315.972, $p < .001$, r = .853 (see Table 20), the first two hypotheses were also tested for students' motivation to pursue a STEM career to substantiate this association.

There was a modest association between HEB exposure and students' interest in a STEM degree program, χ^2 (3, N = 443) = 8.564, $p < .05$, Cramer's V = .134, 95% CI [.070, .234]. As can be seen in Table 41 below, there was a greater proportion of students in the moderate and high HEBEXP groups who were STEM majors (or planned to declare a STEM major) compared to the proportion of STEM majors in the no and low HEBEXP groups. Students' interest in a STEM degree program was not useful for predicting HEBEXP (λ = .000), but HEBEXP did reduce the prediction error for STEMDEG by 1.3%. The only statistically significant result when comparing proportions of students interested in STEM versus non-STEM degrees was for the moderate HEBEXP group which comprised students with more STEM (63%) than non-STEM interest.

Table 41

*HEBEXP * STEMDEG cross-tabulation*

		Interest in a STEM degree program		
		No	Yes	Total
Human evolutionary biology exposure	None	42_a	33_a	75
		56.0%	44.0%	100.0%
	Low	54_a	57_a	111
		48.6%	51.4%	100.0%
	Moderate	29_a	57_b	86
		33.7%	66.3%	100.0%
	High	95_a	109_a	204
		46.6%	53.4%	100.0%
Total		220	256	476
		46.2%	53.8%	100.0%

χ^2 (3, N = 443) = 8.564, $p < .05$, Cramer's V = .134, 95% CI [.070, .234]
Note. Each subscript letter denotes a subset STEMDEG whose column proportions do not differ significantly from each other at the .05 level.

The relationship between HEB exposure and students' motivation to pursue a STEM career was not significant at the .05 level. The moderate HEBEXP group was the only group with a significantly higher proportion of students motivated to pursue a STEM career (71.3%) than not (Table 42). A greater proportion of students desired a STEM career in the low HEBEXP group than in the high HEBEXP group, though this difference was not significant.

There was not a statistically significant relationship between HEB exposure and religion factor, general evolution acceptance or human evolution acceptance (see Table 31 on page 156). Likewise, there was no relationship between these variables and students' interest in a STEM degree program. Students' motivation to pursue a STEM career was not related to their religion factor or acceptance of general evolution. A significant result was obtained,

Table 42

*HEBEXP * STEMCAR cross-tabulation*

		Motivation to pursue a STEM career		
		No	Yes	Total
Human evolutionary biology exposure	None	33_a	33_a	66
		50.0%	50.0%	100.0%
	Low	43_a	62_a	105
		41.0%	59.0%	100.0%
	Moderate	23_b	57_a	80
		28.7%	71.3%	100.0%
	High	81_a	111_a	192
		42.2%	57.8%	100.0%
Total		180	263	443
		40.6%	59.4%	100.0%

Note. Each subscript letter denotes a subset STEM career motivation whose column proportions do not differ significantly from each other at the .05 level.

however, for the association between students' motivation to pursue a STEM career and their acceptance of human evolution, χ^2 (3, N = 443) = 8.740, p < .05, Cramer's V = .138, 95% CI [.071, .248] (Table 43). Among HEACCEP groups, the group with the greatest proportion of students interested in a STEM career was the high HEACCEP group (64.4%). An examination of the data shows, though, that an increase in human evolution acceptance did not directly correspond with an increased likelihood of wanting to pursue a STEM career, as the moderate HEACCEP group had a lower proportion of students interested in a STEM career than did the lower HEACCEP groups.

Binary logistic regression analyses incorporating sex, age, academic aptitude, religion factor, ethnicity, high school region and HEB exposure were conducted to predict students' interest in a STEM degree program and

Table 43

*HEACCEP * STEMCAR cross-tabulation*

		Motivation to pursue a STEM career		
		No	Yes	Total
Human evolution acceptance	0 = Lowest	12_a	16_a	28
		42.9%	57.1%	100.0%
	1	18_a	26_a	44
		40.9%	59.1%	100.0%
	2	57_b	53_a	110
		51.8%	48.2%	100.0%
	3 = Highest	93_b	168_a	261
		35.6%	64.4%	100.0%
Total		180	263	443
		40.6%	59.4%	100.0%

Note. Each subscript letter denotes a subset of STEMCAR whose column proportions do not differ significantly from each other at the .05 level.

motivation to pursue a STEM career. The predictive capacity of the final model for interest in a STEM degree program (57.7%) was only slightly higher than that of the null model (55.2%) and it explained just 4.2% of the variation in the dependent variable, χ^2 (12, N = 442) = 14.235, p = .286. The only significant predictor of interest in a STEM degree program among these independent variables was ethnicity; students of Asian heritage were 2.482 times as likely to be interested in a STEM degree program than Caucasian students, Wald χ^2 (1) = 7.455, $p < .01$. Controlling for ethnicity, the only group for which there was a noteworthy relationship between HEB exposure and interest in a STEM degree was for the students identified as Hispanic, Latino, Spanish, Mexican or Chicano (n = 48); though this result was not statistically significant at an alpha level of .05 (p = .062), data from student interviews support this finding.

Nine interviewed students self-identified as Hispanic or Latina. Four of them had high K-12 HEB exposure and were STEM majors in the life sciences. One student had moderate HEB exposure and was a pre-medical student. Two of the three students with minimal HEB exposure were STEM majors; one was a computer science major and the other was a freshman interested in obtaining a degree in Global Health. The third student with minimal HEB exposure was majoring in Business Management. The Hispanic student with no K-12 HEB exposure was majoring in film studies.

Participant 1192 was the Latina student who had minimal K-12 HEB exposure but wanted to pursue a degree in Global Health and become a doctor. She was a freshman at ASU at the time of the interview. She was born in Ecuador and moved to the United States at the age of 8. She had a high religion factor, was undecided about general evolution and did not accept human evolution. She attended public middle school and graduated from a public high school in Arizona where she completed one biology class and, during her senior year, a Certified Nurses Assistant program. When asked about her experience learning about the concept of evolution she said:

- ...throughout middle school and high school, I did not even hear of evolution until I came [to ASU]. Or [took] anthropology. That's the first time I heard it, like the whole evolution part. ...I knew that there was like Lucy and all of that stuff, I knew that whole thing from teachers and stuff that said that...back in high school, but I never learned the whole evolution thing. And...once [my anthropology professor] told me...that Lucy's our ancestor or something like that [and] I was like, "Oh God, this is not real. I don't believe it...because [pause] I don't believe it at all." But, it was interesting to learn about how...they dig up fossils and stuff like that and how they keep finding stuff. But from my religion, I don't believe it (Participant 1192).

Despite the fact that this student, or this student's high school teacher, did not make the connection between fossil hominins and human evolution, and this student rejected human evolution based on her religious beliefs, she still noted that the element of discovery in the field of paleoanthropology was interesting to her. But that did not encourage her to pursue a STEM degree; when asked about her interest in a Global Health degree and practicing medicine, she said:

- 'Cause I did a health care class in my senior year, in, um, CNA—Certified Nursing Assistant. So, I learned a lot in that class...health class was so much fun. I learned the heart, all the different diseases and after that I was like, "Oh my God, I want to be a doctor" (Participant 1192).

The student was then asked if she learned about bacteria and how they become resistant to antibiotics in her high school health class. She responded:

- Yes, [my teacher] did...a whole section about that. How...certain antibiotics don't work for certain ones because they won't, uh, they're not affected, there are some [that]...actually make it, like, increase what they are; so, she did a whole section on that (Participant 1192).

This student is an example of how learning about human biology and evolution, though not necessarily human evolutionary biology, can foster students' interest in a STEM degree, particularly in the life sciences (even if they do not realize that they are learning about evolution).

This student also shared that she previously had brain cancer; for some interviewed students, personal experiences with illness in their family were a factor that contributed to students' desire for a STEM career. But, for this student, her experience with cancer was what led her and her family to become highly religious. She also shared that she felt, after going through chemotherapy, God had healed her. When asked how she would reconcile her faith and her knowledge of science in medical practice, she said:

- I don't think that would be a good thing to do—if I become a doctor—to put my religion...with the medicine I'm practicing, 'cause that just wouldn't be right 'cause I'm pretty much, like, I wouldn't do that 'cause that's my religion and that has nothing to do with the patients or anything like that, or whatever my teachers do teach me—like, my professors...throughout my whole life here at ASU—and that's not going to change anything of my religion. But I'm not going to stop doing anything [religious] 'cause I need to become a doctor (Participant 1192).

Exposure to human biology and an interest in human biology is not always enough to encourage students to pursue a STEM degree. Recall Participant 5886, the student majoring in Business Management, who was quoted earlier; she had minimal HEB exposure, but completed AP Anatomy and Physiology her senior year of high school. Though human biology proved to be interesting to her, she was not pursuing a STEM degree at ASU. Regarding her high school science class experience she said:

- [Science was] somewhat appealing. I really didn't like it. I took chemistry and I hated it. I never was interested in physics at all. I'm definitely not a "science person..."

This student became convinced in high school she was not a "science person" because she struggled with chemistry. Someone who lacks confidence in his or her ability to "do science" may be less likely to be motivated to pursue further STEM learning, despite any interest in the subject. This student was successful in her AP Anatomy and Physiology class, but, unlike Participant 1192, this did not positively influence her interest in a STEM degree program or career, perhaps because she completed the course after taking chemistry:

- And then it was opposite for when I took a [12th grade] human anatomy class. It was an AP class. And I totally loved that better... So, it was...I did well in [human anatomy], I got an A in that, as opposed to a C in chemistry...I definitely like more...the anatomy and physiology and how the body works because it's something, you know—I'm a human—all these functions are a part of me. I'm definitely more interested in that, as opposed to the chemical compounds of molecules and stuff like that. I like more the anatomy and learning about my muscles and how this works and what chemicals make your body do this and that. Definitely I'm more interested in that...I learned about [evolution and human evolution] when I took my anatomy class, which was my senior year in high school, and we went to Body Worlds. It was all body functions [and] that was very awesome (Participant 5886).

Perhaps because this student was not exposed to human biology until 12th grade and after having a self-described negative experience in a previous science class, her success and interest in the subject did not encourage her to pursue a STEM degree. Evidence from her undergraduate academic records suggests that she may have been a successful STEM degree student. The two courses she completed to meet ASU science course requirements were Plant Biology and Introduction to Geology; she earned an A in both courses. Interestingly, she primarily earned Bs in the business-related courses she completed in her first three years of college. She graduated with a B.S. in Business Management.

These data demonstrate that the relationship between K-12 human evolutionary biology education and students' interest in a STEM degree program depends on multiple factors which include but are not limited to how the science of human evolutionary biology is taught, when students are exposed to it, and students' perceived abilities in STEM. Regardless, students consistently reported that they found human biology and human evolutionary biology interesting. Exposure to human anatomy and physiology education, with or without an evolutionary component, seemed to be most associated with interest in a life science degree program.

The predictive capacity of the final binary logistic regression model for motivation to pursue a STEM career (61.7%) involving sex, age, academic aptitude, religion factor, ethnicity, high school region and HEB exposure was only slightly higher than that of the null model (60.3%) and it explained just 3.7% of the variation in the dependent variable, χ^2 (12, N = 413) = 11.311, p = .502. There were no significant predictors of motivation to pursue a STEM career, even when the model was reduced via backward stepwise (LR) regression.

Though HEB exposure was not directly correlated with students' motivation to pursue a STEM career, other motivating factors revealed an indirect relationship between HEB exposure and STEM career motivation. The study participants with STEM interest who were wanted to pursue a STEM career (including medical, teaching, research, or industry jobs) were asked to identify the degree to which different factors influenced their motivation to follow a STEM path (Appendix G). Recognition of STEM as a way to help animals or people or acknowledgement of a personal long-term curiosity about the world were considered intrinsic factors contributing to STEM career motivation. Extrinsic factors included engagement with various media (e.g., television, movies, or books), a particular class or teacher, informal science learning (e.g., in zoos, aquaria, or museums), a student's parents' jobs or hobbies, a student's own job, a student's desire for a specific career, a student's illness, or the illness of a student's friend or family member. Based on the interviews with students, the following null hypothesis was generated:

- H_0 = For students interested in a STEM degree program and motivated to pursue a STEM career, HEB exposure was not associated with intrinsic motivating factors.

When completing the online survey, students reported whether a factor had *no influence*, *some influence*, or *a lot of influence* on their interest. For all STEM majors in the study, the factors that made the most notable contribution to their motivation to pursue a STEM career (i.e., those for which the greatest proportion of students reported that the factor had *a lot of influence*) were the students' *personal interest in or curiosity about the world* (CURIOUS; 78.2%), *a desire to help other people* (HELPPEOP; 77.5%), *a K-12 teacher* (43.7%), *a K-12 class* (42.3%), *documentary and nonfiction television* (43.3%), and *a university course* (42.3%).

The variables representing potential intrinsic motivators included CURIOUS, HELPPEOP, and HELPANIM (*a desire to help animals*). For each variable, a clustered bar chart shows the relationship between students' responses and their HEB exposure (Figures 38, 39, and 40). In all three cases, the high HEBEXP group had the highest proportion of students who reported that the intrinsic motivator had a lot of influence on their motivation to pursue a STEM career.

Approximately 44% of the students who reported that their own curiosity had a lot of influence on their motivation to pursue a STEM career were in the high HEBEXP group, whereas 13.2% had no HEB exposure, 22.8% low HEB exposure and 20.1% had moderate HEB exposure. But, this difference among the HEBEXP groups was not statistically significant, χ^2 (6, N = 243) = 3.824, p = .70, and there was not a significant correlation between CURIOUS and HEBEXP (Figure 38 and Table 44).

Similar results were obtained for students' desire to help animals (Figure 39 and Table 45). Approximately 50% of the students who reported that a desire to help animals had a lot of influence on their interest in STEM were in the high HEBEXP group, whereas 14.7% had no HEB exposure, 14.7% had low HEB exposure and 20.0% had moderate HEB exposure. This difference among groups was not significant, χ^2 (6, N = 243) = 10.841, p = .093, and there was not a significant correlation between HEBEXP and HELPANIM.

There was a significant correlation between HEBEXP and the variable HELPPEOP, $r_s(243) = .175$, 95% CI [.062, .294], $p < .01$, $\tau = .157$, 95% CI [.055, .267] (Figure 40 and Table 46). For the 75 students who reported that a desire to help people had a lot of influence on their interest in STEM, 48.7% of them had high HEB exposure. This result suggests that exposure to human evolutionary biology education influences students' perspectives in some way that inspires

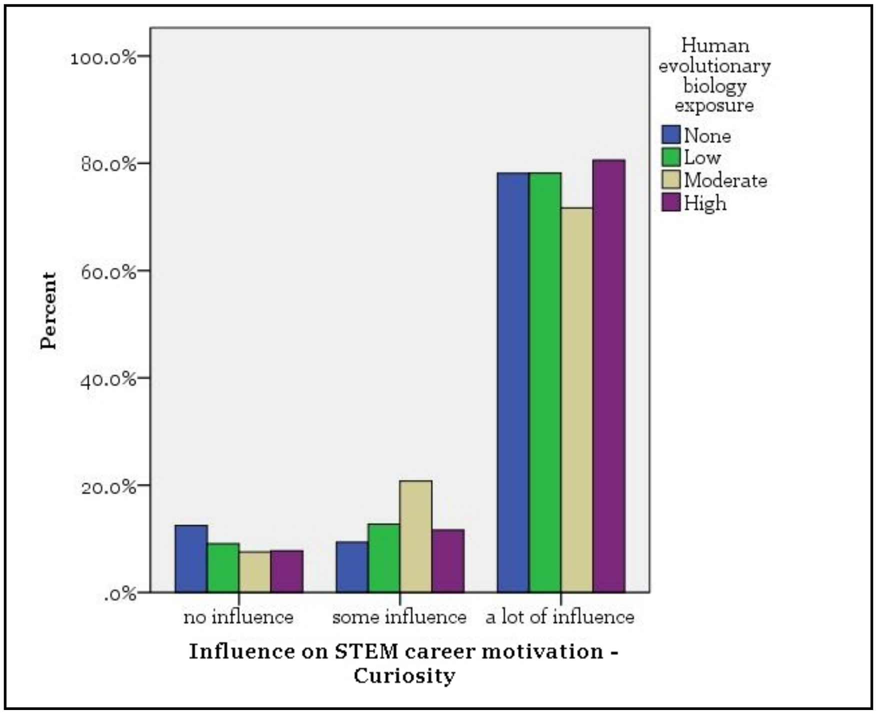

Figure 38. Comparison of the influence of self-reported curiosity on students' motivation to pursue a STEM career for human evolutionary biology exposure groups.

Table 44

*HEBEXP * CURIOUS cross-tabulation*

		Influence on STEM interest -- Curiosity			
		no influence	some influence	a lot of influence	Total
HEB exposure	None	4	3	25	32
		12.5%	9.4%	78.1%	100.0%
	Low	5	7	43	55
		9.1%	12.7%	78.2%	100.0%
	Moderate	4	11	38	53
		7.5%	20.8%	71.7%	100.0%
	High	8	12	83	103
		7.8%	11.7%	80.6%	100.0%
Total		21	33	189	243
		8.6%	13.6%	77.8%	100.0%

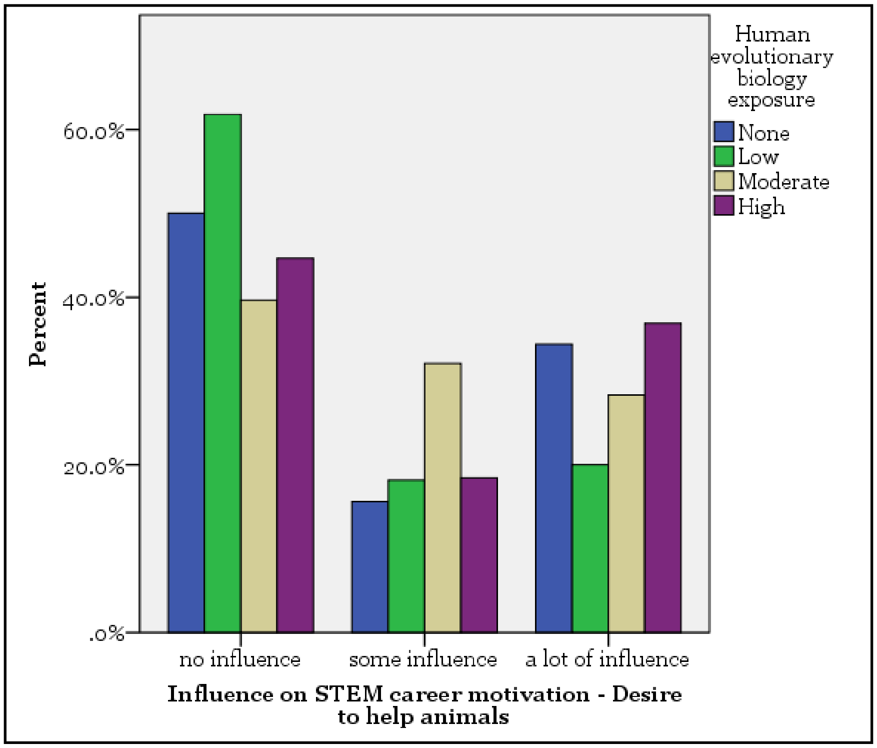

Figure 39. Comparison of the influence of a desire to help animals on students' motivation to pursue a STEM career for HEB exposure groups.

Table 45

*HEBEXP * HELPANIM cross-tabulation*

		Influence on STEM interest — Desire to help animals			
		no influence	some influence	a lot of influence	Total
HEB exposure	None	16	5	11	32
		50.0%	15.6%	34.4%	100.0%
	Low	34	10	11	55
		61.8%	18.2%	20.0%	100.0%
	Moderate	21	17	15	53
		39.6%	32.1%	28.3%	100.0%
	High	46	19	38	103
		44.7%	18.4%	36.9%	100.0%
Total		117	51	75	243
		48.1%	21.0%	30.9%	100.0%

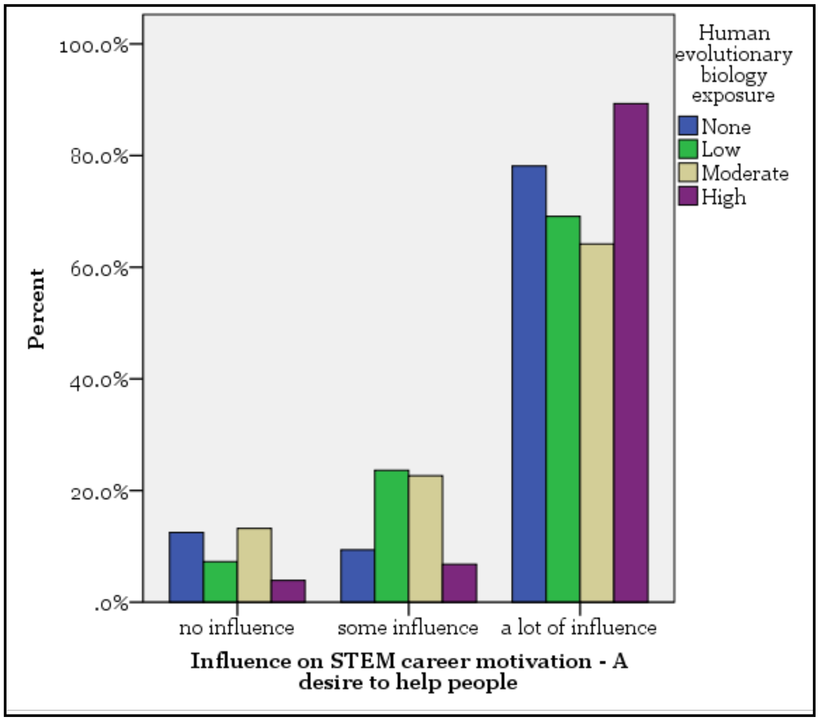

Figure 40. Comparison of the influence of a desire to help people on students' motivation to pursue a STEM career for HEB exposure groups.

Table 46

*HEBEXP * HELPPEOP cross-tabulation*

		Influence on STEM interest – Desire to help people			
		no influence	some influence	a lot of influence	Total
HEB exposure	None	4	3	25	32
		12.5%	9.4%	78.1%	100.0%
	Low	4	13	38	55
		7.3%	23.6%	69.1%	100.0%
	Moderate	7	12	34	53
		13.2%	22.6%	64.2%	100.0%
	High	4	7	92	103
		3.9%	6.8%	89.3%	100.0%
Total		19	35	189	243
		7.8%	14.4%	77.8%	100.0%

$r_s(243) = .175$, 95% CI [.062, .294], $p < .01$

some of them to want to help other people and many of those students see STEM careers as an effective way to do so.

Table 64 (see p. 297) summarizes the findings presented in this chapter. There were significant relationships between students' HEB exposure and some aspects of their high school science class enrollment. The hypothesis that students with high HEB exposure will complete 3 or more years of high school science including one or more years of biological science (HSSCI) was not fully supported. HEBEXP, along with age and ethnicity, contributed significantly to a logistic regression model used to predict HSSCI, but approximately 10% of students with high HEB exposure did not complete those particular classes. Completing three or more years of science including one or more years of biological science was a better predictor of HEB exposure than HEB exposure was of completing those classes.

The hypothesis that HEBEXP is correlated with GPA for students enrolled or interested in a STEM degree program was not supported; however, HEB exposure was associated with students' perceived preparedness for undergraduate coursework, particularly for those students who completed two or more undergraduate coureses that address evolutionary biology.

The hypothesis of an association between students' HEB exposure and interest in a STEM degree program was supported. As hypothesized, there was no relationship between students' interest in a STEM degree program and their religion factor, general evolution acceptance or human evolution acceptance. Likewise, there was no relationship between students' motivation to pursue a STEM career and religion factor or general evolution acceptance. The hypothesis of no association between students' human evolution acceptance and their motivation to pursue a STEM career was not supported. There was no direct association between HEBEXP and students' motivation, but students with high HEB exposure were more likely to say that they wanted to pursue a STEM career to help other people than were students with less HEB exposure.

Socioscientific decision-making: Hypothesis testing. As discussed in Chapter 5, it was necessary to consider students' total human evolutionary biology exposure for this part of the analysis. Therefore, a categorical variable, TOTALHEB, was generated to account for *students' total K-12 and undergraduate academic exposure to human evolutionary biology*. Undergraduate exposure was assessed based on students' responses to questions about the courses they completed as undergraduates (Appendix C). For example, students who completed courses such as ASM 104: Bones, Stones and Human Evolution were placed in the high HEB exposure group.

Table 30 on page 213 and Figure 41 summarize the participants' total HEB exposure. Seventy-eight of the 280 students who had moderate K-12 HEB exposure or less had high HEB exposure as undergraduates, so 284 (58.4%) of the 486 study participants had high total HEB exposure. Bootstrapping was used in many of the following analyses to account for the fact that the majority of students were in the high TOTALHEB group; therefore, confidence intervals are reported when appropriate.

Table 47 identifies the socioscientific issues about which students were surveyed and the categorical variables that were used in the analyses to assess students' decision-making about those issues (also see Appendix G). Other data that provided more information about students' views, habits, education, and

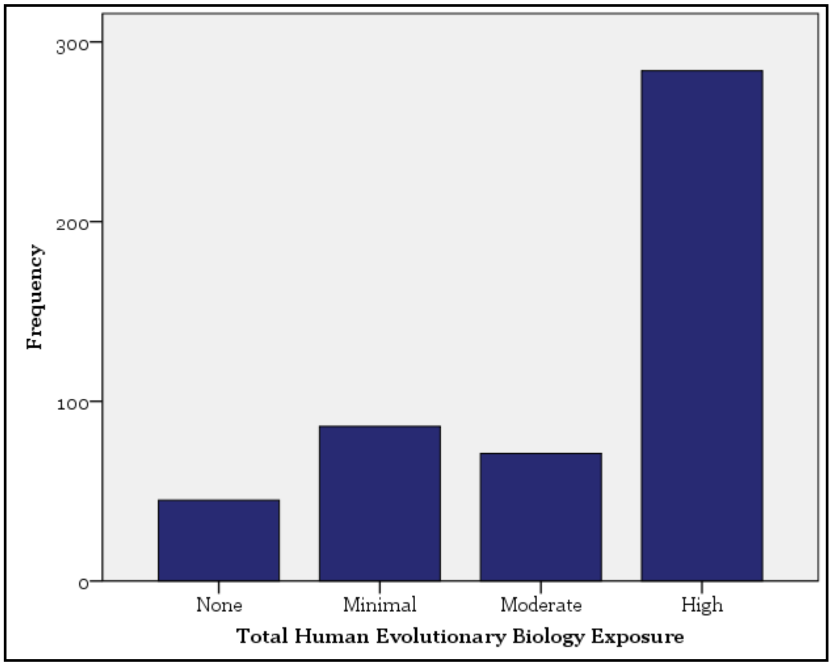

Figure 41. Participants' total human evolutionary biology exposure.

Table 47

Socioscientific issues and actions

Socioscientific issue	Variable label
Voting in the U.S. Presidential election	VOTEPRES
Global warming as a problem	WARMPROB
Causes of global warming	WARMING
Environmentally conscious actions	ENVIRO [a]
U.S. immigration	IMMIG [a]
Same-sex relationships	SAMESEX [a]
Ape and monkey poaching	APES1
Ape habitat conservation	APES2
Drug testing with chimpanzees	APES3
Antibiotic use	ANTIBIOT
Birth control use	BIRTHCON
Human overpopulation	OVERPOP
Human cloning	CLONING
Federal funding for stem cell research	STEMRES
Vaccination of children	VACCINES

Note. See Appendix G for variable values.
[a] These variables were based on students' responses to multiple survey questions.

scientific knowledge and that could potentially predict students' decision-making were also collected (Table 48). These data contributed to hypothesis testing and assisted with the interpretation of the statistical results regarding decision-making.

Table 48

Additional variables for analyses of students' socioscientific decision-making

Variable Label	Variable
Engagement with general news media	NEWS
Engagement with science news and media	SCIMEDIA [a]
Following issues in government and public affairs	GOVFOLLO
Current event awareness	CEAWARE
Registration to vote in U.S. elections	VOTEREG
Belief in divine creation of humans	DIVINE
H.S. exposure to climate change science education	CLIMATE
Awareness of effects of DNA mutations	MUTATE
Explanation for skin color diversity (Bible-based)	BABEL
Explanation for skin color diversity (science-based)	SKINSCI
Views on humans' relationship to apes	REAPES4 [a]
H.S. exposure to stem cell science education	STEMCELL

Note. See Appendix G for variable values.
[a] These variables were based on students' responses to multiple survey questions.

The results of the quantitative analysis supported many of the theories and hypotheses that were based on student interviews. They also demonstrated that undergraduate students' actions and decision-making regarding socioscientific issues can be tied to sociocultural experiences and beliefs as much as or more than to education-based knowledge and habits of mind.

Engagement with news media. Based on the qualitative analysis of student interviews, the following null hypothesis was generated regarding students' interaction with general and scientific news media and their awareness of current events related to socioscientific issues:

- H_0 = There is no relationship between total HEB exposure and engagement with news media outlets including television, print journalism and online news (exposure to information about current events).

The proportion of students with moderate to high HEB exposure who regularly *engaged with general news media* (NEWS) was higher than that for students with no or low HEB exposure, however there was not a significant association between TOTALHEB and NEWS based on a chi-square test, χ^2 (3, N = 483) = 3.116, p = .374 (Table 49). A test involving just the no HEB exposure and high HEB exposure groups showed even less association between the variables, χ^2 (3, N = 326) = 2.617, p = .141.

Table 49

*TOTALHEB * NEWS cross-tabulation*

		Engagement with general news media		
		Not regular	Regular	Total
Total HEB exposure	None	29	16	45
		64.4%	35.6%	100.0%
	Minimal	49	37	86
		57.0%	43.0%	100.0%
	Moderate	35	36	71
		49.3%	50.7%	100.0%
	High	148	133	281
		52.7%	47.3%	100.0%
Total		261	222	483

χ^2 (3, N = 483) = 3.116, p = .374

It was hypothesized that students' engagement with general news media should be correlated with their *awareness of current events* (CEAWARE). The variable that was used to assess students' current event awareness was based on their response to just one question that was used in both rounds of the survey and only 21 of 483 students were not aware of the event (the oil spill in the Gulf of Mexico). There was no relationship between students' engagement with general news media and their awareness of the oil spill; additional statistical analyses involving this variable were not performed.

Students were asked how often they *followed events in government and public affairs* (GOVFOLLO; Table 50). Students' responses were significantly associated with how often they engaged with general news media, χ^2 (3, N = 479) = 124.328, $p < .001$, Cramer's V = .509, 95% CI [.434, .588]. The value of lambda (λ) for engagement with general news media as the dependent variable, $\lambda = .419$, 95% CI [.307, .520], was higher than lambda for GOVFOLLO as the dependent variable, $\lambda = .085$, 95% CI [.007, .165], which shows GOVFOLLO better predicts NEWS than NEWS predicts GOVFOLLO. Using GOVFOLLO to predict NEWS yields a 20.4% reduction in prediction error, 95% CI [15.3%, 27.6%].

Table 50

Participants' frequency of following events in government and public affairs (GOVFOLLO)

		Frequency	Valid Percent
Follow events in government and public affairs	Hardly at all	85	17.6
	Only now and then	130	27.0
	Some of the time	176	36.5
	Most of the time	91	18.9
	I don't know	4	
Total		486	100.00

A correlation analysis of the ordinal variables TOTALHEB and GOVFOLLO found a weak significant relationship between students' HEB exposure and the frequency with which they follow events in government and public affairs, $r_s(482) = .103$, $p < .05$, Kendall's tau-b (τ) = .089, 95% CI [.009, .165] (Table 51). Kendall's tau-b, a nonparametric symmetric measure of the strength of a correlation that ranges from -1 to 1, was equivalent to Somers' d calculated as a symmetric measure. Somers' d is a measure of association, or statistical dependence, that ranges from -1 to 1 and SPSS gives both symmetric and asymmetric versions. Somers' d for TOTALHEB as the dependent variable was .080, 95% CI [.008, .150], whereas Somers'd for GOVFOLLO as the

Table 51

*TOTALHEB * GOVFOLLO cross-tabulation*

		Frequency of following events in government and public affairs				
		Hardly at all	Only now and then	Some of the time	Most of the time	Total
Total HEB exposure	None	10	13	13	7	43
		23.3%	30.2%	30.2%	16.3%	100.0%
	Minimal	20	25	29	11	85
		23.5%	29.4%	34.1%	12.9%	100.0%
	Moderate	11	20	25	15	71
		15.5%	28.2%	35.2%	21.1%	100.0%
	High	44	72	109	58	283
		15.5%	25.4%	38.5%	20.5%	100.0%
Total		85	130	176	91	482
		17.6%	27.0%	36.5%	18.9%	100.0%

$r_s(482) = .103$, $p < .05$, $\tau = .089$, 95% CI [.009, .165] dependent variable was .098, 95% CI [.010, .183], demonstrating that TOTALHEB is a somewhat better predictor of GOVFOLLO than is GOVFOLLO of TOTALHEB, though both values are quite low.

Students were asked how often they *engaged with various types of science-based media*, including scientific television programming, science websites and blogs, and print science journalism (SCIMEDIA; Table 52). The same analyses presented above were performed to test for an association between SCIMEDIA and the variables NEWS, GOVFOLLO, and TOTALHEB. Students' engagement with science news and media was significantly associated with how often they engaged with general news media, χ^2 (3, N = 483) = 56.187, $p < .001$, Cramer's V = .341, 95% CI [.270, .425]. Note that, based on the values of chi-square and Cramer's V, this relationship is less strong than the association between GOVFOLLO and NEWS. The value of lambda (λ) for engagement with general news media as the dependent variable, λ = .225, 95% CI [.155, .329], was higher than lambda for engagement with science news and media as the dependent variable, λ = .000, 95% CI [.000, .051], which shows SCIMEDIA

Table 52

Participants' level of engagement with various forms of science news and media (SCIMEDIA)

		Frequency	Valid Percent
Engagement with science news and media	None regularly	263	54.1
	Some regularly	145	29.8
	Many regularly	45	9.3
	All regularly	33	6.8
Total		486	100.00

better predicts NEWS than NEWS predicts SCIMEDIA. Using SCIMEDIA to predict NEWS yields an 8.9% reduction in prediction error, 95% CI [5.5%, 14.2%].

A correlation analysis of the ordinal variables SCIMEDIA and GOVFOLLO found that there is a modest significant relationship between students' engagement with science news media and the frequency with which they follow events in government and public affairs, $r_s(482) = .293$, $p < .001$, $\tau = .258$, 95% CI [.179, .324]. Kendall's tau-b was nearly equivalent to Somers' d calculated as a symmetric measure of statistical dependence; Somers' d for SCIMEDIA as the dependent variable was .236, 95% CI [.161, .298], whereas Somers'd for GOVFOLLO as the dependent variable was .282, 95% CI [.195, .356], demonstrating that SCIMEDIA is an only slightly better predictor of GOVFOLLO than is GOVFOLLO of SCIMEDIA.

A correlation analysis of the ordinal variables TOTALHEB and SCIMEDIA found that there is a modest significant relationship between students' total HEB exposure and their engagement with science news media, $r_s(486) = .152$, $p < .01$, $\tau = .136$, 95% CI [.059 , .211] (Table 53). Kendall's tau-b was equivalent to Somers' d calculated as a symmetric measure of statistical dependence; Somers' d for TOTALHEB as the dependent variable was .135, 95% CI [.059, .210], whereas Somers' d for SCIMEDIA as the dependent variable was .137, 95% CI [.059, .213], demonstrating that TOTALHEB is not a significantly better predictor of SCIMEDIA than is SCIMEDIA of TOTALHEB.

In summary, there was no direct association between students' total academic human evolutionary biology exposure and their engagement with general news media. The best predictor of students' engagement with general

Table 53

*TOTALHEB * SCIMEDIA cross-tabulation*

		Engagement with science news and media				
		None regularly	Some regularly	Most regularly	All regularly	Total
Total HEB exposure	None	30	11	2	2	45
		66.7%	24.4%	4.4%	4.4%	100.0%
	Minimal	58	23	3	2	86
		67.4%	26.7%	3.5%	2.3%	100.0%
	Moderate	34	24	11	2	71
		47.9%	33.8%	15.5%	2.8%	100.0%
	High	141	87	29	27	284
		49.6%	30.6%	10.2%	9.5%	100.0%
Total		263	145	45	33	486
		54.1%	29.8%	9.3%	6.8%	100.0%

$r_s(486) = .152$, $p < .01$, $\tau = .136$, 95% CI [.059, .211]

news media was how often students followed events in government and public affairs. Students' engagement with science news and media was modestly tied to whether they followed events in government and public affairs, therefore, students' engagement with science news and media could be used to reduce prediction error for their engagement with general news media. Student's total HEB exposure was also weakly to modestly associated with their engagement with science news and media. Based on these data, some students in the high total HEB exposure group may have relatively greater awareness of issues presented in general and science-based media outlets than do some students with less total HEB exposure.

Tests of association and correlation were also conducted between GOVFOLLO and SCIMEDIA and students' religion factor and evolution acceptance. There was no association between religion factor and GOVFOLLO.

There was a similar, but inverse, relationship between religion factor and students' engagement with science news and media as there was between students' total HEB exposure and their engagement with science news and media; for RELFACT and SCIMEDIA, $r_s(481) = -.163$, $p < .001$, $\tau = -.142$, 95% CI [-.219, -.068]. Somers' d for RELFACT as the dependent variable was -.153, 95% CI [-.237, -.072], whereas Somers'd for SCIMEDIA as the dependent variable was -.133, 95% CI [-.204, -.064], demonstrating that SCIMEDIA is only a slightly better predictor of RELFACT than is RELFACT of SCIMEDIA.

Another correlation analysis between TOTALHEB and SCIMEDIA was conducted with RELFACT as a layer in the crosstabs procedure. The significant correlation between students' total academic HEB exposure and their engagement with science news and media held for the students in the moderate and high religion factor groups, but did not hold for the students in the no or low religion factor groups. For both the moderate and high religion factor groups, τ was higher than in the previous analysis, suggesting that significant relationships become stronger when religion is accounted for. For the moderate religion factor group, TOTALHEB became a better predictor of SCIMEDIA (Somers' d = .260) than in the previous analysis (Somers' d = .137), but this was not the case for the students in the high religion factor group (Somers' d = .131). These data suggest that among students with moderate to high religion factors, some students who have higher total HEB exposure may also be more engaged with science news and media than other students and be more aware of issues presented via such media outlets.

There was a weak significant association between students' acceptance of general evolution and whether they followed events in government and public affairs, χ^2 (3, N = 482) = 10.342, $p < .05$, Cramer's V = .146, 95% CI [.102, .223]. A correlation analysis of TOTALHEB and GOVFOLLO with general evolution acceptance as a layer showed that the weak significant relationship between TOTALHEB and GOVFOLLO did not hold for students who did not accept evolution. For students who accepted evolution, the relationship was only slightly stronger, but still weak.

There was a weak significant correlation between student's acceptance of human evolution and whether they followed events in government and public affairs, $r_s(482) = .142$, $p < .01$, $\tau = .124$, 95% CI [.063 , .231]. A correlation analysis of TOTALHEB and GOVFOLLO with human evolution acceptance as a layer showed that the weak correlation for TOTALHEB and GOVFOLLO no longer held within any of the human evolution acceptance categories individually. A correlation analysis of students' human evolution acceptance and GOVFOLLO with TOTALHEB as a layer showed that within the no or minimal HEB exposure groups, there is no relationship between human evolution acceptance and GOVFOLLO, but within the moderate and high HEB exposure groups, some students who had higher human evolution acceptance also more regularly followed events in government and public affairs.

There was also a weak significant association between students' acceptance of general evolution and their engagement with science news and media, χ^2 (3, N = 486) = 15.917, $p < .01$, Cramer's V = .181, 95% CI [.127, .250]. A correlation analysis of TOTALHEB and SCIMEDIA with general evolution acceptance as a layer showed that the modest significant relationship between TOTALHEB and SCIMEDIA did not hold for students who did not accept evolution. For students who accepted evolution, the correlation was still significant, but slightly weaker.

There was a modest significant correlation between student's acceptance of human evolution and whether they engaged with science news and media, $r_s(482) = .288$, $p < .001$, $\tau = .259$, 95% CI [.193 , .327]. A correlation analysis of TOTALHEB and SCIMEDIA with human evolution acceptance as a layer showed that the weak to modest correlation for TOTALHEB and SCIMEDIA only held for the highest human evolution acceptance category, and was a slightly weaker correlation than in the previous analysis. A correlation analysis of students' human evolution acceptance and SCIMEDIA with TOTALHEB as a layer showed that there was a modest to moderate significant relationship between human evolution acceptance and SCIMEDIA within each of the TOTALHEB groups except the minimal TOTALHEB group.

In summary, there was a correlation between total academic HEB exposure and engagement with science news and media for some students with moderate to high religion factors, for students who accepted general evolution, and for students with the highest level of acceptance of human evolution. There was also a correlation between total academic HEB exposure and whether students' followed events in government and public affairs for those students who accepted evolution. In other words, there are some cases in which students with relatively high HEB exposure engage with science news and media and follow events in government and public affairs more than other students, which, in turn, may inform their decisions regarding policy-related issues. All correlations were weak to modest.

Voting. The results of the qualitative analysis yielded the following null hypothesis regarding students' voting behaviors:

- H_0 = Among students who are eligible to vote in the United States, there is no relationship between total HEB exposure and voting behavior.

The online survey asked if students were registered to vote in the U.S. (VOTEREG) and if they voted in the 2008 U.S. Presidential election (VOTEPRES; Tables 54 and 55). There was not a significant relationship between total HEB exposure and whether or not students who could register to vote did. Among the 486 participants, 179 were registered and eligible to vote in the Presidential election. Of those students, 87.2% voted and 12.8% did not.

Table 54

Voter registration (VOTEREG)

		Frequency	Percent
Voter registration	Yes, I am registered	349	71.8
	I can register, but have not	118	24.3
	I cannot legally register	11	2.3
	I don't know	8	1.6
Total		486	100.0

There was a modest significant association between total academic HEB exposure and students' voting action, χ^2 (3, N = 179) = 10.570, $p < .05$, Cramer's V = .243, 95% CI [.111, .433] (Table 56). Lambda for total HEB exposure as the dependent variable was nearly zero, $\lambda = .013$, 95% CI [.000, .122], and lambda for voting action as the dependent variable was zero, $\lambda = .000$, 95% CI [.000, .000].

Using TOTALHEB to predict VOTEPRES yielded a 6.8% reduction in prediction error for VOTEPRES, 95% CI [1.8%, 19.1%].

Table 55

Voting action, 2008 Presidential election (VOTEPRES)

		Frequency	Valid Percent
Voting action	Yes, I voted	156	45.7
	No, though I could have voted	25	7.3
	No, I was too young to vote at the time	160	46.9
	Missing	8	
Total		349	100.0

Table 56

*TOTALHEB * VOTEPRES cross-tabulation*

			Voting action in 2008 Presidential election		
			Yes	No, though I could have	Total
Total HEB exposure	None	Count	10	3	13
		Expected Count	11.2	1.8	
		Count %	76.9%	23.1%	100.0%
	Minimal	Count	23	10	33
		Expected Count	28.4	4.6	
		Count %	69.7%	30.3%	100.0%
	Moderate	Count	27	3	30
		Expected Count	25.9	4.1	
		Count %	90.0%	10.0%	100.0%
	High	Count	96	9	105
		Expected Count	90.5	14.5	
		Count %	91.4%	8.6%	100.0%
Total		Count	156	25	181
		Count %	86.2%	13.8%	100.0%

χ^2 (3, N = 179) = 10.570, $p < .05$, Cramer's V = .243, 95% CI [.111, .433]

Students' voting behavior was also compared to sex, age, ethnicity, high school region, academic aptitude, religion factor, general evolution acceptance, and human evolution acceptance. Only age, χ^2 (3, N = 179) = 10.134, $p < .017$, Cramer's V = .238, 95% CI [.125, .428], and ethnicity, χ^2 (3, N = 179) = 10.269, $p < .036$, Cramer's V = .241, 95% CI [.118, .465] were significantly associated with students' voting action, and weakly so. A binary logistic regression analysis of VOTEPRES was conducted. A model with age, ethnicity, and total HEB exposure as independent variables was significant, χ^2 (3, N = 179) = 17.774, $p < .01$, but only identified total HEB exposure as a significant predictor of voting activity, Wald χ^2 (1) = 6.509, $p < .05$. The model had low predictive capacity, explaining 17.8% of the variation in students' voting action (Nagelkerke R^2), and improving the percentage of correct classification just 1.1% over the null model (87.0%). A lack of sensitivity and specificity in the model may be due in part to the large percentage of students in the sample who did vote.

Students' interest in government and public affairs was positively associated with the likelihood that they would vote in a Presidential election, but only for those students who accepted evolution (regardless of religion factor), χ^2 (2, N = 163) = 9.342, $p < .05$. But HEB exposure was more strongly associated with students' voting in a Presidential election than was their interest in government and public affairs and the former association was not influenced by students' acceptance of evolution. In other words, regardless of religious backgrounds or beliefs, some students who learn about human evolutionary biology are also more likely to vote in a Presidential election, if given the opportunity.

Environment. The interviews as well as the online survey showed that religion factor is particularly influential regarding students' views and actions on environmental issues. Based on the interviews in the qualitative analysis, three null hypotheses were generated that related to the environment:

- H_0 = When holding religion factor constant, there is no relationship between total HEB exposure and students' views on whether human behaviors contribute to global climate change.
- H_0 = When holding religion factor constant, there is no relationship between total HEB exposure and the likelihood that students will identify, favor and engage in specific activities that, based on sound scientific evidence, affect humans' contributions to global climate change.
- H_0 = When holding religion factor constant, there is no relationship between total HEB exposure and the likelihood that students will favor human efforts to conserve biodiversity and natural spaces, such as rain forests.

Students' views regarding conservation and forest preservation are summarized in a later section regarding non-human apes and monkeys.

Students were not only asked their *opinions regarding the causes for global warming* (WARMING), but also *whether global warming is a problem* (WARMPROB). Tables 57 and 58 summarize the responses to each. Twenty four students opined that the Earth is not getting warmer. Fifty-five students said they did not know what their view was regarding the causes of global warming, but more than half of them thought that global warming was a somewhat serious or very serious problem (Table 59). Students who thought that the Earth is getting warmer mostly because of natural changes in the atmosphere were approximately

Table 57

Student views regarding the causes of global warming (WARMING)

		Frequency	Percent	Cumulative Percent
Causes of global warming	The earth is not getting warmer	30	6.2	6.2
	The earth is getting warmer mostly because of natural changes in the atmosphere	133	27.4	33.5
	The earth is getting warmer mostly because of human activity such as burning fossil fuels	268	55.1	88.7
	I don't know	55	11.3	100.0
Total		486	100.0	

Table 58

Student views regarding global warming as a problem (WARMPROB)

		Frequency	Percent	Cumulative Percent
Global warming as a problem	Not a problem	30	6.2	6.2
	Not too serious of a problem	67	13.8	20.0
	I don't know/Neutral	21	4.3	24.3
	A somewhat serious problem	182	37.4	61.7
	A very serious problem	186	38.3	100.0
Total		486	100.0	

split on how much a problem global warming is. Most students who attributed global warming to human activity viewed global warming as a somewhat serious or very serious problem. Six of the students who said that global warming was a somewhat serious problem or a very serious problem also opined that the Earth is not getting warmer, so they were excluded from later analyses due to the inconsistency of their responses. Students who indicated they did not know what their opinion was were excluded as well.

Table 59

*WARMING * WARMPROB cross-tabulation*

		Views on global warming as a problem[a]					
		0	1	2	3	4	Total
Views on global warming cause	The earth is not getting warmer	16 66.7%	8 33.3%	0 .0%	0 .0%	0 .0%	24 100.0%
	The earth is getting warmer mostly because of natural changes in the atmosphere	13 9.8%	44 33.1%	4 3.0%	50 37.6%	22 16.5%	133 100.0%
	The earth is getting warmer mostly because of human activity such as burning fossil fuels	0 .0%	8 3.0%	2 .7%	105 39.2%	153 57.1%	268 100.0%
	I don't know	1 1.8%	7 12.7%	15 27.3%	23 41.8%	9 16.4%	55 100.0%
Total		30 6.3%	67 14.0%	21 4.4%	178 37.1%	184 38.3%	480 100.0%

χ^2 (3, N = 419) = 263.269, p < .001, Cramer's V = .561, 95% CI [.492, .641].
[a] 0 = Not a problem, 1 = Not too serious a problem, 2 = I don't know, 3 = A somewhat serious problem, 4 = A very serious problem

As can be seen in Table 59, there was a strong significant association between whether students thought global warming is happening, the cause students attributed to global warming, and how much of a problem they thought global warming is, χ^2 (3, N = 419) = 263.269, $p < .001$, Cramer's V = .561, 95% CI [.492, .641]. Lambda with students' views on the cause of global warming as the dependent variable was the higher lambda, $\lambda = .340$, and the use of WARMPROB to predict WARMING resulted in a 32.8% reduction in prediction error, therefore, WARMPROB was also used to test for a correlation between students' decision-making about global warming and students' total academic HEB exposure.

Without accounting for religion factor, there was no association between students' views on the causes of global warming and students' total academic HEB exposure. A chi-square analysis with religion factor added as a layer showed that the strongest association between TOTALHEB and WARMING was within the high religion factor group; the greatest proportion of students with a high religion factor who thought that global warming was a result of human action had high total HEB exposure, but this relationship was not significant at the .05 level.

Without accounting for religion factor, there was a weak to modest positive correlation between students' views on whether global warming is a problem and their total academic HEB exposure, $r_s(459) = .100$, $p < .05$, $\tau = .089$, 95% CI [.006, .165]. Somers' d was higher (.094) when WARMPROB was the dependent variable than when TOTALHEB was the dependent variable (.084), indicating that TOTALHEB was slightly better at predicting WARMPROB, but that neither was particularly good for predicting the other.

In the high TOTALHEB group, more students than expected viewed global warming as a somewhat or very serious problem, whereas in the no TOTALHEB group, fewer students than expected thought of global warming as a somewhat or very serious problem. A student with high total HEB exposure was 1.15 times more likely to indicate that global warming was a serious problem than was a student with no HEB exposure. The opposite trend was seen for students who thought global warming was not a problem or not too serious of a problem. A student with no HEB exposure was almost two times more likely to indicate that global warming is not a problem than a student with high HEB exposure.

A partial correlation analysis controlling for religion factor did not change this result; however, a crosstabs analysis with religion factor added as a layer showed that the significant positive correlation between TOTALHEB and WARMPROB was found within the no religion factor group, $r_s(31) = .393$, $p < .05$, $\tau = .35$, and high religion factor group, $r_s(167) = .231$, $p < .01$, $\tau = .203$, and the stronger relationship was a moderate correlation within the no religion factor group. This suggests that students with no influence of religion in their lives are likely to have views that reflect the scientific viewpoints to which they are exposed; this is supported by the fact that their views on global warming are also positively correlated with the frequency of their engagement with science news and media, $r_s(31) = .365$, $p < .05$. And for students who have had the strongest influence of religion in their lives and also think that global warming is a somewhat or very serious problem, their views may be due in part to their human evolutionary biology education.

Students were asked if they were *exposed to the science of climate change in high school* (CLIMATE). The majority of students (76.7%) replied that they were, 18.3% said they were not, and the remaining 5% indicated they did not know. HEB exposure was correlated with CLIMATE, but, there was no relationship between CLIMATE and WARMPROB; the result of a partial correlation analysis of TOTALHEB and WARMPROB did not change if CLIMATE was accounted for, $r_s(436) = .100$, $p < .05$. When CLIMATE was added as a layer to the crosstabs correlation analysis, there was not a significant correlation within any category of CLIMATE.

Age was found to be correlated with students' views on global warming. Older students were more likely to view global warming as a problem or serious problem than younger students, $r_s(459) = .114$, $p < .05$.

Students were also asked how likely they were to make a special effort to behave in a variety of environmentally conscious ways. The students' responses to these questions were subject to factor analysis and internal consistency reliability analysis and a composite variable, ENVIRO, was generated based on the results. Higher scores for ENVIRO indicated a greater *likelihood of students engaging in activities such as recycling, carpooling, bringing their own bags to the grocery store or carrying a reusable water bottle*. More than half of the students (57.1%) fell into the most likely category (Table 60).

Table 60

Likelihood of engaging in environmentally conscious activities (ENVIRO)

		Frequency	Percent	Cumulative Percent
Likelihood of activity	1=Least likely	9	1.9	1.9
	2	48	10.0	11.9
	3	149	31.0	42.9
	4=Most likely	274	57.1	100.0
Total		480	100.0	

Without accounting for religion factor, there was a modest positive correlation between total HEB exposure and the likelihood of students' engaging in pro-environmental behaviors, $r_s(480) = .144$, $p < .01$, $\tau = .130$, 95% CI [.045, .211]. A partial correlation controlling for religion factor produced a similar, though slightly less strong, result, $r_s(480) = .141$, $p < .01$. A crosstabs correlation with religion factor added as a layer showed that the strongest positive correlation between TOTALHEB and ENVIRO occurred within the high religion factor group, $r_s(175) = .174$, $p < .05$, $\tau = .158$. Student's pro-environmental actions were negatively associated with their *belief in divine creation* (DIVINE); students who agreed divine creation is the best explanation for the existence of humans were less likely to engage in environmentally conscious behaviors. The results suggest that students with a high degree of exposure to religion who believe in divine creation are more likely to be concerned about climate change when they have high TOTALHEB exposure than are students with high RELFACT and belief in divine creation and less or no exposure to human evolutionary biology.

A correlation between TOTALHEB and ENVIRO controlling for students' exposure to climate science education was still modestly positive, $r_s(453) = .138$, $p < .01$. When CLIMATE is added to the crosstabs correlation for TOTALHEB and ENVIRO, there is a slightly stronger, though less significant, relationship between for students who were not exposed to climate change science, $r_s(456) = .208$, $p = .052$, $\tau = .186$, than for students who were, $r_s(456) = .112$, $p < .05$, $\tau = .102$, though CLIMATE and TOTALHEB are correlated with each other.

Human evolutionary biology exposure was also positively correlated with environmentally conscious behaviors for students who do not regularly engage with science news media. This demonstrates the potential influence of HEB education on students' actions when access to other sources of scientific information is limited, regardless of the students' religion factor or beliefs about divine creation.

During the student interviews, the researcher asked multiple groups of students whether (regardless of their own personal belief) they thought that humans' obligation to care for the planet was greater if humans are a product of natural evolution or if they were created by a supernatural creator. And, in the online survey, students were asked to respond to the statement, "Divine creation is the best explanation for the existence of humans" on a Likert scale from completely agree to completely disagree (DIVINE). A partial correlation test holding DIVINE constant identified a stronger positive correlation between TOTALHEB and ENVIRO, $r_s(175) = .168$, $p < .01$, than when religion factor was controlled for previously. When DIVINE was added as a layer to crosstabs correlation, there was no significant correlation between TOTALHEB and ENVIRO within any of the individual DIVINE categories.

Skin color diversity. Based on the results of the qualitative analysis, the following null hypotheses were generated:

- H_0 = There is no relationship between total HEB exposure and exposure to scientific explanations for modern human skin color diversity.
- H_0 = There is no relationship between total HEB exposure and students' basic knowledge structure of evolutionary biology concepts.
- H_0 = Holding religion factor constant, there is no relationship between HEB exposure and the likelihood that students will agree that human skin color diversity can be explained by science, rather than by faith-based explanations.

The first hypothesis will not be tested here because early in the analysis of the survey data, it was determined that students' exposure to scientific explanations for human skin color diversity was a reliable indicator of students' exposure to human evolutionary biology, so that datum was included in the set of responses that contributed to the composite variable representing K-12 HEB exposure.

To test the second hypothesis, students were asked to respond to some survey questions about inheritance. The first (INHERIT) asked them to respond with "agree," "disagree," or "I don't know" to the statement, *Children resemble their parents because the children inherited their parents' genetic material (DNA)*. The students' responses were not useful for testing this hypothesis because 473 (97.3%) of the students agreed with the statement. Four students disagreed and nine students said they did not know. They were also presented with the statement, *All DNA mutations are harmful* (MUTATE), and had the same response options as for the previous question. The majority (77.4%) of the students correctly disagreed with this statement, 7.4% agreed and 15.2% did not know how to respond. When the students who responded "I don't know" were included in the analysis, there was a significant association between MUTATE and TOTALHEB, χ^2 (6, N = 486) = 36.409, $p < .001$, Cramer's V = .194, 95% CI [.138, .275]; however, λ was equal to zero regardless of which variable was the dependent variable and each reduced the prediction error of the other by less than 5% (Table 61). There was a noticeable difference among TOTALHEB groups in the proportion of students who responded that they did not know if all mutations are harmful. Approximately three times as many students in the no and minimal HEB exposure groups (28.9% and 30.2%) indicated that they did not know how to respond to the question than in the moderate and high TOTALHEB groups (9.9% for each). When the students who responded that they did not know if all mutations are harmful were excluded from the analysis, the strength of the association was weaker and less significant, χ^2 (3, N = 412) = 8.049, $p < .05$, Cramer's V = .140, 95% CI [.050, .291]. The relative proportion of students who disagreed with the statement also increased with HEB exposure for this group; in the minimal to high HEB exposure groups 90-93% of students disagreed, as opposed to 78.1% of students in the no HEB exposure group. TOTALHEB and MUTATE were not useful for prediction purposes, however, suggesting an additional factor or factors influenced students' responses to this statement.

Table 61

*TOTALHEB * MUTATE cross-tabulation*

		All DNA mutations are harmful.			
		Agree	I don't know	Disagree	Total
Total HEB exposure	None	7	13	25	45
		15.6%	28.9%	55.6%	100.0%
	Minimal	6	26	54	86
		7.0%	30.2%	62.8%	100.0%
	Moderate	5	7	59	71
		7.0%	9.9%	83.1%	100.0%
	High	18	28	238	284
		6.3%	9.9%	83.8%	100.0%
Total		36	74	376	486
		7.4%	15.2%	77.4%	100.0%

To test the last of the three hypotheses, students were asked to respond to two statements with Likert scaled responses. The scales were completely disagree to completely agree for, *Differences in human skin color can be explained by science* (SKINSCI), and completely agree to completely disagree for, *The scattering of peoples from the tower of Babel across the Earth is the cause of modern races of humans* (BABEL). There was an association between students' responses to these two statements: χ^2 (16, N = 486) = 99.697, $p < .001$, Cramer's V = .226 with "I don't know" responses included in the analysis, and $r_s(273)$ = .364, $p < .001$, τ = .337 with "I don't know" responses excluded (Somer's d = .415 when BABEL is the dependent variable). Only two students mostly disagreed or completely disagreed with both statements; however, the strength of the correlation between the students' responses was attenuated by the 69 students who mostly agreed or completely agreed with both statements. The cross-tabulation of these two variables was conducted with the goal of excluding students with conflicting responses from further analyses and then recoding students' responses into one variable, but the data imply that some of the seemingly contradictory responses may have been deliberately selected (Table 62). Therefore, each variable was compared to TOTALHEB separately, and the results of those analyses compared to each other.

There was no correlation between TOTALHEB and BABEL; approximately 50% of students in each HEB exposure group completely disagreed with the bible-based explanation for the origin of human diversity, approximately 15-25% mostly disagreed, 10-15% mostly agreed, and about 15-25% completely agreed. Though, students with moderate to high HEB exposure were more likely to respond to the statement with *I don't know/Neutral* than students with less HEB exposure. Students with higher religion factors, who favored divine creation as the explanation for the origin of humans, and/or who rejected general evolution, were more likely to agree with the statement. Among the students who had moderate to high religion factors and/or completely agreed with divine creation as the best explanation for the origin of humans, those with moderate to high HEB exposure were more likely to disagree with the statement.

Table 62

*SKINSCI * BABEL cross-tabulation*

		The scattering of peoples from the tower of Babel across the Earth is the cause of the modern races of humans.				
		Completely agree	Mostly agree	Mostly disagree	Completely disagree	Total
Differences in human skin color can be explained by science.	Completely disagree	1	1	1	0	3
	Mostly disagree	2	4	1	0	7
	Mostly agree	9	20	22	17	68
	Completely agree	23	17	28	127	195
Total		35	42	52	144	273

There was a modest correlation between total HEB exposure and whether students agreed or disagreed that human skin color diversity can be explained by science, $r_s(423) = .162$, $p < .01$, $\tau = .150$, 95% CI [.065, .240] (Table 59). Somers' d for TOTALHEB as the dependent variable was .167 and for SKINSCI as the dependent variable, it was .135, indicating that SKINSCI reduced the prediction error for TOTALHEB just slightly more (16.7%) than TOTALHEB reduced the prediction error for SKINSCI (13.5%).

Controlling for religion factor reduced the strength of the correlation by a small amount, $r_s(423) = .127$, $p < .01$. Adding religion factor to the crosstabs correlation analysis shows that the relationship between TOTALHEB and SKINSCI is only significant for students with a moderate religion factor, $r_s(423) = .381$, $p < .001$, $\tau = .356$, 95% CI [.179, .520]. There was also a relationship between TOTALHEB and SKINSCI for those students who did not know if divine creation was the best explanation for the existence of humans.

Students who rejected general evolution but had moderate to high HEB exposure were more likely to respond with “I don’t know” to the statement, suggesting that HEB exposure may have led them to question their views, whereas students who accepted evolution and had moderate to high HEB exposure were less likely to respond with “I don’t know,” suggesting that HEB exposure gave them more confidence that science can explain differences in human skin color. Controlling for human evolution acceptance, there was no correlation between TOTALHEB and SKINSCI; students’ acceptance of human evolution was correlated strongly enough with students’ agreement with the statement about skin color, that HEB exposure had little effect on their views.

The relationship between students’ HEB exposure and confidence regarding the causes of human diversity may be attributable to the fact that HEB exposure is correlated with students’ knowledge structure regarding basic principles of evolutionary biology. Students with higher HEB exposure were more likely to know that all DNA mutations are not harmful and were nearly three times as likely to be confident about that knowledge, whereas students with less HEB exposure were more likely to express indecision about it. This association primarily applied to students who did not regularly engage with science news media. As was discovered in the interviews, students with more HEB exposure were better able to apply their fundamental knowledge of evolution to confidently support a scientific explanation for phenotypic differences among modern humans.

To assess students' decision-making regarding a social issue that has a basis in human diversity, there were two survey questions pertaining to students' views on immigrants in the United States. The students' responses to these questions were subject to factor analysis and internal consistency reliability analysis and the composite variable, IMMIG, was based on their responses to both questions. Students responded using Likert scaled responses of completely disagree to completely agree for the statement, *Immigrants to the U.S. today strengthen our country because of their hard work and talents*, and completely agree to completely disagree for the statement, *Immigrants today are a burden on our country because they take our jobs, housing and healthcare*. For IMMIG, a score of 1 reflected the least favorable view and a score of 4 reflected the most favorable view of U.S. immigrants (Table 63).

Table 63

Views of U.S. immigrants (IMMIG)

		Frequency	Percent	Cumulative Percent
Views on U.S. immigrants	1.0=Least favorable	33	6.8	6.8
	2.0	82	16.9	23.7
	3.0	130	26.7	50.4
	4.0=Most favorable	241	49.6	100.0
	Total	486	100.0	

Students' views of U.S. immigrants were not correlated with total academic HEB exposure. They were most closely associated with the students' ethnicity and beliefs. They were weakly correlated with whether the students thought that human skin color diversity can be explained by science, $r_s(423) = .128$, $p < .01$, $\tau = .117$, 95% CI [.026, .198], and modestly correlated with whether or not students agreed with a bible-based explanation for the origin of human diversity, $r_s(298) = .231$, $p < .001$, $\tau = .202$, 95% CI [.095, .300]. Students who strongly agreed divine creation is the best explanation for the existence of humans tended to have a less favorable opinion of immigrants. Therefore, though some students of faith were more likely to acknowledge scientific explanations for human diversity with greater HEB exposure, this was not a factor when making decisions about immigration issues.

Same-sex relationships. The survey included a series of four questions regarding same-sex relationships. Based on factor analysis and internal consistency reliability analysis, three of the four questions were used to generate the composite variable, SAMESEX. The three questions had to do with same-sex marriage, adoption and acceptance of homosexuality as a way of life (see Appendix C). The fourth, excluded from the analysis, pertained to students' views on homosexuals in the military. As with IMMIG, a score of 1 for SAMESEX indicated the least favorable view and a score of 4 indicated the most favorable view of same sex relationships. Homosexuality was a considered a socioscientific issue, rather than just a social issue, due to the scientific evidence that there is a genetic contribution to humans' sexual orientation, as with other biological traits.

There was a moderate negative correlation between religion factor and SAMESEX, $r_s(481) = -.386$, $p < .001$, $\tau = -.343$, 95% CI [-.409, -.270]. And there was not a significant correlation between SAMESEX and TOTALHEB (p = .058) without controlling for religion factor. When controlling for religion factor, there was a weak positive correlation between SAMESEX and TOTALHEB, $r_s(486)$ = .106, $p < .05$, 95% CI [.013, .188]. For students with a moderate to high religion factor or who agreed with a biblical explanation for the origin of human races, higher HEB exposure was positively correlated with a more favorable view of homosexuality. There was a not a significant correlation when controlling for human evolution acceptance or within individual human evolution acceptance groups. And there was not a significant association between SAMESEX and students' engagement with science media.

Humans and other primates. The survey included three questions related to students' views on humans' interactions with other apes. Students were asked to provide their *opinions on poaching apes and monkeys* (APES1), *preserving the forest habitats in which apes live* (APES2), and *testing drugs on chimpanzees* (APES3). A Likert scale from completely disagree to completely agree was used to collect students' responses (Appendix G). In each case, the students' responses were scored so that higher numbers reflected a more positive view toward protecting primates and their habitats.

In addition, multiple survey questions were used to assess students' views on humans' relationship to other apes. Based on factor and internal consistency reliability analyses, two questions, one about what humans can learn about ourselves by studying apes, and the other about the similarities of ape and human anatomy, were used to generate the composite variable APES4. A score of 1 for APES4 represented the lowest *acceptance of humans' biological relationship to other apes* and a score of 4 represented the highest acceptance. Seventy-three percent of the participants scored a 4, 22.8% scored a 3, and only a combined 4.1% scored a 1 or 2. There was a weak significant relationship between students' views on humans' relationship to other apes and their total HEB exposure, $r_s(486) = .180$, $p < .001$, $\tau = .166$ 95% CI [.076, .252].

The proportion of students who disagreed with poaching and drug testing and agreed with habitat preservation did increase with increasing HEB exposure, but there were not statistically significant relationships between total HEB exposure and students' views on poaching, drug testing, or habitat preservation, even if students' views on humans' relationship to other apes or their human evolution acceptance were controlled for.

Antibiotic use. Students were asked in the survey: *Do antibiotics kill viruses as well as bacteria* (ANTIBIO)? Just over half (52.9%) of the participants responded correctly by answering "no," 22.8% did not know and 24.3% incorrectly answered "yes." There was not a significant relationship between total academic HEB exposure and students' responses to this question based on any association tests.

Birth control use. Students were asked about their *personal views on birth control use* (BIRTHCON); response options included, *Birth control should be used to prevent unwanted pregnancies, It is wrong to use birth control,* and *I don't know*. There was no association between TOTALHEB and students' opinions. Religion factor and human evolution acceptance were each added to the crosstabs analysis as a layer and there was no association between TOTALHEB and BIRTHCON within religion factor groups or human evolution acceptance groups.

Overpopulation. Students were asked to indicate *the degree to which they thought human overpopulation was a problem* (OVERPOP). There was a significant association between total HEB exposure and students' views on overpopulation, χ^2 (12, N = 486) = 40.940, $p < .001$, Cramer's V = .168, with "I don't know" responses included in the analysis, and $r_s(470) = .131$, $p < .01$, τ = .117 with "I don't know" responses excluded (Somer's d = .123 when OVERPOP is the dependent variable). Students with moderate or high HEB exposure were more likely than students with no or low HEB exposure to identify overpopulation as a serious problem. The correlation is only slightly stronger when controlling for religion factor, $r_s(463) = .155$, $p < .01$, and is weaker when controlling for human evolution acceptance, $r_s(467) = .112$, $p < .05$.

Cloning. Students were asked their opinion about *whether technologies for cloning or genetic modification should be used on humans* (CLONING), based on a Likert scale from strongly oppose to strongly favor; 56% of students somewhat or strongly opposed the use of cloning or genetic modification technologies for humans. Students with no or minimal HEB exposure were most likely to express strong opposition, but there was not a statistically significant association between total HEB exposure and the students' responses when responses of "I don't know" were included. When they were excluded, the relationship became weakly positive, $r_s(437) = .103$, $p < .05$, $\tau = .089$, 95% CI [.006, .170]. A partial correlation correcting for religion factor was weaker, though significant at $p = .05$. A partial correlation correcting for human evolution acceptance was not significant; students' acceptance of human evolution was the factor most strongly associated with their views—as human evolution acceptance increased, so did the likelihood that students would favor the use of these technologies for humans, regardless of their HEB exposure.

Federal funding for stem cell research. Students were asked if they *favored or opposed federal funding for stem cell research* (STEMRES). More than half (54.3%) of students indicated that they favored stem cell research funding, 37.7% did not support stem cell research funding and 8% did not know. Students with moderate to high HEB exposure tended to favor federal funding for stem cell research more than students with less HEB exposure. There was a weak association between TOTALHEB and STEMRES, χ^2 (6, N = 486) = 14.277, $p < .05$, Cramer's V = .121, 95% CI [.083, .203], with "I don't know" responses included in the analysis that was no longer significant when the "I don't know" responses were excluded.

A binary logistic regression showed that religion factor and human evolution acceptance were significant factors in a model predicting federal funding for stem cell research. When religion factor was added as a layer to the crosstabs analysis of TOTALHEB and STEMRES, the only group for which there was a statistically significant relationship between TOTALHEB and STEMRES was the low religion factor group, χ^2 (3, N = 134) = 11.307, $p < .05$. For students with moderate to high religion factors, higher HEB exposure was associated with a decrease in confidence about their views; in other words, higher HEB was associated with a greater proportion of responses of "I don't know," which suggests that learning about human evolutionary biology may have made these students less inclined to make a decision that firmly reflected a religious viewpoint. There was no significant relationship between TOTALHEB and STEMRES within any of the human evolution acceptance groups.

Vaccination. The participants were asked if they *favored or opposed required vaccinations for all children* (VACCINES). Most students (69.8%) favored required vaccinations, 14.6% opposed required vaccinations, and 15.6% did not know. There was not a significant relationship between TOTALHEB and VACCINES when the responses of "I don't know" were included in the analysis and it became less significant when they were removed. Adding religion factor to as a layer to the first analysis showed that, within the no religion factor group only, there was a statistically significant positive association between TOTALHEB and VACCINES, χ^2 (6, N = 32) = 12.998, $p < .05$. Among the 32 students with no religion factor, those with moderate or high total HEB exposure were statistically more likely to favor vaccines. For students with moderate religion factors, higher HEB exposure increased the likelihood that they would respond "I don't know." Adding human evolution acceptance as a layer to the analysis showed that, within the second lowest human evolution acceptance group only, there was a significant association between TOTALHEB and VACCINES, χ^2 (6, N = 47) = 14.190, $p < .05$. Though the modern anti-vaccine movement is not typically associated with faith-based concerns, there is some evidence here to suggest that exposure to religion may influence students' views on vaccinations.

In sum, there is a significant relationship between students' total academic HEB exposure and their behaviors and decision-making for some socioscientific issues. For example, students with higher total HEB exposure are more likely to vote in a U.S. Presidential election and engage in environmentally conscious behaviors than students with less total HEB exposure. They are also more likely to have a positive view of homosexual relationships and acknowledge that modern human skin color diversity can be explained by science. Students with high HEB exposure may also be more likely to engage with science news and media and view global warming and human overpopulation as serious problems. Many of these relationships are dependent, at least in part, on students' religion factors and acceptance of evolution or human evolution; sometimes higher total HEB exposure has a stronger correlation with behaviors or decision-making for students with high religion factors, sometimes this is true for students with low religion factors. Religion factor is associated with students' environmentally conscious behaviors and their views on modern human diversity, homosexuality and stem cell research. The data presented here provide evidence that high total academic HEB exposure can offset the potential influence of religion factor for these and other socioscientific issues.

Table 64

Summary of the findings

Hypothesis (H_0)	Support	Reject	Text Reference	Sig.[a]	Comments
There is no association between students' acceptance of general evolution and acceptance of human evolution.		×	206	$p < .001$	
There is no association between students' views on the role of a supernatural being in the phenomenon of evolution and their acceptance of human evolution.		×	207-208	$p < .001$	Negative association
There is no difference among religion factor groups for general evolution acceptance.		×	210	$p < .001$	Negative association
There is no correlation between religion factor and human evolution acceptance.		×	210	$p < 0.01$	Negative association
There is no association between students' K-12 HEB exposure and their:					
Self-identified sex	√		214		
Age	√		214		
Ethnicity	√		214		
State of high school graduation	√		214		
Academic aptitude	√		214		
Religion factor	√		214		
General evolution acceptance	√		214		
Human evolution acceptance	√		214		

Hypothesis (H_0)	Support	Reject	Text Reference	Sig.[a]	Comments
High School science class enrollment					
There is no correlation between K-12 HEB exposure and total enrollment in high school science classes.		×	216-217, 228-	$p < .01$	If total high school science class enrollment is a categorical variable with five categories, then $p < .05$.
There is no correlation between K-12 HEB exposure and total enrollment in high school biological science classes.		×	217	$p < .001$	
There is no association between completing at least three years of high school science classes that include at least one year of biological science and K-12 HEB exposure.	√		145, 218-222		If no and low HEBEXP groups recoded into new (*lower*) exposure group and moderate and high HEBEXP groups recoded into new (*higher*) exposure group, the association is statistically significant, though weak, and null hypothesis is rejected when $p = .05$.
There is no association between completing four years of high school science classes that include one or more years of advanced biological science and K-12 HEB exposure.		×	226-227	$p < .05$	
There is no association between completing more than two years of high school biological science classes that include one or more years of advanced biological science and K-12 HEB exposure.		×	227-228	$p < .01$	

Hypothesis (H_0)	Support	Reject	Text Reference	Sig.[a]	Comments
Achievement and preparedness					
For traditional students interested in a STEM degree, there is no association between K-12 HEB exposure and university GPA.	√		145, 240		
For traditional students interested in a STEM degree, there is no association between K-12 HEB exposure and perceived ease of undergraduate science coursework.	√		241		
For traditional students interested in a STEM degree, there is no relationship between K-12 HEB exposure and perceived preparedness for undergraduate science coursework.	√		241		Reject for students who enrolled in two or more undergraduate courses that included evolution-based content ($p < .05$).
Interest in a STEM degree program					
There is no association between K-12 HEB exposure and interest in a STEM degree program.		×	154, 214, 245-246, 249	$p < .05$	
Religion factor and general evolution acceptance and human evolution acceptance cannot be used to predict if a student will enroll in a STEM degree program.	√		154, 246-247		

Hypothesis (H_0)	Support	Reject	Text Reference	Sig.[a]	Comments
Motivation to pursue a STEM career					
There is no relationship between interest in a STEM degree program and motivation to pursue a STEM career.		×	160, 246	$p < .001$	
There is no relationship between K-12 HEB exposure and motivation to pursue a STEM career.	√		160, 214, 246-247, 254		
Religion factor and general evolution acceptance and human evolution acceptance cannot be used to predict if a student will be motivated to pursue a STEM career.		×	160, 246-248	$p < .05$	Reject for human evolution acceptance only, though not a linear positive relationship.
For students interested in a STEM degree program and motivated to pursue a STEM career, K-12 HEB exposure was not associated with intrinsic motivating factors, which included:			155, 160, 254-256		
Personal interest in or curiosity about the world	√		256-257		
A desire to help animals	√		256, 258		
A desire to help other people		×	256, 259-260	$p < .01$	

Hypothesis (H_0)	Support	Reject	Text Reference	Sig.[a]	Comments
Socioscientific issues: actions and decision-making					
There is no relationship between total HEB exposure and engagement with news media outlets including television, print journalism and online news (exposure to information about current events).	√		164, 264		
There is no relationship between total HEB exposure and the frequency with which students follow events in government and public affairs.		×	266, 270-271	$p < .05$	Failed to reject for students who did not accept general evolution. Failed to reject when controlling for human evolution acceptance. If moderate-high total HEB and high human evolution acceptance, then higher frequency of following.
There is no relationship between total HEB exposure and engagement with science media, including television programming, science websites and blogs, and print science journalism.		×	267-268, 270, 271-272	$p < .01$	Failed to reject for students with no or low religion factor. Failed to reject for students who did not accept general evolution. Failed to reject for students with less than the highest level of human evolution acceptance.

Hypothesis (H_0)	Support	Reject	Text Reference	Sig.[a]	Comments
Among students who are eligible to vote in the United States, there is no relationship between total HEB exposure and voting behavior in a Presidential election.		×	166, 273-275	$p < .05$	
There is no relationship between total HEB exposure and students' views on whether human behaviors contribute to global climate change.	√		279		
When holding religion factor constant, there is no relationship between total HEB exposure and students' views on whether human behaviors contribute to global climate change.	√		179, 276, 279		Though not significant at $p = .05$, the strongest relationship between total HEB exposure and students' views was within the high religion factor group.
There is no relationship between total HEB exposure and students' views on whether global climate change is a problem.		×	279	$p < .05$	Failed to reject for students with low-moderate religion factor.
When holding religion factor constant, there is no relationship between total HEB exposure and students' views on whether global climate change is a problem.		×	276, 280	$p < .05$	

Hypothesis (H_0)	Support	Reject	Text Reference	Sig.[a]	Comments
There is no relationship between total HEB exposure and the likelihood that students will identify, favor and engage in specific activities that, based on sound scientific evidence, affect humans' contributions to global climate change.		×	282, 283	$p < .01$	Failed to reject for students with no-moderate religion factor. Failed to reject when holding constant students' belief that divine creation is the best explanation for the existence of humans.
When holding religion factor constant, there is no relationship between total HEB exposure and the likelihood that students will identify, favor and engage in specific activities that, based on sound scientific evidence, affect humans' contributions to global climate change.		×	179, 282	$p < .01$	
There is no relationship between total HEB exposure and students' basic knowledge structure of an evolutionary biology concept (whether all DNA mutations are harmful).		×	193, 283-285	$p < .001$	When the students who responded that they did not know if all mutations are harmful were excluded from the analysis, the strength of the association was weaker and less significant, $p < .05$.
There is no relationship between HEB exposure and the likelihood that students believe that human skin color diversity can be accounted for by faith-based explanations.	√		193-194, 286		Rejected for students with moderate-high religion factor and/or who accepted divine creation as best explanation for the origin of humans (negative association).

Hypothesis (H_0)	Support	Reject	Text Reference	Sig.[a]	Comments
There is no relationship between total HEB exposure and the likelihood that students accept that human skin color diversity can be explained by science.		×	193-194; 287-288	$p < .01$	Fail to reject for students with no-low or high religion factor ($p < .001$ for moderate religion factor). Fail to reject for students who accepted or rejected divine creation as best explanation for origin of humans (i.e., reject for students who did not know if divine creation is the best explanation). Fail to reject when controlling for human evolution acceptance.
When holding religion factor constant, there is no relationship between total HEB exposure and the likelihood that students accept that human skin color diversity can be explained by science.		×	193-194, 288	$p < .01$	
There is no relationship between total HEB exposure and the likelihood that students have positive views of U.S. immigration.	√		289-290		
There is no relationship between total HEB exposure and the likelihood that students have positive views of same-sex relationships.	√		290-291		Fail to reject for students with no-low religion factor or who disagreed that divine creation is the best explanation for the origin of humans.

Hypothesis (H_0)	Support	Reject	Text Reference	Sig.[a]	Comments
When holding religion factor constant, there is no relationship between total HEB exposure and the likelihood that students have positive views of same-sex relationships.		×	290-291	$p < .05$	
When controlling for human evolution acceptance, there is no relationship between total HEB exposure and the likelihood that students have positive views of same-sex relationships.	√		291		
There is no relationship between total HEB exposure and students' views on humans' biological relationship to other apes.		×	291-292	$p < .001$	
There is no relationship between total HEB exposure and students' views on primate poaching, primate habitat conservation, and drug testing on chimpanzees.	√		291		Fail to reject even if students' views on humans' relationship to other apes is controlled for.
There is no relationship between total HEB exposure and students' knowledge that antibiotics do not kill viruses as well as bacteria.	√		292		
There is no relationship between total HEB exposure and students' views on birth control.	√		292		

Hypothesis (H_0)	Support	Reject	Text Reference	Sig.[a]	Comments
There is no relationship between total HEB exposure and the likelihood that students view human overpopulation as a problem.		×	293	$p < .001$	Also reject when controlling for religion factor and human evolution acceptance.
There is no relationship between total HEB exposure and whether students think technologies for cloning or genetic modification should be used on humans.		×	293-294	$p < .05$	Fail to reject when students who did not know were included in the analysis. Fail to reject when controlling for human evolution acceptance.
There is no relationship between total HEB exposure and whether students favored federal funding for stem cell research.		×	294	$p < .05$	Fail to reject when students who did not know were excluded from the analysis. For students with moderate-high religion factor, higher HEB was associated with greater likelihood of "I don't know" response. Fail to reject when controlling for human evolution acceptance.
There is no relationship between total HEB exposure and whether students favored required vaccinations for all children.	√		295		Reject for students with no religion factor. Reject for students with low human evolution acceptance. For students with moderate religion factor, higher HEB was associated with greater likelihood of "I don't know" response.

[a] All significant relationships are positive unless otherwise noted in the comments column.

CHAPTER NOTES

[1] The questions associated with a relatively high dropout rate were:

- Divine creation is the best explanation for the existence of humans.
  - Completely agree
  - Mostly agree
  - Mostly disagree
  - Completely disagree
  - I don’t know/Neutral
- Which comes closer to your personal view?
  - The age of the Earth is at least 4 billion years.
  - The age of the Earth is less than 20,000 years.
  - I don't know.
  - Other

CHAPTER 7

DISCUSSION

This chapter consists of a summary of the study, a discussion of significant findings, implications of the results, and recommendations for further research. Results will be discussed in the context of the material presented in the literature review regarding the national STEM initiative in the United States and science literacy. The proposed implications will address issues related to K-12 public school science education in America and undergraduate STEM education. Recommendations for further research are dispersed throughout and identify potentially interesting, unexplored aspects of evolution or human evolution education research.

Summary of the Study

The purpose of this study was to explore the relationship between human evolutionary biology (HEB) education and American public high school graduates' interest in STEM disciplines, academic success, motivation to pursue a STEM career and socioscientific decision-making. There is a national agenda in the United States to stimulate student interest in STEM degrees, maximize student success in STEM programs, motivate students to pursue STEM careers and, thus, increase the number of American citizens who are qualified, employable, STEM professionals. In addressing this, science education researchers and other groups, such as the President's Council of Advisors on Science and Technology, have suggested that STEM education at all levels must foster students' interest and motivation by giving students the opportunity to learn in the context of real-world problems that are personally and culturally relevant to students. The foundation for part of this study was the idea that human evolutionary biology is a personally and culturally relevant subject area because it deals with humans and addresses real-world problems, such as interactions between people and their environment, and thus, has the potential to generate or foster students' interest and engagement in STEM coursework and degree programs and motivation to pursue a STEM career.

In addition, this study examined whether human evolutionary biology education is associated with students' socioscientific decision-making through enhanced science literacy. Science literacy is defined in this study as it is by AAAS's Project 2061 (2009, para. 1-2):

> People who are literate in science are not necessarily able to do science, mathematics or engineering in a professional sense...Such people are, however, able to use the habits of mind and knowledge of science, mathematics, and technology they have acquired to think about and make sense of many of the ideas, claims, and events they encounter in everyday life. Accordingly, science literacy enhances the ability of a person to observe events perceptively, reflect on them thoughtfully, and comprehend explanations offered for them. In addition, those internal perceptions and reflections can provide the person with a basis for making decisions and taking action.

Socioscientific issues are those that have conceptual or technical links to science, technology, engineering and math. Specifically, this project examined the association between human evolutionary biology education and students' views on climate change, same-sex relationships, U.S. immigration, humans' treatment of primates and primate habitats, human overpopulation, birth control use, cloning, stem cell research, vaccinations, conservation, and the students' environmentally conscious behaviors, as well as their voting action.

Research design. The exploratory methods used in this study were chosen because of a lack of *a priori* knowledge about the relationship between HEB education and students' entrance, persistence and success in the STEM pipeline and science literacy. The researcher did know that approximately 25% of public school biology teachers do not teach about evolution in their classrooms, and a greater percentage do not teach about human evolution; therefore, the research plan involved comparing and contrasting groups of students who were exposed to the science of human evolutionary biology to varying degrees. K-12 human evolutionary biology education exposure and total HEB exposure (which included K-12 and undergraduate exposure) were categorized as *none, low*, *moderate* or *high*, and were relative for the study sample, meaning that a student with high K-12 HEB exposure had high exposure compared to other students in the sample (see Tables 29 and 30).

The study involved complementary qualitative and quantitative analyses. The qualitative analysis involved interview, focus group, and questionnaire data used to identify conceptual trends in those data and to generate hypotheses via the Grounded Theory Method. Forty-four Arizona State University (ASU) students, recruited by faculty members via electronic and verbal in-class announcements, were interviewed in focus groups or individually for 60 to 90 minutes and each completed a questionnaire; all but three students also granted the researcher access to their undergraduate academic records. Interviews, questionnaires, and academic transcripts were analyzed with NVivo computer assisted qualitative data analysis software. The results of the qualitative analysis were the foundation for the development of the research hypotheses, which were tested using data collected from ASU students via a confidential online survey.

Undergraduates at ASU were recruited to complete the anonymous survey via electronic announcements and paper fliers. Ultimately, survey data from 486 ASU undergraduates met the research criteria, a response rate of 65.5%. Calculations in G*Power confirmed that this was an adequate sample size to achieve powerful results (see page 56). The final study sample included students, age 18-22, who graduated from public high schools in the United States. These data were analyzed to further explore the conceptual trends identified in the qualitative analysis and to test the hypotheses. Survey data were explored and analyzed using Excel and SPSS statistical data analysis software. Statistical analyses included nonparametric tests of association and correlation as well as binary and ordinal logistic regression analyses. For some statistical analyses (e.g., see Table 31 on page 214), post hoc tests of achieved power ($1-\beta$) were conducted in G*Power; these tests confirmed that power was typically between 0.60 and 0.99, even when effect size was small.

Most of the findings were assessed in the context of students' acceptance of general biological evolution and human evolution, as well as their exposure to and engagement with religious beliefs and practices (their *religion factor*). For the 44 interview participants and the 486 survey respondents, there was not a significant relationship between their K-12 HEB exposure and their religion factor. Nor was there a significant relationship between their K-12 HEB exposure and their general evolution acceptance or their K-12 HEB exposure and their human evolution acceptance; for the latter, there was a weak positive correlation identified, but neither variable reduced the prediction error of the other in an association test.

The lack of association between HEB exposure and religion factor and between HEB exposure and acceptance demonstrates that human evolutionary biology education during K-12 schooling does not affect students' expressed opinions regarding the origin and evolution of life on Earth, including the origin and evolution of humans, in a statistically predictable way. There is a substantial body of education research pertaining to evolution acceptance (e.g., see Ha, Haury and Nehm, 2011, and references therein); in fact, the current paradigm of evolution education research could be defined by the papers that examine the relationships between students' education, knowledge and acceptance of evolution. The goal of this study was not to explore if or how learning about human evolutionary biology "changes students' minds" about evolution and/or religion, but to determine if—in the context of their religion and acceptance—being exposed to the science of human evolutionary biology appeals to students' interests, contributes to their academic achievement, and/or enhances their science literacy as defined above. This is a novel approach in the field of evolution education research.

Discussion of the Findings

The findings of this study support the conclusion of many other social science research projects—that human beings are complex and complicated animals. Unraveling the mystery of whether, why and to what degree humans accept evolution and/or human evolution is no less challenging than—and in fact is delicately intertwined with—the task of interpreting the influence of religion on people's thinking and reasoning (see Tables 27 and 28 on page 211). Religious views and acceptance of evolution are nuanced psychosocial issues that depend on myriad factors not limited to cultural tradition, dogma, politics, human health, self-identity, self-esteem, familial relationships, and fundamental knowledge of science. Asking a person to identify his or her "religion" or tell you whether he or she accepts that all living things have evolved from a common ancestor simply by checking a box reveals little. The participants in this study showed that a self-described atheist's views may be influenced by the 12 years she spent in Catholic school and attending church services, and that a self-described Jewish man may have been a self-described Catholic if surveyed a few years earlier.

Understanding the ways in which religion can be used to characterize people and influence people's world views requires more than a question eliciting a one-word response. As other studies have shown, the responses one gets when asking about people's acceptance of evolution depend heavily on how questions are worded and the opportunities participants are given to provide open responses rather than having to select from a limited set of response options. This study sought to capture some of the nuances of religion and evolution acceptance, but certainly did not succeed in extracting each and every one. But, as stated earlier, it was important to view the findings of the research regarding human evolution education in light of religion and acceptance, and the researcher strove to do so in a meaningful way.

Again, the outcome was not without precedent in social science research—the treatment has different effects on different people due to different factors, and some factors remain to be identified. The data presented in Chapters 4 and 6 identify some of the factors that contribute to students' interest in STEM classes and degrees, academic achievement, motivation to pursue STEM careers and socioscientific decision-making. For some students, human evolutionary biology education was one of those factors, though it was not the sole determining factor and is certainly not the lone gatekeeper at the entrance to the STEM pipeline.

Table 64 on page 297 summarizes the results of hypothesis testing. There was a positive relationship between K-12 HEB exposure and students' enrollment in high school science classes. K-12 HEB exposure accounted for 2.6% of the variation in enrollment—students with higher HEB exposure were 1.24 times more likely to complete two more science classes than students with less HEB exposure. There was a clear connection between students' enrollment in advanced biological science classes and HEB exposure; 20% of students with high HEB exposure completed two or more biological science classes that included at least one advanced biological science class, whereas only 5-9% of students with no or low HEB exposure completed this combination of classes. This was most likely driven by the fact that students are more likely to learn about human evolution in an AP or IB Biology class than in another biology class, given that evolution is officially part of the AP and IB curricular requirements. But, anecdotes and statistical results were, for at least some students, evidence that HEB exposure was driving enrollment. For example, some students who had high K-12 HEB exposure and relatively high science class enrollment reported learning about human evolution in non-science class, demonstrating that the correlation was not always due to their exposure in advanced biology.

The elements that most clearly linked HEB exposure with enrollment were interest and achievement. The overwhelming view of the interview participants was that human biology, in all aspects, is a subject about which they enjoyed learning or wanted to learn more. And, regardless of the degree of their exposure to human evolutionary biology, not one interview participant said that they would not want to learn about it or did not want to better understand the science of and evidence for human evolution, if given the opportunity to do so. Some students indicated that completing, and in particular succeeding in, a human biology class was encouraging and influenced their attitudes toward STEM disciplines in a positive way. Participant 203 was particularly influenced by her AP Biology class, though she first learned about human evolutionary biology in middle school and 9th grade:

- For me, my AP Biology course was like, really, I think it set me on the right track for all of high school, because I did really well in that class and I felt like I understood everything and things made so much sense and that's why I'm a biology major because I feel like with biology things can really make sense, as opposed to English, where things can get subjective, and I'm not good with math, so physics and chemistry were kind of like abstract for me. It really geared me toward science and then I think because I took AP Biology first and I could understand it and do well is the only reason I would even try to take AP Chemistry and Physics because I've always just since day one...really liked biology (Participant 203).

Note that, with regard to achievement, Participant 203 says she felt as though she was set on the "right track" by AP Biology in part because she performed well in the class.

Education research has shown that completion of more credits in advanced math and science is correlated with increased post-secondary enrollment and a greater likelihood of enrolling in a four-year degree program (National Science Board, 2010). According to data from the National Center for Education Statistics, "among students with more than two advanced mathematics or science credits, 88% and 90%, respectively enroll in a four-year college" (National Science Board, 2010, Chapter 1, p. 37). And the number of American students enrolling in advanced placement courses has increased by five times in the last two decades; unfortunately, "passing rates [for AP exams] have declined or remained steady in most subjects," and have declined significantly in biology (National Science Board, 2010, Chapter 1, p. 36). This shows that advanced placement biology classes may not adequately prepare students for the AP Biology exam. Evolutionary science composes approximately 75% of the AP Biology curriculum, and though the results of this study show that students who complete AP Biology are more likely to have high HEB exposure, some of the interviewed students shared that their AP Biology classes did not include any evolutionary biology, which would affect their knowledge structure and, therefore, their exam performance.

The survey data showed that HEB exposure is correlated with students' knowledge structure regarding a basic principle of evolutionary biology; among students who did not regularly engage with science news media, those who had relatively high HEB exposure were more likely than students with less HEB exposure to know that not all DNA mutations are harmful. The predicted outcome of improved knowledge structure would be higher grades and greater achievement. But, students with relatively high K-12 HEB exposure did not necessarily achieve higher grades in their science coursework. They did, however, perceive themselves as better prepared for university coursework, particularly if they completed two or more undergraduate courses that addressed evolution. And evidence from some participants' interviews demonstrated that self-perceived academic success had as much or more to do with students' perception of their preparedness and progression toward their career goals as did their grades. It is feasible, therefore, that K-12 HEB exposure is not only useful for generating or fostering some students' interest in STEM subject matter in high school, but also may increase the likelihood that undergraduate students, particularly those who major in the life sciences, would remain in their degree programs because they felt adequately prepared for their coursework. Interpreting and understanding the relationship between students' grades, perceived preparation, and feelings of success was not easy, like unraveling the connections between religion and evolution acceptance.

Among the interview participants, all of the students with high HEB exposure were STEM majors at ASU, primarily in the life sciences. And among the 486 survey participants, there was a positive relationship between K-12 HEB exposure and students' declaration of or interest in a STEM degree program, particularly for students who self-identified as Hispanic, Latino, Spanish, Mexican or Chicano. But the relationship between evolution education and interest in a STEM degree program also depended on how evolution was taught, when the students were exposed to it, and the students' perceived abilities in science (i.e., whether they were "good at science"), among other factors. Students with high acceptance of human evolution were also more likely to pursue a STEM degree than students with low or no acceptance. Religion did not directly influence students' interest in STEM degree programs in a significant way.

Participant 203, quoted above, provides an example of another finding of this study—the theme of biology subject matter “making sense” to students. Many of the interview participants used this exact phrasing when expressing their attitudes toward evolution in general and human evolution in particular. Even students with relatively low acceptance of evolution tended to say that evolution “makes sense” when asked to reflect upon the concept. Many students described the phenomenon of evolution as “logical” and said that the logical nature of evolutionary science appealed to them, even if they were undecided about their level of acceptance. Some students had difficulty reconciling their faith-based beliefs with their scientific knowledge, whereas others felt that there was no conflict between them. The students who struggled most with the idea of human evolution were those who had a stronger influence of religion in their lives and/or those who had little to no exposure to the science of human evolution.

The frequency with which students described evolution as “making sense” was striking, and an interesting question for educational psychology researchers is why would people reject scientific concepts that they identify as logical or sense-making? A recent study by Nyhan, Reifler, Richey and Freed (2014, p. 7) tested the effectiveness of messages designed to reduce misperceptions about vaccination and increase vaccination rates. The authors identified a backfire effect—when parents with the least favorable vaccine attitudes were presented with corrective information about the purported vaccine-autism link, the parents’ misperceptions were reduced, but their intentions to vaccinate were also reduced. The backfire effect is an intriguing phenomenon that may have meaningful implications regarding the interplay of religion, evolution education and evolution acceptance.

Religion factor and total academic HEB exposure were associated with students' views on childhood vaccination. For students with no religion factor; greater HEB exposure increased the likelihood that they favored, rather than opposed, vaccinations, perhaps because a better understanding of human evolutionary biology was correlated with a better understanding of the susceptibility of humans to virulent communicable diseases and the need to prevent them from spreading in the population. For students with moderately high religion factors, greater HEB exposure seemed to make them less decisive—it increased the likelihood that they would respond that they did not know if they favored or opposed required childhood vaccinations. The modern anti-vaccine movement is not typically associated with faith-based concerns, but this study suggests that exposure to religion may influence students' socioscientific decision-making in this case and that this influence could be counteracted by high-quality HEB, even if just by stimulating critical thinking about the issue. Similar results were obtained for questions about students' views on stem cell research. Students with higher HEB exposure were more likely to support federal funding of stem cell research if they had low religion factors, but students with higher religion factors were less decisive if they had higher HEB exposure.

In some cases, if students with relatively high religion factors had greater HEB exposure, they made more confident decisions about socioscientific issues. Among the students who had moderate to high religion factors and/or completely agreed with divine creation as the best explanation for the existence of humans, those with moderate to high HEB exposure were more likely to disagree with a Biblical statement about the origin of human races and agree that human skin color diversity can be explained by science. Students with moderate to high religion factors who also agreed with a biblical explanation for the origin of human races were more likely to be supportive of same-sex relationships and homosexuality if they had higher HEB exposure.

The interviews as well as the online survey showed that religion factor is particularly influential regarding students' views and actions on environmental issues. Students with no religion factor or a high religion factor were more likely to identify global warming as a serious problem if they had higher HEB exposure. As stated in the results, this suggests that students with no influence of religion in their lives are likely to have views that reflect the scientific viewpoints to which they are exposed; this is supported by the fact that their views on global warming are also positively correlated with the frequency of their engagement with science news and media. Among those students who had the strongest influence of religion in their lives, human evolutionary biology education seems to be a significant factor in their decision-making about global warming and whether they engaged in environmentally conscious behaviors. The likelihood that students would act in ways considered environmentally conscious was negatively correlated with their belief in divine creation, but total academic HEB exposure was a significant positive influence on those students, particularly those who did not regularly engage with science news media.

Higher HEB exposure was weakly associated with greater engagement with science news media for students with high religion factors, but also for students with high acceptance of evolution or human evolution. Students with a greater influence of religion in their lives are more likely to seek out information about science through print media, television or the internet, perhaps due to a natural curiosity about or interest in science content that they do not otherwise have access to, or maybe to learn more about the scientific discipline that they perceive as being most in conflict with their beliefs. Students who are more accepting of evolution and human evolution in particular may be more likely to seek out science news media because they have a natural curiosity about or interest in science, are more open to scientific viewpoints, or are more likely to be interested in a STEM career; there was a significant positive relationship between human evolution acceptance and motivation to pursue a STEM career.

There was a not a direct relationship between motivation to pursue a STEM career and HEB exposure, or any other factors in the study; however, there was an interesting indirect relationship detected between STEM career motivation and HEB exposure. Greater HEB exposure was positively correlated with students indicating that they were motivated to pursue a STEM career because they wanted to help other people. One possible explanation for this is that learning about humans' place in nature increases a person's capacity for compassion and empathy and students make a connection between caring for or servicing others and STEM careers. It is also possible that this connection between desire and professional goals is made early enough to influence students' high school science class enrollment, such that they take more biology classes, which would increase the likelihood of HEB exposure.

Though the relationship between human evolutionary biology education and students' interest in STEM classes, degrees and careers, and science literacy is not always a direct one, there is ample evidence to suggest that HEB education can make a difference in how some students view the world and their place in it and how they behave as a result. HEB exposure can foster or spark a curiosity about the world that encourages students to seek out information and pursue a course of study that reflects this intrinsic motivator. When close consideration is given to students' backgrounds, beliefs, and acceptance of scientific principles, one begins to see the potential societal impacts of teaching them—particularly those who have high exposure to religious practices and beliefs—about the scientific explanations for the origin and evolution of humans and about modern human anatomy and physiology.

For example, there are a number of socioscientific issues for which exposure to human evolutionary biology is associated with an increased likelihood that students are indecisive; in these circumstances, they seem to be choosing "I don't know" over a more religious-based view. In other words, students' confidence in their decision-making is reduced by increased exposure to human evolutionary biology. This observation could be interpreted in a number of ways, including: (a) students who are exposed to more science education are genuinely confused about how to respond to a question with a scientific basis the answer to which potentially conflicts with their religious views, (b) students who are exposed to more science education are more likely to critically evaluate their views or positions when presented with a question with a scientific basis that potentially conflicts with their religious views, or possibly (c) students who are exposed to more science education are inclined to respond to a question with a scientific basis that potentially conflicts with their religious views in a way that is "safe" and neither reflects their science-based knowledge, nor conflicts with their religious views. It may be the case that any of these three options is a reasonable explanation, depending on the individual. For at least some people, it may be the case that exposure to human evolutionary biology inspires critical thinking skills and it is critical thinking that then determines their decision-making and actions regarding particular socioscientific issues. In other words, it is not the fact of human evolution, but the habits of mind inspired by thinking about human evolution in contrast with religious views on the origin and diversity of humans, that link HEB exposure to socioscientific decision-making. If this is the case, it could be that human evolutionary biology exposure is an essential component to the development of science literacy, cultivating flexible minds that weigh evidence even if when that evidence conflicts with preconceptions or beliefs.

For some socioscientific issues, it seems human evolutionary biology education actually "offsets" the effects of religious teachings and practices. Students' views and actions related to the environment and their views on modern human skin color variation, same-sex relationships, cloning, and stem cell research are all significantly influenced by religion factor. And, for example, students with a high religion factor are more likely to think that global warming is a problem and engage in environmentally-conscious activities if they also have high HEB exposure. However, human evolution acceptance also significantly influences students' views on some of these issues and HEB exposure is not significantly correlated with human evolution acceptance. It can be deduced, then, that there are other factors, not revealed by this study, that are correlated with human evolution acceptance, and therefore students' decision-making, that are outside the realm of formal education. Therefore, the value of formal human evolutionary biology education is dependent upon the "desired" outcome; if interest, engagement, and critical thinking skills are the ultimate goals, then HEB exposure may be a keystone discipline about which students should learn, but if the goal is to inspire specific decisions via increased acceptance of human evolution, then aspects of informal science education, as well as other psychosocial components of a students' development, may need to be given consideration.

Implications for STEM Education in the United States.

The most recent evidence of the national STEM initiative in the United States is the drafting and publication of the Next Generation Science Standards (NGSS) in 2013. The NGSS, like the National Science Education Standards of 1996 which were discussed in Chapter 2: Review of the Literature, are a set of expectations regarding what students should know and be able to do with proficiency at different grade-band levels from kindergarten through twelfth grade. The performance expectations in the NGSS integrate disciplinary core ideas from life, physical, and earth and space sciences with science and engineering practices and cross-cutting concepts that are applicable to all disciplines. The NGSS were designed—through the integration of content and practices—to promote coherent classroom instruction while allowing educators the flexibility to create interesting and relevant curricula for their students (Lead States, 2013).

The NGSS development process was spearheaded by the National Academy of Sciences, Achieve, Inc., the American Association for the Advancement of Science, and the National Science Teachers Association. The initial step in the process was the publication of the National Research Council's document *A Framework for K-12 Science Education* (2012). Then, a contingent of 26 "lead states" worked with a team of writers to draft the NGSS based on the *Framework*. Each state, various stakeholders, and the general public were all given the opportunity to review drafts of the NGSS prior to publication in 2013. The 26 lead states were not obligated to adopt the NGSS as their official science education standards and, as of March, 2014, just 10 states and the District of Columbia had adopted the NGSS.

The development, adoption and implementation of the NGSS in the United States are relevant to this discussion in four ways. The first three are germane to the findings about: (a) HEB exposure and students' interest in STEM degrees and perceived preparedness for undergraduate coursework, (b) HEB exposure and students' interest and engagement in STEM classwork, and (c) HEB exposure and STEM class enrollment, particularly for advanced biology. They are addressed in the introduction to the NGSS document:

- The United States has a leaky K-12 STEM talent pipeline, with too few students entering STEM majors and careers at every level...We need new science standards that stimulate and build interest in STEM. The current education system cannot successfully prepare students for college, careers, and citizenship unless the right expectations and goals are set...Implementing the NGSS will better prepare high school graduates for the rigors of college and careers (Lead States, p. xv).
- The affective domain—the domain of learning that involves interests, experience, and enthusiasm—is a critical component of science education. As pointed out in the *Framework*, there is a substantial body of research that supports the close connection between the development of concepts and skills in science and engineering and such factors as interest, engagement, motivation, persistence and self-identity...For example, research suggests that personal interest, experience, and enthusiasm...may also be linked to later educational and career choices (Lead States, p. xvii).

- Certainly students will be more likely to succeed in achieving [the science and engineering] competencies [identified in the NGSS] if they have the curricular and instructional support that encourages their interests in science and engineering. Further, students who are motivated to continue their studies and to persist in more advanced and challenging courses are more likely to become STEM-engaged citizens and in some cases to pursue careers in STEM fields (Lead States, xix).

Intentionally, neither the *Framework* nor the NGSS specifies affective learning goals. In other words, they do not specify performance expectations that are identified as directly related to interest, motivation, persistence, and career goals. Thus, it is the role of the education researcher, the curriculum developer, and the instructor to identify best practices for teaching and learning that stimulate interest, inspire motivation, support persistence and influence career goals.

This study provides evidence that, for some students, K-12 human evolutionary biology education is associated with increased STEM enrollment in high school (particularly biology enrollment), greater perceived academic success in STEM, heightened interest in STEM degree programs and, indirectly, motivation to pursue STEM careers. Once in college, having learned about human evolutionary biology in high school, some students reported they felt more prepared for their undergraduate STEM coursework—particularly if they completed two or more courses that dealt with the topic of evolution; and feelings of preparation can be critical to retention and recruitment of STEM majors.

And, as stated earlier, there was extensive evidence that most students, regardless of their beliefs or acceptance of evolution, found the science of human evolutionary biology and human anatomy and physiology interesting. The framework for part of this study was the idea that human evolutionary biology education can contribute to goals in the affective domain because it is a personally relevant subject area for students and addresses real-world problems.

Students with the greatest exposure to human evolutionary biology in K-12 were more likely to be interested in a STEM degree program, particularly in the life sciences. And, though K-12 human evolutionary biology education was not directly associated with students' motivation to pursue a STEM career, the findings of this study showed that higher exposure to human evolutionary biology was associated with a greater likelihood that a student would pursue a STEM career because he or she wanted to help other people.

The fourth way in which the NGSS are relevant to this discussion is that the adoption of (or, more appropriately, the failure of most states to adopt) the NGSS reflects, in part, Americans' attitudes towards evolution education. According to a survey conducted by Achieve, Inc., 87% of potential voters showed broad support for standards that are "internationally benchmarked, more challenging, and [that] require students to apply their science knowledge and understand how science concepts fit together" (National Center for Science Education, 2012, para. 6). So why, as of the writing of this thesis, have only ten states and Washington, D.C. adopted the NGSS?

One potential barrier to state adoption of the NGSS, among many, is the treatment of evolution in the standards. The *Framework* and the NGSS recognize evolutionary theory and the principles of evolutionary biology as foundational for the life sciences. But, as discussed in Chapter 2, nearly half of Americans in some surveys oppose the teaching of evolution in public schools and approximately

30% would be more likely to vote for a presidential candidate who supported the teaching of creationism or intelligent design alongside evolution in public schools (e.g., Coalition of Scientific Societies, 2008; ABC News/Washington Post, 2011). In addition to a lack of acceptance of evolution due to religious beliefs, there is also a lack of understanding about the science of human evolutionary biology that may contribute to these views about the teaching of evolution; only 51% of Americans are confident that scientists agree that humans have evolved, therefore half of Americans may not be inclined to view human evolutionary biology as "good science" that students should be learning (Public Religion Research Institute/Religion News Service, 2011).

The Establishment Clause of the First Amendment of the Constitution prevents the promotion or denigration of any religious view in a public school science classroom, and yet, in 2014, bills are being considered in multiple states that would allow public school science teachers the "academic freedom" to promote religious-based views on the origin and diversity of life. For decades, in fact, states have proposed laws that restrict the teaching of evolution in public schools or supplement it with the teaching of "alternative theories" (i.e., intelligent design), and this has led to court cases that received a great deal of publicity, such as the Scopes trial of 1925, *Epperson* v. *Arkansas* in 1968, and *Kitzmiller* v. *Dover Area School District* in 2005, among others.

Some states reject components of their own proposed state science standards that include evolution-related terminology (NCSE, 2014, para. 1). For example, in South Carolina, the Education Oversight Committee did not approve the use of the phrase "natural selection" in its state science standards—according to Senator Mike Fair (R-District 6), "To teach that natural selection is the answer to origins is wrong. ... I don't have a problem with teaching theories. I don't think it should be taught as fact" (National Center for Science Education, 2014a, para. 1). In other states, bills are being proposed that allow parents to excuse their children from learning about evolution in science class. In Missouri, Rick Brattin (R-District 55), sponsor of House Bill 1472, said that requiring students to study evolution is "an absolute infringement on people's rights" and that evolution is "just as much faith and, you know, just as much pulled out of the air as, say, any religion" (National Center for Science Education, 2014b, para. 2). Another antievolution bill in Missouri, House Bill 1587, referred in February, 2014, would prevent administrators from disallowing teachers to teach students about "scientific controversies" around evolution (National Center for Science Education, 2014b, para. 6).

What all of this means is that—even though there is a national STEM initiative to increase the number of American citizens who are qualified STEM professionals, a set of K-12 science education standards that support that initiative by expecting students to achieve proficiency in all scientific disciplines, and fields of study that are known to stimulate student interest in STEM classes, degrees and careers—there are policies and points-of-view in the United States that continue to stand in the way of progress. Learning about human evolutionary biology is identified here as one way to stimulate or foster students' interest in science, and learning about humans' place in nature may even inspire some students to pursue a STEM career with the specific goal of helping other people. There is also evidence presented here that exposure to the science of human evolutionary biology may influence students' decision-making and actions in ways that benefit society. As explained earlier, some groups of students, particularly those who have relatively high exposure to religious practices and beliefs, are more likely to make decisions that align with scientific viewpoints if they also have high human evolutionary biology exposure. They are even more likely to vote in a presidential election. But, if the general public and policy-makers continue to reject the basic tenets of biology, many students in the United States may be deprived of the opportunity to discover their true potential in society, as citizens, as STEM students and STEM professionals.

The implications of this for higher education are substantial. A lack of evolution education affects students' preparedness for university coursework. Preparing high school students for success at the undergraduate level is a priority of the STEM initiative; reducing attrition rates from introductory-level courses at universities is essential for increasing the number of STEM graduates in the U.S. This all puts pressure on university faculty to effectively accommodate a wide range of student knowledge structures, which can be difficult or impossible, especially in massive introductory-level courses. Essentially, to deprive students of the opportunity to learn about evolution in K-12 is to deprive them of the opportunity to feel confident and prepared for their undergraduate education.

This study provides evidence that academic success is not necessarily defined by letter grades and GPAs. Students need to feel confident that they are, or, if they want to be they can be, a "science person." They need to feel as though they can "do science." The best way to ensure this type of success for students is to provide them with a solid foundation of STEM learning in K-12. This involves exposing students to the epistemology of science, sharing with them the evidence that supports scientific hypotheses and theories, and allowing them to think critically and problem-solve, but without the confounding elements of religion-based, unscientific teachings in the classroom.

The paradigm of evolution education research needs to shift to one in which less emphasis is placed on factual knowledge and acceptance and more emphasis is placed on students' interests, perceived preparation for continued learning, professional goals and potential contributions to society. Future evolution education research must explore how students who are and are not exposed to the science of evolutionary biology in K-12 (along with or without religion-based teachings) persist and succeed in STEM fields and contribute to society as citizens of a democracy and stewards of the Earth.

A stumbling block to implementing high quality K-12 evolution education is teacher preparation and professional development. As explained in Chapter 2: Review of the Literature, there are a variety of reasons why teachers do not teach about evolution in public school classrooms. Some have to do with the legislation discussed here, but an issue that cannot be ignored is the failure of higher education to prepare teachers to deliver high quality evolution instruction in the classroom. In addition, there is a lack of support for practicing teachers who are interested in professional development training to help them teach about evolution, especially human evolution. Even if there are training resources or opportunities available, the teachers may not have the funds or the time to take advantage of them. One potential solution to this problem is to increase the quality of evolution education provided to pre-service K-12 teachers during science discipline-specific training. Future research in the field of evolution education must examine not only teachers' knowledge structures and attitudes about evolution, since those are so often mirrored by students, but also the resources available to teachers to support the teaching of evolution and how those resources are used.

In sum, even if K-12 public school students in America receive the highest quality evolution and human evolution education possible, not all of them are going to enter or persist in the STEM pipeline. There are many factors that influence students to enroll in science classes and pursue STEM degrees, including their age, academic aptitude, in what part of the country they attend high school, their ethnicity, their self-confidence, their home and school environments, and certainly other factors that were not identified in this study. But it is clear that the affective domain—students' interest—is a key element, and this study shows that human evolutionary biology is an inherently interesting subject that appeals to students as being logical and relevant to their lives and thus has the potential to spark students' interest in STEM classes and degree programs, regardless of their religious beliefs or acceptance of evolution. This is because human anatomy, physiology, and evolution are about them. Learning about science in the context of humans demonstrates to students that science as a discipline is not a rigorous, structured, and intangible one, but that it has intrinsic value and is associated with exploration and contemplation and is relevant to students' lives. Students who enter the STEM pipeline may pursue STEM careers because they were motivated by a teacher, a television show, a university course, an illness in their family, or their innate curiosity about the world, among many other reasons, but there is also something about learning about one's place in nature that could be associated with a desire to help other people and evidence presented here shows that students see STEM careers as an effective way to accomplish that goal.

In conclusion, one final topic should be addressed. When should human evolutionary biology be taught? It is this researcher's opinion that the answer is the sooner the better. Anecdotal evidence from the interviews with ASU undergraduates suggest that introducing students to the concept of human evolution during adolescence is not the ideal time to do so, as this is the time in students' lives when they tend to be wrestling with a host of different biological, psychological and social issues, including, but not limited to gender and sexual identity, interpersonal relationships with peers and authority figures, growth and developmental changes, and other significant life transitions. Many students who were interviewed said when they first learned about evolution, especially the concept of human evolution, they were confused or disturbed, that they "shut down," that they couldn't trust or believe their teachers, and that they either rejected what they were learning because it called their faith into question or they felt anxiety over the fact that their faith was called into question.

Withholding the scientific evidence for human origins and evolution from students until they are young adults not only diminishes the potential value of learning about HEB, but is in many ways a social injustice; it deprives students of the opportunity to critically consider information about their world and their place in it at an age when the development of critical thinking skills is crucial and it can cause sudden mental and emotional turmoil during adolescence. Young children, even those in elementary school, are adept at considering and weighing evidence and doing so is beneficial to their intellectual development. The interviewed student who was exposed to human evolutionary biology in elementary school had strong, positive memories of learning about it and did not speak negatively about any academic experience later in his life associated with learning about evolution. Perhaps this is because young children's minds are open and malleable and, when students are exposed to information at an early age, they can carry that information and their evaluation of that information with them into their later lives. It was the students who did not learn about evolution until late in high school, or as undergraduates, who had the most disruptive educational and personal experience due to the cognitive dissonance they experienced when presented with information that so strongly contradicted what they had been taught their whole lives.

Thus, it is imperative that pre-service and in-service elementary school teachers receive the support, educational opportunities and professional development they need to introduce young students to the unifying concept of biology—evolution—and to allow their students to explore the unique and wonderful place they hold in nature as *Homo sapiens*.

POSTFACE

"I take it that the whole object of education is, in the first place, to train the faculties of the young in such a manner as to give their possessors the best chance of being happy and useful in their generation; and, in the second place, to furnish them with the most important portions of that immense capitalized experience of the human race which we call knowledge in its widest possible sense; and the question is, what subjects to select by training and discipline, in which the object I have just defined may be best attained."

- Sir Thomas Henry Huxley

"On Science and Art in Relation to Education," 1882

REFERENCES

@JoshRosenau. (2011). *But also shows the danger of creationism. To be an engaged patient or citizen of 21st century, you need evolution education! [Twitter post]*. Retrieved October 6, 2011, from http://twitter.com/JoshRosenau/status/122109109855199232

The 8th Annual AP Report to the Nation. (2012). The College Board. Retrieved from http://media.collegeboard.com/digitalServices/public/pdf/ap/rtn/AP-Report-to-the-Nation.pdf

American Association for the Advancement of Science. (2006). *Statement on the teaching of evolution*. Retrieved February 10, 2010, from http://www.aaas.org/news/releases/2006/pdf/0219boardstatement.pdf

American competitiveness initiative: Leading the world in innovation. (2006). The White House, Domestic Policy Council & Executive Office of the President, Office of Science and Technology Policy. Retrieved from http://www.eric.ed.gov/ERICWebPortal/detail?accno=ED503266

American Institute of Physics. (2013). *Joint statement on the education of future teachers and list of physics departments that have endorsed it*. Retrieved June 5, 2013, from http://www.aip.org/education/futeach.html

Arizona high school eligibility study. (2006). Arizona Board of Regents. Retrieved from http://www.azregents.edu/1_the_regents/reports_factbook/reports_factbook.html

ASU Common Data Set. (2011). University Office of Institutional Analysis. Retrieved from http://uoia.asu.edu/sites/default/files/common/Common_Data_Set_2010-2011.pdf

ASU Enrollment Summary. (2010). University Office of Institutional Analysis. Retrieved from http://uoia.asu.edu/sites/default/files/ensmry/Enrollment_Summary_Fall_2010.pdf

ASU Fact Book. (2009). University Office of Institutional Analysis. Retrieved from http://uoia.asu.edu/fact-book

Auerbach, C. F., & Silverstein, L. B. (2003). *Qualitative data: an introduction to coding and analysis*. New York: New York University Press.

Ayres, L. (2008). Semi-structured Interview. *The Sage Encyclopedia of Qualitative Research Methods* (pp. 811-813). Thousand Oaks, CA: SAGE. Retrieved from http://sage-ereference.com/view/research/n410.xml

Barnett, J. (2008). *Focus Group Tips for Beginners.* Retrieved November 26, 2008, from www.tcall.tamu.edu/orp/opr1.htm

Barton, A. H., & Lazarsfeld, P. F. (1955). Some Functions of Qualitative Analysis in Social Research. *Frankfurter Beitrage Zur Soziologie. I. Frankfurt a. M.: Europaische Verglagsanstalt*, 321-361.

Bell, R. L., & Lederman, N. G. (2003). Understandings of the nature of science and decision making on science and technology based issues. *Science Education, 87*(3), 352-377. doi:10.1002/sce.10063

Benaquisto, L. (2008). Codes and Coding. *The Sage Encyclopedia of Qualitative Research Methods* (pp. 86-89). Thousand Oaks, CA: SAGE. Retrieved from http://sage-ereference.com/view/research/n48.xml

Berkman, M. B., & Plutzer, E. (2010). *Evolution, creationism, and the battle to control America's classrooms.* New York: Cambridge University Press.

Böhm, A. (2004). Theoretical Coding: Text Analysis in Grounded Theory. In U. Flick, E. vonKardorff & I. Steinke (Eds.), *A Companion to Qualitative Research* (pp. 270). London: SAGE.

Bryan, R. R., Glynn, S. M., & Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. *Science Education, 95*(6), 1049-1065. doi:10.1002/sce.20462

Bryant, A. (2009). *Grounded Theory and Pragmatism: The Curious Case of Anselm Strauss*. Forum Qualitative Sozialforschung / Forum: Qualitative Social Research, 10(3), Art. 2. Retrieved from http://nbn-resolving.de/urn:nbn:de:0114-fqs090325.

Carnegie Corporation of New York. (2012). *$22M Fund to Kick-Off Effort by Cross-Sector Partnership to Hire, Develop, Retain Excellent STEM Teachers.* Retrieved May 5, 2012, from http://www.prnewswire.com/news-releases/22m-fund-to-kick-off-effort-by-cross-sector-partnership-to-hire-develop-retain-excellent-stem-teachers-138854044.html

Carnevale, A. P., Smith, N., & Strohl, J. (2010). *Help Wanted: Projections of Jobs and Education Requirements through 2018.* Georgetown University Center on Education and the Workforce. Retrieved from www9.georgetown.edu/grad/gppi/hpi/cew/pdfs/FullReport.pdf

Carr, J. (2010). Stimulating science: One year after the Recovery Act. *Bioscience, 60*(2), 101. doi:10.1525/bio.2010.60.2.4

Cavanagh, S. (2008). Projects try to prepare students to succeed at STEM in college. *Education Week, 28*(4), 8. Retrieved from http://www.edweek.org/ew/articles/2008/09/12/04albany.h28.html?qs=cavanagh

Charette, R. N. (2013) *The STEM crisis is a myth*. IEEE Spectrum. Retrieved August 30, 2013 from http://spectrum.ieee.org/at-work/education/the-stem-crisis-is-a-myth

Charmaz, K., & Bryant, A. (2008). Grounded Theory. *The Sage Encyclopedia of Qualitative Research Methods* (pp. 375-377). Thousand Oaks, CA: SAGE. Retrieved from http://sage-ereference.com/view/research/n189.xml

Choffnes, E. R., Relman, D. A., & Mack, A. (2010). *Antibiotic resistance: Implications for global health and novel intervention strategies, workshop summary*. Washington, DC, USA: National Academies Press. Retrieved from http://www.nap.edu/catalog.php?record_id=12925

Coalition of Scientific Societies. (2008). You say you want an evolution? A role for scientists in science education. *Developmental Biology, 316*(1), 2-5. doi:10.1016/j.ydbio.2008.01.021

Committee on Prospering in the Global Economy of the 21st Century. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future.* Washington, D.C.: National Academy of Sciences. Retrieved from http://www.nap.edu/catalog.php?record_id=11463

Educating America: The President's initiatives for high school, higher education, and job training. (2004). (). Washington, D.C.: Executive Office of the President. Retrieved from http://www.eric.ed.gov/ERICWebPortal/detail?accno=ED503739

Eggert, S., & Bogeholz, S. (2010). Students' use of decision-making strategies with regard to socioscientific Issues: An application of the Rasch Partial Credit model. *Science Education, 94*(2), 230-258. doi:10.1002/sce.20358

Ehrlich, P. R. (2011). Paul R. Ehrlich: Seeking environmental solutions in the social sciences [Interview]. *Bulletin of the Atomic Scientists, 67*(5), 1-8. doi:10.1177/0096340211421469

Eide, P. J. (2008). Recruiting Participants. *The Sage Encyclopedia of Qualitative Research Methods* (pp. 744-747). Thousand Oaks, CA: SAGE. Retrieved from http://sage-ereference.com/view/research/n374.xml

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). *G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences.* Behavior Research Methods, 39, 175-191.

Federman, M. (2007). State graduation requirements, high school course taking, and choosing a technical college major. *The B.E. Journal of Economic Analysis and Policy*, *7*(1), 4. doi:10.2202/1935-1682.15212

Feller, R. (2011). Advancing the STEM workforce through STEM-centric career development. *Technology & Engineering Teacher*, *71*(1), 6-12. Retrieved from http://eric.ed.gov/ERICWebPortal/detail?accno=EJ941849

Flick, U. (2006). *An Introduction to Qualitative Research*. Thousand Oaks, CA: SAGE.

Fontana, A., & Frey, J. H. (2000). The Interview: From Structured Questions to Negotiated Text. In N. Denzin, & Y. S. Lincoln (Eds.), *Handbook of Qualitative Research* (2nd ed., pp. 645-672). London: SAGE.

Gibbs, G. R. (2003). CAQDAS (Computer Assisted Qualitative Data Analysis Software). *Encyclopedia of Social Science Research Methods* (pp. 88-90). Thousand Oaks, CA: SAGE. Retrieved from http://sage-ereference.com/view/socialscience/n86.xml

Glaser, B. (1978). *Theoretical Sensitivity*. Mill Valley: University of California.

Glaser, B. (1992). *Basics of Grounded Theory Analysis: Emergence vs. Forcing*. Mill Valley: Sociology Press.

Glaser, B., & Strauss, A. L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*. New York: Aldine.

Green, S., & Salkind, N. J. (2010). *Using SPSS for Windows and Macintosh: Analyzing and Understanding* (6th ed.). New York: Pearson.

Grigg, W. S., Lauko, M. A., & Brockway, D. M. (2006). *The nation's report card: Science 2005.* (No. NCES 2006-466). Washington, D.C., U.S. Government Printing Office: U.S. Department of Education National Center for Education Statistics. Retrieved from http://nces.ed.gov/nationsreportcard/pubs/main2005/2006466.asp

Groenewald, T. (2008). Memos and Memoing. In SAGE (Ed.), *The Sage Encyclopedia of Qualitative Research Methods* (pp. 506-507). Thousand Oaks, CA: SAGE. Retrieved from http://sage-ereference.com/view/research/n260.xml

Hardin, G. (1968). The Tragedy of the Commons. *Science, 162*(3859), 1243-1248. doi:10.1126/science.162.3859.1243

Hawkins, R. Z. (2002). Seeing ourselves as primates. *Ethics and the Environment, 7*(2), 60-103. doi:10.2979/ETE.2002.7.2.60

Hermanns, H. (2004). Interviewing as an Activity. In U. Flick, E. vonKardorff & I. Steinke (Eds.), *A Companion to Qualitative Research* (pp. 203-208). London: SAGE.

Herschbach, D. R. (2011). The STEM initiative: Constraints and challenges. *Journal of sTEm Teacher Education, 48*(1), 96-122. Retrieved from http://www.eric.ed.gov/ERICWebPortal/detail?accno=EJ952045

Hillis, D. (2007). Making evolution relevant and exciting to biology students. *Evolution, 61*(6), 1261-1264. doi:10.1111/j.1558-5646.2007.00126.x

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education, 29*(11), 1347-1362. doi:10.1080/09500690601007549

Holbrook, J., & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental and Science Education, 4*(3), 275-288. Retrieved from http://www.eric.ed.gov/ERICWebPortal/detail?accno=EJ884397

Horn, S. S., & Heinze, J. (2011). "She can't help it, she was born that way": Adolescents' beliefs about the origins of homosexuality and sexual prejudice. *Anales De Psicologia, 27*(3), 688-697. Retrieved from http://hdl.handle.net/10027/8228

Jablonski, N. G. (2006). *Skin: A natural history*. Berkeley: University of California Press.

Jick, T. (1983). Mixing Qualitative and Quatitative Methods: Triangulation in Action. In J. v. Maanan (Ed.), *Qualitative Methodology* (pp. 135-148). London: SAGE.

Jones, R. M. (2013) Congressional Committees Start Work on Reauthorization of COMPETES Legislation. *FYI: The American Institute of Physics Bulletin of Science Policy News*. *152*. Retrieved from http://www.aip.org/fyi/2013/152.html

Kitzmiller v. Dover Area School District, 400 F.Supp.2d 707 (United States District Court, M.D. Pennsylvania 2005). Retrieved from http://scholar.google.com/scholar_case?case=16465861447416053365&q=%22Kitzmiller+v+Dover%22&hl=en&as_sdt=2,9

Kolarova, T. (2011). Modern biotechnology from the point of view of 15-19-year-old high school students. *Biotechnology & Biotechnological Equipment, 25*(3), 2538-2546. doi:10.5504/BBEQ.2011.0069

Kuenzi, J. J. (2008). *Science, technology, engineering, and mathematics (STEM) education: Background, federal policy, and legislative action.* (No.

35).Congressional Research Service. Retrieved from http://digitalcommons.unl.edu/crsdocs/35

Lacey, T., & Wright, B. (2009). Occupational employment projections to 2018. *Monthly Labor Review*, *132*(11), 82-123. Retrieved from http://infousa.interchange.at/infousa_final/economy/workforce/docs/art5full.pdf

Leech, N. L., & Obwuegbuzie, A. J. (2011). Beyond Constant Comparison Qualitative Data Analysis: Using NVivo. *School Psychology Quarterly*, *26*(1), 70-84.

Lerner, L. (2000). *Good science, bad science: Teaching evolution in the states.* Washington, D.C.: The Thomas B. Fordham Foundation. Retrieved from http://www.eric.ed.gov/ERICWebPortal/detail?accno=ED447099

Liu, S., Lin, C., & Tsai, C. (2011). College students' scientific epistemological views and thinking patterns in socioscientific decision making. *Science Education*, *95*(3), 497-517. doi:10.1002/sce.20422

Madrid, O. (2008). Arizona students struggle on first science AIMS test. *The Arizona Republic,* Retrieved from http://www.azcentral.com/arizonarepublic/news/articles/2008/09/17/20080917scienceaims0917.html

Maietta, R. C. (2008). Computer-assisted Data Analysis. *The Sage Encyclopedia of Qualitative Research Methods* (pp. 104-109). Thousand Oaks, CA: SAGE. Retrieved from http://sage-ereference.com/view/research/n56.xml

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education*, *95*(5), 877-907. doi:10.1002/sce.20441

Masnick, A. M., Valenti, S. S., Cox, B. D., & Osman, C. J. (2010). A multidimensional scaling analysis of students' attitudes about science careers. *International Journal of Science Education*, *32*(5), 653-667. doi:10.1080/09500690902759053

Maxwell, J. A., & Mittapalli, K. (2008). Theory. *The Sage Encyclopedia of Qualitative Research Methods* (pp. 877-881). Thousand Oaks, CA: SAGE. Retrieved from http://sage-ereference.com/view/research/n457.xml

Mead, L. S., & Mates, A. (2009). Why Science Standards are Important to a Strong Science Curriculum and How States Measure Up. *Evolution Education and Outreach*, *2*, 359-371. doi:10.1007/s12052-009-0155-y

Merkens, H. (2000). Selection Procedures, Sampling, Cas Construction. In U. Flick, E. vonKardorff & I. Steinke (Eds.), *A Companion to Qualitative Research* (pp. 165-171). London: SAGE.

Merton, R. K., Fiske, M., & Kendall, P. L. (1956). *The Focused Interview*. Glenoe, IL: Free Press.

Mills, M. (2008). Comparative Research. *The Sage Encyclopedia of Qualitative Research Methods* (pp. 101-104). Thousand Oaks, CA: SAGE. Retrieved from http://sage-ereference.com/view/research/n55.xml

Mooney, C., & Kirshenbaum, S. (2010). *Unscientific America : How scientific illiteracy threatens our future*. New York, NY, USA: Basic Books.

Moore, R., & Kraemer, K. (2005). The teaching of evolution & creationism in Minnesota. *The American Biology Teacher, 67*(8), 457-457. doi:10.1662/0002-7685(2005)067[0457:TTOECI]2.0.CO;2

Moore, R. (2004). How well do biology teachers understand the legal issues associated with the teaching of evolution? *Bioscience, 54*(9), 860-865. doi:10.1641/0006-3568(2004)054[0860:HWDBTU]2.0.CO;2

Moore, R. (2007a). The differing perceptions of teachers & students regarding teachers' emphasis on evolution in high school biology classrooms. *The American Biology Teacher, 69*(5), 268-271. doi:10.1662/0002-7685(2007)69[268:TDPOTS]2.0.CO;2

Moore, R. (2007b). What are students taught about evolution? *McGill Journal of Education, 42*(2), 177. Retrieved from http://mje.mcgill.ca.ezproxy1.lib.asu.edu/index.php/MJE/article/view/2218

Morgan, D. L. (1988). *Focus Groups as Qualitative Research*. Newbury Park, CA: SAGE.

Museus, S. D., Palmer, R. T., Davis, R. J., & Maramba, D. C. (2011). Racial and ethnic minority students' success in STEM education. *ASHE Higher Education Report, 36*(6), I-XVIII, 1-140. Retrieved from http://works/bepress.com/robert_palmer/32

Myers III, R. E., & Fouts, J. T. (1992). A cluster analysis of high school science classroom environments and attitude toward science. *Journal of Research in Science Teaching, 29*, 929-937. doi:10.1002/tea.3660290904

Nahum, T., Ben-Chaim, D., Azaiaz, I., Herskovitz, O., & Zoller, U. (2010). Does STES-oriented science education promote 10th-grade students' decision-making capability? *International Journal of Science Education, 32*(10), 1315-1336. doi:10.1080/09500690903042533

National Academy of Sciences & Institute of Medicine. (2008). *Science, evolution, and creationism*. Washington, D.C.: The National Academies Press.

National Center for Education Statistics (2013). *Performance of U.S. 15-year-old Students in Mathematics, Science, and Reading Literacy in an International Context: First Look at PISA 2012*. Retrieved December 3, 2013, from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2014024

National Math and Science Initiative. (2013) *About the National Math and Science Initiative*. Retrieved June 5, 2013, from http://www.nms.org/AboutNMSI.aspx

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, D.C.: The National Academies Press. Retrieved from http://www.nap.edu/catalog.php?record_id=13165#

National Research Council. (2009). *New biology for the 21st Century : Ensuring the United States leads the coming biology revolution*. Washington, D.C.: The National Academies Press. Retrieved from http://www.nap.edu/catalog.php?record_id=12764

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

National Science Board (2010). *Science and Engineering Indicators 2010*. Arlington, VA: National Science Foundation (NSB 10-01).

National Science Teachers Association. (2011). *NSTA position statement: The teaching of evolution*. Retrieved September 30, 2011, from http://www.nsta.org/about/positions/evolution.aspx

Nehm, R. (2011). Can This Approach Improve Student Learning of Evolution? The Evidence Base. Paper presented at the *Thinking Evolutionarily: Evolution Education Across the Life Sciences*, Carnegie Institution for Science, Washington, D.C. Retrieved from http://nas-sites.org/thinkingevolutionarily/topics-and-agenda/

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press.

Nicholls, G. M., Wolfe, H., Besterfield-Sacre, M., & Shuman, L. J. (2010). Predicting STEM degree outcomes based on eighth grade data and standard test scores. *Journal of Engineering Education*, *99*(3), 209-223. Retrieved from http://www.jee.org/2010/july/3.pdf

Noerager Stern, P. (2008). Constant Comparison. *The Sage Encyclopedia of Qualitative Research Methods* (pp. 115-117). Thousand Oaks, CA: SAGE. Retrieved from http://sage-ereference.com/view/research/n63.xml

Nordstokke, D. W., Zumbo, B. D., Cairns, S. L., & Saklofske, D.H. (2011). The operating characteristics of the nonparametric Levene test for equal variances with assessment and evaluation data. *Practical Assessment, Research, and Evaluation, 16*(5), 1-8. Retrieved from http://pareonline.net/getvn.asp?v=16&n=5

Novacek, M. (2008). Engaging the public in biodiversity issues. *PNAS : Proceedings of the National Academy of Sciences, 105*(Suppl 1), 11571-11578. doi:10.1073/pnas.0802599105

Offit, P. A. (2008). *Autism's false prophets: Bad science, risky medicine, and the search for a cure*. New York: Columbia University Press.

Panel on Addressing the Challenges of Climate Change Through the Behavioral and Social Sciences & National Research Council. (2010). In Stern P. C. (Ed.), *Facilitating climate change responses : A report of two workshops on insights from the social and behavioral sciences*. Washington, DC, USA: National Academies Press.

Patton, M. Q. (2002). *Qualitative Evaluation and Research Methods* (3rd ed.). London: SAGE.

Piburn, M. D., & Baker, D. R. (1993). If I were the teacher: Qualitative study of attitude toward science. *Science Education, 77*(4), 393-406. doi:10.1002/sce.3730770404

Puchta, C., & Potter, J. (2004). *Focus Group Practice*. London: SAGE.

President's Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K-12 science, technology, engineering, and math (STEM) education for America's future*. Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stem-ed-final.pdf

President's Council of Advisors on Science and Technology. (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Working Group Report*. Retrieved from http://purl.fdlp.gov/GPO/gpo21068

Project 2061. (2009). *Benchmarks online*. Retrieved September 30, 2011, from http://www.project2061.org/publications/bsl/online/index.php?chapter=14#B

PRRI/RNS Religion News Survey. (2011). University of Connecticut: The Roper Center for Public Opinion Research. Retrieved from http://www.ropercenter.uconn.edu.ezproxy1.lib.asu.edu/data_access/ipoll/ipoll.html

QSR International Pty Ltd. (2008). *QuestionPro Online Help Tutorials*

Ragin, C. C., & Becker, H. S. (1992). *What is a Case? Exploring the Foundations of Social Inquiry*. Cambridge: Cambridge University Press.

Ragin, C. C., Nagel, J., & White, P. (2004). *Workshop on Scientific Foundations of Qualitative Research*. National Science Foundation.

Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2011). Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education, 95*(3), 458-476. doi:10.1002/sce.20431

Ruse, M. (2012). *The Philosophy of Human Evolution*. Cambridge: Cambridge University Press.

Rutledge, M. L., & Mitchell, M. A. (2002). High school biology teachers' knowledge structure, acceptance & teaching of evolution. *The American Biology Teacher*, *64*(1), 21-28. doi:10.1662/0002-7685(2002)064[0021:HSBTKS]2.0.CO;2

Rutledge, M. L., & Sadler, K. C. (2007). Reliability of the Measure of the Acceptance of the Theory of Evolution (M.A.T.E.) Instrument with University Students. *The American Biology Teacher*, *69*(6), 332-335.

Rutledge, M. L., & Warden, M. A. (2000). Evolutionary Theory, the Nature of Science and High School Biology Teachers: Critical Relationships. *The American Biology Teacher*, *62*(1), 23-31. doi:10.1662/0002-7685(2000)062[0023:ETTNOS]2.0.CO;2

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching, 41*(5), 513-536. doi:10.1002/tea.20009

Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, *46*(8), 909-921. doi:10.1002/tea.20327

Saumure, K., & Given, L. M. (2008). Convenience Sample. *The Sage Encyclopedia of Qualitative Research Methods* (pp. 125-126). Thousand Oaks, CA: SAGE. Retrieved from http://sage-ereference.com/view/research/n68.xml

Schreiner, C., Henriksen, E. K., & Hansen, P. J. K. (2005). Climate education: Empowering today's youth to meet tomorrow's challenges. *Studies in Science Education, 41*(1), 3-49. doi:10.1080/03057260508560213

Schwartz, M. S., Sadler, P. M., Sonnert, G., & Tai, R. H. (2008). Depth versus breadth: How content coverage in high school science courses relates to later success in college science coursework. *Science Education, 93*(5), 798-826. doi:10.1002/sce.20328

Scotchmoor, J. (2011). The Case for Thinking Evolutionarily Across the Life Sciences. Paper presented at the *Thinking Evolutionarily: Evolution Education Across the Life Sciences,* Carnegie Institution for Science, Washington, D.C. Retrieved from http://nas-sites.org/thinkingevolutionarily/topics-and-agenda/

Sharma, A. (2011). Global climate change: What has science education got to do with it? *Science and Education,* doi:10.1007/s11191-011-9372-1

Simmons, P. (2011). Spirit, opportunity, and innovation: Science education for a smarter planet. *Science and Children*, *49*(1), 8. Retrieved from http://www.nsta.org/publications/browse_journals.aspx?action=issue&thetype=all&id=10.2505/3/sc11_049_01

Strauss, A. L. (1987). *Qualitative Analysis for Social Scientists*. Cambridge: Cambridge University Press.

Strauss, A. L., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Thousand Oaks, CA: SAGE.

Sullins, E. S., Hernandez, D., & Fuller, C. (1995). Predicting who will major in a science discipline: Expectancy-value theory as part of an ecological model for studying academic communities. *Journal of Research in Science Teaching, 32*, 99-119. doi:10.1002/tea.3660320109

Tapping America's potential: The education for innovation initiative (2005). Business Roundtable, Washington, DC. Retrieved from http://www.eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED485768

The need for science education reform. (2009). Retrieved January 7, 2008, from http://www.accessexcellence.org/LC/SER/background.php

Thompson, R., & Bolin, G. (2011). Indicators of success in STEM majors: A cohort study. *Journal of College Admission,* (212), 18-24. Retrieved from https://webportal.nacacnet.org/Purchase/ProductDetail.aspx?Product_code=693cb746-2fb2-e011-9a4b-001b216f1440

U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress Science Assessment. (2009). Retrieved October 4, 2013, from: http://nces.ed.gov/nationsreportcard/naepdata/report.aspx

U.S. government expands STEM degree program list. (2011). *International Educator, 20*(4), 6. Retrieved from http://nafsa.org/publications/default.aspx?id=27639 Degree program list is available at www.ice.gov/doclib/sevjs/pdf/stem-list-2011.pdf

Vest, C. M. (2011). *Engineers: The next generation - Do we need more? Who will they be? What will they do? Transcript of a speech presented at the NAE annual meeting, October 16, 2011* Retrieved from http://www.nae.edu/Activities/Events/AnnualMeetings/19611/53074.aspx

Wai, J., Lubinski, D., Benbow, C. P., & Steiger, J. H. (2010). Accomplishment in science, technology, engineering, and mathematics (STEM) and its relation to STEM educational dose: A 25-year longitudinal study. *Journal of Educational Psychology*, *102*(4), 860-871. doi:10.1037/a0019454

Wadhwa, V., Gereffi, G., Rissing, B., & Ong, R. (2007) Where the engineers are. *Issues in Science and Technology*, *23*(3), 73-84. Retrieved from www.issues.org/23.3/wadhwa.html

Warburton, N. (2011). *A Little History of Philosophy*. Yale University Press.

Ware, N. C., & Lee, V. E. (1988). Sex differences in choice of college science majors. *American Educational Research Journal, 25*, 593-614. Retrieved from http://www.jstor.org/stable/1163131

Weiss, I. R., Banilower, E., McMahon, K., & Smith, P. (2001). *Report of the 2000 national survey of science and mathematics education.* Chapel Hill, NC.

Woolnough, B. E. (1994). *Effective science teaching*. Philadelphia: Open University Press.

Wu, Y., & Tsai, C. C. (2011). High school students' informal reasoning regarding a socio-scientific issue, with relation to scientific epistemological beliefs and cognitive structures. *International Journal of Science Education*, *33*(3), 371-400. doi:10.1080/09500690903505661

Zeidler, D. L., & Keefer, M. (2003). The role of moral reasoning and the status of socioscientific issues in science education. In D. L. Zeidler (Ed.), *The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education* (pp. 7-38). Netherlands: Kluwer Academic Publishers.

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education, 89*(3), 357-377. doi:10.1002/sce.20048

Zeidler, D. L. (2003). *The role of moral reasoning on socioscientific issues and discourse in science education*. Dordrecht; Boston: Kluwer Academic Publishers.

APPENDIX A

SUMMARY OF RECENT RESEARCH IN STEM EDUCATION AND RELEVANT FINDINGS

Source	Research Question(s)	Sample	Instrument(s) / Methods	Conclusions Relevant to This Study
Bryan, Glynn & Kittleson, 2011	How are students' intrinsic motivation, self-efficacy, self-determination, and achievement related?	14 – 16 year olds attending a suburban public high school in southeastern U.S. (*n* = 288)	Questionnaire and essay responses, achievement and enrollment data and semi-structured interviews; Structural equation modeling, independent samples χ^2 tests, analytic induction	*Essays and interviews* [based on sample quotes provided in the published paper]*:* Students who were motivated to take AP science courses used words/phrases such as "enjoy," "fun," "I love it," "favorite subject," "challenge," "college," "future career." Students with low motivation to learn more science used words or phrases such as "I don't like," "hate," "boring," "I don't really care," and "someone helping me."
Maltese & Tai, 2011	How do educational experiences affect persistence and degree completion in STEM?	Students who participated in the National Educational Longitudinal Study of 1988 (NELS:88; *n* = 4,700)	NELS:88 dataset (data for professional research use only which includes academic records); Logistic regression model (built in chronological blocks)	Students who persist in STEM and/or complete a degree in STEM: *10th grade block*: ranked usefulness of science high, desired STEM careers in 8th grade *11th/12th grade block*: enrolled in 11th grade biology, had teachers who emphasized further study in science, expressed a personal interest in STEM *College block*: ranked usefulness of science high, completed more STEM credits in first year of college *Final model*: indicated interest in STEM in 8th grade, indicated interest in STEM college major in 12th grade, had high enrollment in H.S. science classes

Source	Research Question(s)	Sample	Instrument(s) / Methods	Conclusions Relevant to This Study
Thompson & Bolin, 2011	What factors can be used to predict if a STEM student will switch majors, drop out or graduate?	First time freshman cohort at a large public university in Texas (*n* = 1,400)	Seven-year longitudinal enrollment data; χ^2 contingency tables	Graduation rates for freshman who identified intent to major in STEM = 17%. There is a significant relationship between a STEM major's high school rank and "action" as an undergraduate (dropping out, switching majors or graduating). Gender should not be used to predict degree completion in STEM degree programs. Ethnicity should not be used to predict persistence in STEM degree programs.
Nicholls, Wolfe, Besterfield-Sacre, & Shuman, 2010	Are there data collected in 8th grade and from standardized tests that can be used to predict STEM degree outcomes?	Students who participated in NELS:88 (*n* = 11,320)	NELS:88 dataset (professional research data); logistic regression, survival analysis, receiver operating characteristics (ROC) curve analysis	There are students who do not achieve a STEM degree who could if they are encouraged to develop an interest in the subject and motivation to major in STEM.
Riegle-Crumb, Moore, & Ramos-Wada, 2010	How do students' attitudes and academic achievements account for differences in	Caucasian, Hispanic and African-American 8th grade students from 232	Data from Trends in International Mathematics and Science Study (TIMSS) 2003; Logistic regression and χ^2 tests	Prior to entering high school, four out of 10 males and three out of 10 females report that they "enjoy science" (this is a statistically significant difference between sexes). There is a significant positive

Source	Research Question(s)	Sample	Instrument(s) / Methods	Conclusions Relevant to This Study
	STEM career aspirations for genders and races / ethnicities?	schools (*n* not reported)		relationship between "science enjoyment" and STEM career aspirations. There is a more positive relationship for "science enjoyment" and science career aspirations than there is for science test scores and science career aspirations.
Wai, Lubinski, Benbow, & Steiger, 2010	What is the relationship between precollegiate advanced / enriched experiences ("dose") and adult accomplishments in STEM?	*Study 1*: participants drawn from the Study of Mathematically Precocious Youth at ~33 years of age (~20 years post-SMPY; *n* = 1,467) *Study 2*: "highly motivated" STEM graduate students at ~25 and ~35 years of age (*n* = 714)	*Study 1*: Follow-up surveys of SMPY participants (via internet, mail or phone) and publicly-available data about participants; independent samples *t* tests and confidence intervals *Study 2:* 10-year longitudinal survey data, retrospective profiles of educational experiences; independent samples *t* tests and confidence intervals	*Study 1*: Among mathematically gifted students, those who received a greater dose of curricular and / or extra-curricular STEM opportunities as adolescents were more likely to become STEM professionals (have a STEM Ph.D. and/or STEM career, STEM publication, or tenure) *Study 2*: Professional STEM outcomes covaried with past doses of STEM experiences (regardless of the sex of the participant).
Schwartz, Sadler, Sonnert, & Tai, 2008	How does the performance of college students	Students in introductory biology,	Surveys; multiple linear regression (hierarchical linear models)	Approximately 18% of students report not learning about evolution in high school (h.s.) biology.

Source	Research Question(s)	Sample	Instrument(s) / Methods	Conclusions Relevant to This Study
	in introductory science courses relate to the amount of content covered in their high school science courses?	chemistry or physics courses at 55 colleges and universities (*n* = 8,310; *n* = 6999 for extended models when data missing)		Fewer than 10% of students identified evolution as a recurring topic in h.s. biology. There is a negative relationship between breadth (vs. depth) of content coverage in h.s. biology courses and performance in undergraduate coursework (baseline and extended models).

APPENDIX B

RECRUITMENT SCRIPT, INVITATION EMAIL, INFORMATION LETTER AND QUESTIONNAIRE FOR INTERVIEW SESSIONS

Dear Professor,

I am a doctoral candidate in the School of Human Evolution and Social Change and am seeking your assistance with my dissertation research. I am a student of Drs. Robert Williams and Richard Toon. My dissertation research examines the effects of pre-collegiate human evolutionary biology education on university students' personal, academic and professional goals, achievements and decision-making. I am currently recruiting ASU undergraduates for participation in upcoming focus groups.

If you could either post the following message on your courses' Blackboard sites or send this message out to all of your students via email using your Blackboard mailing list (or your lab TAs), I would be very appreciative. If you do so, please let me know in a quick response to this email.

The IRB has found this study exempt under Federal regulations, 45 CFR, Part 46.101(b)(1)(2).

Thank you very much for your valuable time.

Sincerely,
Caitlin Schrein
Graduate Student, School of Human Evolution and Social Change
Teaching Assistant, School of Life Sciences
Arizona State University

****

Round 1 Recruitment Text
Are you interested in a free meal? Are you interested in participating in cutting edge research? If so, please consider participating in a moderated student focus group addressing evolutionary biology education lead by ASU researchers. All ASU undergraduates are eligible to participate and no particular knowledge of or opinion about evolutionary biology is required.

Focus groups will be held on the main campus, will last no more than 90 minutes, a full meal will be provided, and you may opt-out of the study at any time. All data will be kept strictly anonymous.

Your participation will contribute to the improvement of science education in public schools and universities.

If interested, please email ASUevolution@gmail.com for details about the research and the schedule of focus group meetings. We are only asking for you to participate in one 90-minute session.

Focus groups run through March 27th. You may sign up anytime, but spots are limited, so act soon.

Round 2 Recruitment Text
Attention undergrads! Want to make some spare cash fast? Researchers at ASU are recruiting participants for a scientific study of the effects of biological evolution education on students' goals, performance and decision-making.

We are looking for ASU undergraduates who can participate in one 60-minute interview session on the Tempe campus (Matthews Center, Room 206).

NO prior knowledge of, experience with, or attitude about evolution is expected or required.

Participants will be paid $10 cold-hard-cash for a one-hour session.

Sessions will run nearly all day Friday, April 24th, Tuesday, April 28th, and Thursday, April 30th.

If you are interested, email ASUEVOLUTION@GMAIL.COM for a time slot.

Dear _____________,

Thank you for your interest in our upcoming student discussion (focus) groups. This email does not indicate an obligation to participate, but is intended to provide you with important information about signing up for a focus group. Open time slots are listed below.

By participating in a upcoming focus group, you will have the opportunity to contribute to our research study, "*Where did you come from? Where will you go? The effects of human evolutionary biology education on American students' academic, professional and personal achievements and decision-making*."

The main goal of our study is to determine how learning -- or not learning -- about evolution in middle/high school affects how public university students, such as yourself, perform in intro level science courses and the decisions students make about majors, careers, whether or not to stay in school, and how students perceive global issues and make decisions that impact their lives and the lives of others.

We ask that each volunteer participate in one (and only one) one-hour session.

Each participant will be compensated $10 cash at the conclusion of the session.

If you choose to participate in this ground-breaking research, you can be guaranteed the following:

*Complete anonymity (Your identity will not be disclosed to anyone outside the research group at any time for any reason.)
*A unique, interesting experience -- a chance to share your opinions regarding your education and make a difference for the future of science education in America
*The choice to opt out of the study at any time (even during or after the focus group)

Additional information:

*Each focus group will last no more than 60 minutes. Please try to arrive five minutes early so you can get settled before we begin - the start times below indicate when the group discussion will begin.

*A moderator will lead the discussion by asking questions of the group; you will also be asked to fill out a short questionnaire and to sign a FERPA release. The FERPA release grants the project leaders access to your educational records for a temporary period so we can track your course enrollment, though this is optional and NOT required for focus group participation. All data from educational records are kept private and anonymous and are used for this research project and only this research project.

All sessions will be held in the Matthews Center building on the Tempe campus in Room 206 (conference room).

Please REPLY directly to this email with your TOP X choices of days and times (see below) you would like to participate (in order from first to last). We will do our best to give you your top choice (if you can absolutely only participate in one of the sessions, please let us know).

AVAILABLE TIME SLOTS:

Caitlin Schrein
Doctoral Candidate, School of Human Evolution and Social Change
Arizona State University

Dr. Richard Toon
Morrison Institute for Public Policy, ASU

Where did you come from? Where *will* you go? The effects of human evolutionary biology education on students' academic, professional and personal goals, achievements and decision-making

Dear ______________________________:
(Please print your name neatly here.)

Your participation in the above named research study is voluntary. You have the right not to answer any question, and to stop participation at any time. If you choose not to participate or to withdraw from the study at any time, there will be no penalty.

There are no foreseeable risks or discomforts to your participation. Because of the group interview setting, complete confidentiality cannot be maintained, however, your responses to the interview will be kept confidential. Your signature below indicates your permission to be audio recorded. You will not be asked to identify yourself on the recording except by number and you may ask for the recording to be stopped at any time. Your identity will be known only to those individuals involved in the study. Your name will not be known or used in any presentations or publications that result from this study.

Your participation in this study may help to increase awareness of the issues and concerns of students associated with the learning of human evolutionary biology in public secondary-schools and universities. It may also assist in the goal of many to improve student success at Arizona's public universities and to help identify how to increase university student enrollment in science, technology, and engineering-related courses of study.

If you agree to participate in this study, you will be asked to sign a FERPA release that will grant the researchers involved in this study access to your educational records for a temporary period, allowing us to track your enrollment in classes for next semester, your choice of major and to determine your final performance in your science-related coursework. These records will be matched to any demographic information or survey responses you provide. Your educational records will be secure and access to them will not be granted to anyone outside the research group and your academic information will be kept anonymous in all research-related publications or presentations.

If you have any questions about your participation in this study, please contact the research team at caitlin.schrein@asu.edu.

If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board through the ASU Office of Research Integrity and Assurance at (480) 965-6788.

By signing below you are agreeing to participate in the above named research study.

__________________________ ______________
Signature Date

By signing below, you are agreeing to be audio recorded.

__________________________ ______________
Signature Date

DO NOT WRITE YOUR NAME ON THIS OR THE FOLLOWING PAGES! Your participant number has been randomly generated and only the researchers in charge of the study will be able to identify you by participant number. All data will be kept confidential. Please print neatly.

Participant # ________

Age: ________ Gender: M / F
Academic status (Freshman, Sophomore, etc.): ___________________________

High School Education (includes 9th – 12th grade)

From what high school did you *graduate*? Please provide the full name of the school and the city, state and/or country where the school is located. Please also indicate whether the school is public or private.____
____
____

If you completed coursework in biological and/or physical sciences while in high school, please list the courses you took and the grade you received below (if you are not sure about the grade, please approximate).

Examples include: Regular Biology, Chemistry or Physics, Honors Biology/Chemistry/Physics, AP Biology/Chemistry/Physics, Anatomy, Anatomy and Physiology, Biochemistry, etc. (continue on back if necessary).

Course: ____________________________________ Grade:_____
Course: ____________________________________ Grade:_____
Course: ____________________________________ Grade:_____
Course: ____________________________________ Grade:_____
Course: ____________________________________ Grade:_____
Course: ____________________________________ Grade:_____
Course: ____________________________________ Grade:_____
Course: ____________________________________ Grade:_____

If you took AP, IB or SAT II exams in science (e.g., Biology, Chemistry, Physics, etc.), please list them here with your score:

Exam: ____________________________________ Score:_____
Exam: ____________________________________ Score:_____
Exam: ____________________________________ Score:_____
Exam: ____________________________________ Score:_____
Exam: ____________________________________ Score:_____
Exam: ____________________________________ Score:_____
Exam: ____________________________________ Score:_____

Do you recall being taught about any of the following concepts/topics in your middle school or high school science course(s)?

	YES	**NO**
Genetics	☐	☐
Plate tectonics	☐	☐
Charles Darwin	☐	☐
DNA	☐	☐
The origins of humans	☐	☐
Paleontology (fossils)	☐	☐
Natural selection	☐	☐
Origins of life on earth	☐	☐
Dinosaurs	☐	☐
Australopithecus	☐	☐
Evolution	☐	☐
Primates (apes and monkeys)	☐	☐
Inheritance of traits	☐	☐
Pea plants	☐	☐
Anatomy (the skeleton, muscles, etc.)	☐	☐
Lucy	☐	☐
Mitosis/meiosis	☐	☐
Cells (nucleus, organelles, etc.)	☐	☐
Galapagos finches	☐	☐
Phylogeny (evolutionary trees)	☐	☐
Geology (types of rocks, age and structure of the Earth)	☐	☐

Post-secondary Education (College)

Academic major at ASU: ___________________________________
(If you are unsure about your major, please indicate the field of study in which you are most likely to major: ____________________________________)

If you have completed other science coursework in biological and/or physical sciences *since* high school, please list the courses you took and the grade you received. Also, if courses were taken at a community college or a college or university other than Arizona State University, please identify the institution, as well.

		Institution
Course: _________________________________	Grade:_____	_________________
Course: _________________________________	Grade:_____	_________________
Course: _________________________________	Grade:_____	_________________
Course: _________________________________	Grade:_____	_________________
Course: _________________________________	Grade:_____	_________________
Course: _________________________________	Grade:_____	_________________
Course: _________________________________	Grade:_____	_________________
Course: _________________________________	Grade:_____	_________________
Course: _________________________________	Grade:_____	_________________

Personal Data

How would you describe your ethnic background (e.g., Caucasian, Hispanic, Asian, etc.)?
____

Is there a religious and/or cultural group with which you associate? If so, please identify the group(s):
____

Do you attend regular meetings or gatherings of this group? If so, about how often do you gather (please provide information for each group identified above)?
____
____

Are you interested in pursuing a career related to science (research/teaching/industry)?
____

If yes, what do you think is the main reason why you are interested in a science-related career?
____
____
____
____

Questionnaire (adapted from Rutledge and Sadler, 2007)

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

A = Strongly agree B = Agree C = Undecided D = Disagree E = Strongly disagree

1. Organisms existing today are the result of evolutionary processes that have occurred over millions of years. _____

2. There is a significant body of data that supports evolutionary theory. _____

3. Organisms exist today in essentially the same form in which they always have. _____

4. Modern humans are the product of evolutionary processes that have occurred over millions of years. ______

5. The theory of evolution cannot be correct since it disagrees with the Biblical account of creation. _____

6. Evolutionary theory is supported by factual historical and laboratory data. _____

7. Much of the scientific community doubts that evolution occurs. _____

Thank you for your participation in this important research study.

APPENDIX C

RECRUITMENT SCRIPT, INFORMATION LETTER AND QUESTIONS FOR THE ONLINE SURVEY

An asterisk (*) preceding a question indicates a question was part of the first version of the survey used in the Fall 2009 academic semester and 2009 – 2010 winter session. A double asterisk (**) following content (e.g., dates) or preceding a question indicates content or questions were edited or written for the second version of the survey used in the Spring 2010 academic semester.

Note that page breaks differ here than in the online format of the survey. Also note that, due to embedded survey logic, not every student saw every question (i.e., students who went to public high school did not see questions about home schooling). Detailed information about survey logic is available upon request from the researcher.

Dear Professor,

We are seeking your assistance with data gathering for a doctoral dissertation project, which should not require more than a few minutes of your time.

Out project is using a questionnaire to address the relationship between undergraduate students' science education and their academic and personal achievements, goals, views and decision-making.

We would appreciate it if you would take a moment to notify your students of our questionnaire. This survey is part of a larger project that may improve the quality of public secondary and post-secondary science education.

Please copy the text below (between the [orange] asterisks) and post it as an announcement on Blackboard for your current undergraduate courses (or forward this email to your teaching assistant(s) for posting).

IMPORTANT NOTES:
- Please do not offer any academic incentives (extra credit, etc.) to your students for completing the survey.
- We are recruiting all enrolled ASU undergraduate students, 18-22 years of age, to participate in this end-of-term general science survey.
- Students do not have to be enrolled in science coursework or be science majors to complete the survey.
- Completion of the questionnaire should require no more than 25 minutes.

Please feel free to forward this email to your colleagues.

This project has been approved for exemption by the ASU Office of Research Integrity and Assurance (IRB Protocol # 0810003328). If you have any questions, please contact Caitlin.Schrein@asu.edu. Thank you for your help with this important research.

TEXT FOR POSTING:
****
If you are currently enrolled as an ASU undergraduate student and are 18-22 years old, please complete this anonymous online survey which will qualify you to enter a drawing for a $150.00 gift card! Simply go to the following URL to start the survey: [link to survey]. This survey is part of a larger project being conducted by ASU researchers (IRB Protocol # 0810003328) and your participation in this research is very important.

****

And thank you for your valuable time.

Sincerely,

Caitlin Schrein
Doctoral Candidate and Teaching Associate
School of Human Evolution and Social Change
Institute of Human Origins
Arizona State University

Dr. Richard Toon
Associate Research Professor
School of Human Evolution and Social Change
Arizona State University

Dr. Donald Johanson
Faculty with Administrative Appointment
Institute Of Human Origins
School of Human Evolution and Social Change
Arizona State University

Welcome to the General Science Survey.

Please maximize this browser window.

Scroll down as needed.

Your participation in this study is voluntary and all information collected from this survey is anonymous. If you choose not to participate or to withdraw from the study at any time, you may click the Exit Survey link at the top of the page.

You qualify to take this survey if:

- you have never completed this survey before (e.g., between December, 2010, and January, 2011)**
- you are 18-22 years old,
- and you are/were enrolled as an undergraduate in at least one course at ASU for the current/most recent (Spring, 2011) semester.

If you do not fit our research criteria, the survey will close automatically.

Note: You do not have to be a science major or have taken any science coursework to participate in this survey.

Completion of the survey should take about 25 minutes, however there is no time limit.

There are no foreseeable risks or discomforts to your participation. Your responses to the survey will be used to assess the relationship between ASU undergraduates academic (science) background and experiences and their academic and/or personal achievements, goals, views and decision-making.

Your responses will be anonymous. In no way will your responses be associated with identifying information now or in the future.

The results of this study may be used in reports, presentations, or publications but your name will not be known or used. Results will only be shared in the aggregate form.

Upon completion of this survey, you will be given the opportunity to enter a drawing for a $150 gift card by providing identifying information, including a 10-digit ASU affiliate ID (which is printed on your Sun card). Your identifying information, provided for the purposes of the drawing, will not be associated in any way with your survey responses. The closing date for the drawing is May 31st, 2011**, but the survey will be available until the number of respondents meets the researchers' requirements.

This research is being conducted by Caitlin Schrein under the direction of Dr. Richard Toon and Dr. Donald Johanson in the School of Human Evolution and Social Change at Arizona State University.

If you have any questions concerning the research study, please contact the research team at: Caitlin.Schrein@asu.edu or Richard.Toon@asu.edu. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788. IRB Protocol #: 0810003328

Responses you provide to the survey questions will be considered your consent to participate in this research study.

❑ I understand the information provided above.

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

By checking the box below I agree to answer all questions truthfully and accurately. I understand that providing false data about myself can exclude me from both the study and participation in the gift card drawing.

❏ I agree to the terms of the survey.

Tell us about yourself.

How old are you?
1. under 18
2. 18
3. 19
4. 20
5. 21
6. 22
7. 23 or older

Which of the following best describes your biological sex?
1. Male
2. Female
3. Other ____

Are you currently or have you been enrolled as an undergraduate student at Arizona State University?
1. Yes
2. No

Which of the following best describes your status at ASU during the Spring, 2011**, semester?
1. Freshman
2. Sophomore
3. Junior
4. Senior
5. Other ____

Are/Were you enrolled in at least one undergraduate course for this most recent (Spring, 2011**) semester at Arizona State University?
1. Yes
2. No

Which one of the following best describes you?
1. I attended a high school and have a high school diploma.
2. I was home schooled during my high school years.
3. I was not home schooled and took the GED test.

Please identify the location of the school from which you received your high school diploma.

	City	State	Country
Location of High School			

Which of the following best describes your high school?
1. Public
2. Private
3. Other ____

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

Please indicate which of the following science courses you took in HIGH SCHOOL. (Check all that apply.)

1. Integrated Science
2. Earth Science/Earth and Space Science
3. Astronomy
4. Environmental Science
5. Physics
6. Honors Physics
7. AP or IB Physics
8. Chemistry
9. Honors Chemistry
10. AP or IB Chemistry
11. Biology
12. Honors Biology
13. AP or IB Biology
14. Plant Biology/Botany
15. Zoology
16. Forensics
17. Anatomy and Physiology
18. Exercise Physiology
19. Historical Geology
20. Other ____

Where were you home schooled during your high school years?

	City	State	Country
Location where you were home schooled			

Did you take the SAT?

1. Yes
2. No
3. I don't know

What was your highest score on the reading and math sections combined?
(This should be the score you used to apply to ASU. Do not count the recently added writing section of the SAT.)

1. less than 1000
2. 1000 to 1099
3. 1100 to 1199
4. 1200 to 1299
5. 1300 to 1399
6. 1400 to 1499
7. 1500 to 1600

Did you take the ACT?

1. Yes
2. No
3. I don't know

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

What was your highest total score on the ACT?

1. less than 20
2. 20-22
3. 23-25
4. 26-28
5. 29-31
6. 32-34
7. 35-36

Can you recall being taught about any of the following concepts or topics in your middle school or high school SCIENCE classes or as part of your official home schooling in SCIENCE?

	Yes, I recall being taught about this in science class	No, I do not recall being taught about this in science class	I don't know
Genetics	❑	❑	❑
Big bang theory	❑	❑	❑
Animal behavior	❑	❑	❑
Plate tectonics	❑	❑	❑
Charles Darwin	❑	❑	❑
DNA	❑	❑	❑
Botany (plants)	❑	❑	❑
Scientific explanations for the origin of humans	❑	❑	❑
Paleontology (fossils)	❑	❑	❑
Natural selection	❑	❑	❑
Primates (apes and monkeys)	❑	❑	❑
Origins of life on earth	❑	❑	❑
Intelligent Design (ID)	❑	❑	❑
Dinosaurs	❑	❑	❑
Alternative explanations for human origins (ex., Native American explanations, Bible-based explanations)	❑	❑	❑

(Same question...) Can you recall being taught about any of the following concepts or topics in your middle school or high school SCIENCE classes or as part of your official home schooling in SCIENCE?

	Yes, I recall being taught about this in science class	No, I do not recall being taught about this in science class	I don't know
Human reproductive biology (sex, conception, etc.)	❑	❑	❑
Evolution	❑	❑	❑
Inheritance of traits	❑	❑	❑
Explanations for variation in human skin color	❑	❑	❑
Creationism	❑	❑	❑
Pea plants	❑	❑	❑
Anatomy (bones, muscles or organs)	❑	❑	❑
Mitosis and meiosis	❑	❑	❑

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

The fossil skeleton called Lucy	❑	❑	❑
Climate change	❑	❑	❑
The parts of the cell	❑	❑	❑
Phylogeny (evolutionary trees)	❑	❑	❑
Geology (rock types, structure of the Earth)	❑	❑	❑
Galapagos Island finches	❑	❑	❑
Stem cell research	❑	❑	❑

(Different question...) Can you recall being taught about any of the following concepts or topics in your middle school or high school NON-SCIENCE classes, such as a social studies/history class or a religious studies class, or as part of your official home schooling in NON-SCIENCE subject areas?

	Yes, I recall learning about this in NON-science classes	No, I do not recall learning about this in NON-science classes	I don't know
Charles Darwin	❑	❑	❑
Scientific explanations for the origin of humans	❑	❑	❑
Alternative explanations for human origins (ex., Native American explanations, Bible-based explanations)	❑	❑	❑
Evolution	❑	❑	❑
Explanations for variations in human skin color	❑	❑	❑
The fossil skeleton called Lucy	❑	❑	❑

The questions that follow ask for your opinion about various social and/or political issues or test your knowledge of a particular topic or subject area. Please choose the answer you think is the best or most correct answer. Please do not seek or ask for assistance with the survey. Remember, your answers are anonymous.

Would you say you follow what's going on in government and public affairs?

1. Most of the time
2. Some of the time
3. Only now and then
4. Hardly at all
5. I don't know

Please indicate your level of agreement with the following statements. (Please read the wording carefully.)

	Completely agree	Mostly agree	Mostly disagree	Completely disagree	I don't know/ Neutral
Immigrants to the US today strengthen our country because of their hard work and talents.	❑	❑	❑	❑	❑
Homosexuality is a way of life that should be accepted by society.	❑	❑	❑	❑	❑
Same-sex couples should not be allowed to adopt children.	❑	❑	❑	❑	❑

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

Immigrants today are a burden on our country because they take our jobs, housing and health care.	❑	❑	❑	❑	❑
People who are openly gay or homosexual should be allowed to serve in the United States military.	❑	❑	❑	❑	❑
It should be illegal for same sex couples to marry.	❑	❑	❑	❑	❑

*Are you aware of the recent oil spill in the Gulf of Mexico?
1. Yes
2. No

**Are you aware of the last year's major oil leak in the Gulf of Mexico?
1. Yes
2. No

**Are you aware of the recent social/political conflicts in Egypt and Libya?
1. Yes
2. No

**Are you aware of the recent natural disasters in Japan?
1. Yes
2. No

Are you now, or have you ever been, registered to vote?
1. Yes
2. I can register, but I haven't
3. I cannot legally register to vote in the US
4. I don't know

Did you vote in the 2008 United States presidential election?
1. Yes
2. No, though I could have voted
3. No, I was too young to vote at the time
4. Other ____

Did you vote in the November 2010 mid-term elections?
1. Yes
2. No, though I could have voted
3. No, I was too young to vote at the time
4. Other ____

Do you regularly read the newspaper, check news websites and/or listen to the news on the radio?
1. Yes, regularly
2. No, not regularly
3. I don't know

Do you regularly watch television programs or channels about science (ex., NOVA or Discovery Channel)?
1. Yes, regularly
2. No, not regularly
3. I don't know

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

Do you regularly visit science web sites and blogs (ex., the National Geographic website or ScienceDaily.com)?

1. Yes, regularly
2. No, not regularly
3. I don't know

Do you regularly read science magazines (ex., Scientific American or Popular Science)?

1. Yes, regularly
2. No, not regularly
3. I don't know

Which comes closer to your personal view?

1. Living things have evolved over time.
2. Living things have existed in their present form since they came into being.
3. I don't know

Which comes closer to your personal view?

1. Living things have evolved solely due to natural biological processes, such as random mutations, natural selection and genetic drift.
2. A supreme being guided the evolution of living things for the purpose of creating life in the form it exists today.
3. I don't know.

Which comes closer to your personal view?

1. The age of the Earth is at least 4 billion years.
2. The age of the Earth is less than 20,000 years.
3. I don't know.
4. Other ____

Please indicate your level of agreement with the following statements.

	Completely agree	Mostly agree	Mostly disagree	Completely disagree	I don't know/ Neutral
Divine creation is the best explanation for the existence of humans.	❑	❑	❑	❑	❑
All humans on the planet today are descendants of humans who once lived in Africa.	❑	❑	❑	❑	❑
It is wrong for humans to poach (hunt) and eat monkeys and apes.	❑	❑	❑	❑	❑
Ape-like creatures that walked upright on two legs lived millions of years ago.	❑	❑	❑	❑	❑
Humans have always existed in the same form and have not evolved.	❑	❑	❑	❑	❑
It is possible for humans to catch diseases from monkeys and apes.	❑	❑	❑	❑	❑
Humans and other living things are the result of evolutionary processes.	❑	❑	❑	❑	❑
Differences in human skin color can be explained by science.	❑	❑	❑	❑	❑

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

(Same question...) Please indicate your level of agreement with the following statements.

	Completely agree	Mostly agree	Mostly disagree	Completely disagree	I don't know/ Neutral
Humans and apes share a common ancestor that lived millions of years ago.	❑	❑	❑	❑	❑
It is important to preserve the forests where chimpanzees, gorillas and orangutans live.	❑	❑	❑	❑	❑
Scientists can learn a lot about humans by studying monkeys and apes.	❑	❑	❑	❑	❑
The scattering of peoples from the tower of Babel across the earth is the cause modern races of humans.	❑	❑	❑	❑	❑
Humans have things in common (anatomy and behaviors) with monkeys and apes that they do not have in common with other animals.	❑	❑	❑	❑	❑
Scientists should not use chimpanzees for drug testing.	❑	❑	❑	❑	❑
There is significant scientific evidence indicating that humans evolved over the course of millions of years.	❑	❑	❑	❑	❑

The technology now exists to clone or genetically alter animals. How much do you favor or oppose allowing the same thing to be done with humans?

1. Strongly favor
2. Somewhat favor
3. Somewhat oppose
4. Strongly oppose
5. I don't know/Neutral

Which comes closer to your personal view?

1. Science and religion are often in conflict.
2. Science and religion are mostly compatible.
3. I don't know

Thinking about some different professions, how much do you think each of the following contributes to the well-being of our society?

	A lot	Some	Not very much	Nothing at all	I don't know
Scientists	❑	❑	❑	❑	❑
Engineers	❑	❑	❑	❑	❑
Journalists	❑	❑	❑	❑	❑
Artists	❑	❑	❑	❑	❑
Lawyers	❑	❑	❑	❑	❑
Members of the military	❑	❑	❑	❑	❑
Clergy	❑	❑	❑	❑	❑
Medical doctors	❑	❑	❑	❑	❑
Business executives	❑	❑	❑	❑	❑
Teachers	❑	❑	❑	❑	❑

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

Which comes closer to your personal view?

1. The earth is getting warmer mostly because of natural changes in the atmosphere.
2. The earth is getting warmer mostly because of human activity such as burning fossil fuels.
3. The earth is not getting warmer.
4. I don't know.

Indicate the degree to which you think global warming is a problem.

1. A very serious problem
2. A somewhat serious problem
3. Not too serious of a problem
4. Not a problem
5. I don't know

Indicate the degree to which you think human overpopulation is a problem.

1. A very serious problem
2. A somewhat serious problem
3. Not too serious of a problem
4. Not a problem
5. I don't know

How likely are you to make a special effort to do each of the following actions?

	Extremely likely	Very likely	Moderately likely	Somewhat likely	Not at all likely
Reuse water bottles	❑	❑	❑	❑	❑
Carpool or take public transportation	❑	❑	❑	❑	❑
Buy recycled paper products	❑	❑	❑	❑	❑
Bring your own shopping bags to stores	❑	❑	❑	❑	❑
Adjust thermostats by two degrees	❑	❑	❑	❑	❑
Wash laundry in cold water	❑	❑	❑	❑	❑
Eat less meat	❑	❑	❑	❑	❑
Recycle bottles and cans	❑	❑	❑	❑	❑

All in all, do you favor or oppose each of the following?

	Favor	Oppose	I don't know/Neutral
Federal funding for embryonic stem cell research	❑	❑	❑
Building more nuclear power plants to generate electricity	❑	❑	❑
The use of animals in scientific research	❑	❑	❑
Required vaccinations for all children	❑	❑	❑
Preservation of existing rain forests	❑	❑	❑
US intervention to combat genocide, as in Darfur.	❑	❑	❑
US efforts to help foreign countries recover from natural disasters, as in Haiti* or Japan**.	❑	❑	❑

Do antibiotics kill viruses as well as bacteria?

1. Yes
2. No
3. I don't know

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

Do you agree or disagree with the following statements?

	Agree	Disagree	I don't know.
You cannot contract a sexually transmitted disease if you and/or your partner is wearing a condom.	❑	❑	❑
A woman's chances of becoming pregnant are lowest during her period.	❑	❑	❑
Children resemble their parents because the children inherited their parents genetic material (DNA).	❑	❑	❑
All DNA mutations are harmful.	❑	❑	❑
The use of sunscreen prevents mutations in DNA that can lead to skin cancer.	❑	❑	❑

Which comes closer to your personal view?
1. Birth control should be used to prevent unwanted pregnancies.
2. It is wrong to use birth control.
3. I don't know.

Before you go, we'd like to know more about you...

Have you officially declared your major?
1. Yes
2. No

What do you think your major will be? (If you don't know the answer, you can leave this blank.)

Have you taken any science courses at Arizona State University (either online or at the Tempe, Downtown, West, or Polytechnic campuses)?
1. Yes
2. No
3. I don't know

At any time have you COMPLETED any of the following courses at Arizona State University?
(Check all that apply and be sure to include courses you are taking now or have just completed. If you have not taken any of these courses, that's ok.)
1. HPS 330 History of Biology - Conflicts and Controversies
2. BIO 100 The Living World
3. BIO 181 (previously BIO 188) General Biology I
4. BIO 182 (previously BIO 187) General Biology II
5. BIO 189 (General Biology Recitation) Global Change
6. BIO 189 (Rec.) The Dark Side of the Force
7. BIO 189 (Rec.) Evolutionary Genetics and Disease
8. BIO 189 (Rec.) Nature's Medicine
9. BIO 189 (Rec.) Detecting Disease from a Blood Drop
10. BIO 189 (Rec.) Evolution in the Classroom
11. BIO 189 (Rec.) Impact of Infectious Diseases on Human History
12. BIO 189 (Rec.) Mind, Madness, and Medicine
13. BIO 189 (Rec.) Tracking Diversity in the Natural World
14. BIO 189 (Rec.) Darwin and the Voyage of the Beagle
15. BIO 189 (Rec.) Evolution of a Superorganism
16. BIO 189 (Rec.) The Global Biodiversity Crisis
17. BIO 189 (Rec.) Controversial Issues in Ecology

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

18. BIO 191 Species, Systematic Biology and Society
19. BIO 201 Human Anatomy and Physiology I
20. BIO 202 Human Anatomy and Physiology II
21. BIO 305 Biology Behind the Crime Scene
22. BIO 311 Biology and Society
23. BIO 312 Bioethics
24. BIO 318 History of Medicine
25. BIO 340 General Genetics
26. BIO 345 Organic Evolution
27. BIO 351 Developmental Biology
28. BIO 353 Cell Biology
29. BIO 360 Animal Physiology
30. BIO 370 Vertebrate Zoology
31. BIO 394 Sex and Our Species
32. BIO 446 Principles of Human Genetics
33. BIO 461 Comparative Animal Physiology
34. BIO 344/HPS 311 Origins, Evolution and Creation
35. BIO 346/HPS 332 The Darwinian Revolution
36. ASB 100 Introduction to Global Health
37. ASB 101 Anthropology: Understanding Human Diversity
38. ASB 102 Introduction to Cultural and Social Anthropology
39. ASB 191 Origins of Human Culture and Social Complexity
40. ASB 301 Global History of Health
41. ASM 104 Bones, Stones and Human Evolution
42. ASM 246 Human Origins
43. ASM 301 Peopling of the World
44. ASM 342 Human Biological Variation
45. ASM 344 Fossil Hominids
46. ASM 345 Disease and Human Evolution
47. ASM 446 Principles of Human Genetics
48. CHM 460 Biological Chemistry
49. CHM 481/GLG 481 Geochemistry
50. CHM 483/GLG 460 Astrobiology
51. GLG 101 Introduction to Geology I
52. GLG 102 Introduction to Geology II
53. GLG 106 Habitable Worlds
54. GLG 430 Paleontology
55. GPH 111 Introduction to Physical Geography
56. GPH 314 Global Change
57. MBB 245 Principles of Molecular and Cellular Biology
58. MBB 343 Genetic Engineering and Society
59. PGS 222 Human Sexual Behavior

Have you ever taken a class on ASU's West Campus (at Thunderbird Road in Phoenix)?

1. Yes
2. No

At any time have you completed any of the following courses at ASU's West Campus?
(Check all that apply and be sure to include courses you are taking now or have just completed. If you have not taken any of these courses, that's ok.)

1. LSC 241 Human Genetics
2. LSC 294 Dinosaurs
3. LSC 347 Fundamentals of Genetics
4. LSC 360 The Biology of Human Experience

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

5. LSC 361 Human Sexual Biology
6. LSC 362 The Human Environment
7. LSC 363 Genes, Race, Gender and Society
8. LSC 365 The Human Organism

Have you ever taken a class on ASU's Polytechnic Campus (at Power Road in Mesa)?

1. Yes
2. No

At any time have you completed any of the following courses at ASU's Polytechnic Campus?
(Check all that apply and be sure to include courses you are taking now or have just completed. If you have not taken any of these courses, that's ok.)

1. ABS 207 Applied Plant Taxonomy
2. ABS 270 Sustainable Biological Systems
3. ABS 302 Ethical and Policy Issues in Biology
4. ABS 311 Molecular and Cell Biology
5. ABS 355 Anatomy and Physiology of Vertebrates
6. ABS 376 Wildlife Ecology
7. ABS 470 Life History of Mammals

All in all, how would you describe your science coursework at ASU?

1. Extremely easy
2. Somewhat easy
3. Somewhat challenging
4. Extremely challenging

How well did your high school or home school science coursework prepare you for your university science courses?

1. I felt extremely prepared
2. I felt somewhat prepared
3. I felt somewhat unprepared
4. I felt extremely unprepared
5. Other ____

What is your approximate GPA at ASU?

1. less than 2.0
2. 2.0 - 2.49
3. 2.5 - 2.99
4. 3.0 - 3.49
5. 3.5 - 3.99
6. 4.0
7. I don't know

Is it your intention to remain at ASU until you graduate?

1. Yes
2. No
3. I don't know
4. I just graduated from ASU

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

At this time, how likely do you think it is that you will earn your undergraduate degree (at ASU or elsewhere)?

1. Extremely likely
2. Very likely
3. Somewhat likely
4. Not at all likely
5. I don't know
6. I just received my undergraduate degree from:

____

Are you interested in pursuing a science, technology or engineering-related career (including medical, teaching, research or industry jobs)?

1. Yes
2. No
3. I don't know

To what degree did each of the following influence your interest in a science, technology or engineering-related career (including medical, teaching, research or industry jobs)?

	A lot of influence	Some influence	No influence
Your parents/guardians careers	❑	❑	❑
Your parents/guardians hobbies	❑	❑	❑
Elementary, Middle or High School class	❑	❑	❑
Elementary, Middle or High School teacher	❑	❑	❑
Participation in science fairs	❑	❑	❑
Visits to hands-on style science centers/museums	❑	❑	❑
Visits to natural history museums	❑	❑	❑
Visits to zoos, aquaria or wildlife parks	❑	❑	❑
Illness or death of a family member	❑	❑	❑
Personal illness	❑	❑	❑
A college/university professor	❑	❑	❑
A college/university course	❑	❑	❑
An internship or job	❑	❑	❑
Books	❑	❑	❑
Movies	❑	❑	❑
Documentary/Nonfiction television programs	❑	❑	❑
Fiction television programs (primetime dramas/sitcoms)	❑	❑	❑
Print or online news media (newspapers, magazines)	❑	❑	❑
Personal interest in or curiosity about the world	❑	❑	❑
A desire to help other people	❑	❑	❑
A desire to help animals	❑	❑	❑
This survey	❑	❑	❑
Other (see next question)	❑	❑	❑

If you indicated other in the previous question as having some or a lot of influence, please explain. (If you chose no influence you may skip this question.)

Do you have a specific career in mind?

1. Yes
2. No

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

Which of the following best describe(s) you?
(Check all that apply. These options follow the 2010 US Census categories.)

1. White or Caucasian
2. Black, African American or Negro
3. American Indian or Alaska Native
4. Asian Indian
5. Japanese
6. Native Hawaiian
7. Chinese
8. Korean
9. Guamanian or Chamorro
10. Filipino
11. Vietnamese
12. Samoan
13. Mexican, Mexican American, or Chicano
14. Puerto Rican
15. Cuban
16. Other Hispanic, Latino or Spanish origin (please enter information in "other" box below; ex., Argentinean, Colombian, Dominican, etc.)
17. Other Asian (please enter information in "other" box below; ex. Thai, Hmong, Laotian, Pakistani, etc.)
18. Other Pacific Islander (please enter information in "other" box below; ex. Fijian, Tongan, etc.)
19. Other

Which of the following, if any, best describe(s) you? (Check all that apply.)

1. Protestant (please also specify affiliation in "other" box below; ex., Baptist, Methodist, Lutheran, Presbyterian, etc.)
2. Catholic
3. Mormon
4. Orthodox (ex., Greek or Russian)
5. Jewish
6. Muslim
7. Buddhist
8. Hindu
9. Jehovah's Witness
10. Atheist
11. Agnostic
12. Wiccan
13. Pagan
14. Nondenominational evangelical
15. Nondenominational fundamentalist
16. Nondenominational charismatic
17. Interdenominational
18. Other Christian (please also specify affiliation in "other" box below)
19. I don't know
20. Nothing in particular
21. Other

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

Which of the following, if any, best describe(s) your parents/guardians? (Check all that apply.)

1. Protestant (please also specify affiliation in "other" box below; ex., Baptist, Methodist, Lutheran, Presbyterian, etc.)
2. Catholic
3. Mormon
4. Orthodox (ex., Greek or Russian)
5. Jewish
6. Muslim
7. Buddhist
8. Hindu
9. Jehovah's Witness
10. Atheist
11. Agnostic
12. Wiccan
13. Pagan
14. Nondenominational evangelical
15. Nondenominational fundamentalist
16. Nondenominational charismatic
17. Interdenominational
18. Other Christian (please also specify affiliation in "other" box below)
19. I don't know
20. Nothing in particular
21. Other

Do you or have you ever attended religious services?

1. Yes
2. No, never

In the past year, approximately how often have you attended religious services?

1. More than once per week
2. Once per week
3. Every couple of weeks
4. Every couple of months
5. Only for special occasions (holidays, weddings, funerals, etc.)
6. Almost never
7. It has varied

Thank you so much for completing our survey! We truly value the time you spent taking it.
Would you like to enter the drawing for a $150 gift card?

If you select yes, your survey responses will remain anonymous and you will be redirected to a form where you can enter your contact information. Again, your contact information will not be associated with your survey responses.

If you select no, your survey responses will be submitted to the researchers; however, you will not be able to enter the drawing for a gift card now or in the future.

NOTE: The drawing officially closes May 31st, 2011**, at 11:59pm, but the survey will remain available until the number of responses meets the researchers' requirements.

1. Yes, I would like to enter the drawing.
2. No, I do not want to enter the drawing.

There is no "back" button provided (do not use your browser's "back" button), so please be sure you have answered all questions to your satisfaction before continuing. Questions? Email: sciencesurvey@asu.edu

This is the entry form for the $150.00 gift card drawing. The data from this entry form will not be associated with your survey responses.

Only one drawing entry is permitted per person. Multiple entries with the same ASU email address or ID number will be disqualified from the drawing.

To qualify for the drawing you must be able to provide:
- your 10-digit affiliate ID number, which can be found on your ASU ID (Sun Card) and, preferably,
- an active, valid ASU email address (ex., jsmith@asu.edu).

The drawing will officially close on May 31, 2011**, at 11:59pm, however, the survey will continue to be available until the number of respondents meets the researchers' requirements.

If your name is drawn and you cannot be reached within 72 hours, another name will be drawn and you will no longer be eligible for a gift card.

Thank you and good luck!

❑ I understand the terms described above.

Contact Information for Gift Card Drawing
First Name

Last Name

Do you have a valid, active ASU email address? (ex., jsmith@asu.edu)
1. Yes
2. No
3. I don't know

ASU email address (ex., jsmith@asu.edu):

Please re-enter your ASU email address:

10-digit ASU affiliate ID (printed on your Sun Card):

Please provide an alternate email address if you have one (optional):

Please re-enter your alternate email address:

Would you like to be notified by phone if your name is selected?

1. Yes
2. No

Phone number with area code:

Please choose the retailer for which you would like to receive a $150.00 gift card.
(Please note that for some retailers you will receive one gift card or certificate, for others you may receive multiple gift cards that total $150.00 and for others, you may receive a $150.00 electronic gift card for which you will receive the code via email.)

1. Amazon.com
2. Target
3. Bath and Body Works
4. The Home Depot
5. Lowe's
6. Pottery Barn
7. Pier 1 Imports
8. GAP/Old Navy/Banana Republic
9. Lucky Brand Jeans
10. American Apparel
11. Urban Outfitters
12. Zappos.com
13. Sport Chalet
14. Dick's Sporting Goods
15. Macy's
16. JC Penny
17. AMC Movie Theaters
18. Harkins Movie Theaters
19. Borders Books
20. Barnes and Noble
21. Jamba Juice
22. PetSmart
23. Best Buy
24. iTunes

APPENDIX D

INSTITUTIONAL REVIEW BOARD EXEMPTION

ASU Knowledge Enterprise Development

Office of Research Integrity and Assurance

To:	Richard Toon SHESC
From:	Mark Roosa, Chair Soc Beh IRB
Date:	02/22/2011
Committee Action:	**Exemption Granted**
IRB Action Date:	10/23/2008
IRB Protocol #:	0810003328
Study Title:	Where Did You Come From, Where Will You Go? The Impact of Human Biological Evolution Education on the Academic and Professional Achievements and Goals of America's Public University Students

The above-referenced protocol is considered exempt after review by the Institutional Review Board pursuant to Federal regulations, 45 CFR Part 46.101(b)(1) (2) .

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

You should retain a copy of this letter for your records.

APPENDIX E

MODERATOR QUESTIONS FROM TWO INTERVIEW SESSIONS

Interview 1 (Round 1, Group 1)

Q: Tell me where you're from and what high school (HS) you went to and what your major is here.

Q: Let's talk about your HS background a little bit. I'd like to know if you took science classes in high school and if so, did your teachers talk about evolution?

Q: {Was it more frustrating} for teachers or students?

Q: How did that experience affect you personally, when you first heard your teacher talking about it? Did you feel yourself shutting down or were you intrigued?

Q: Do you remember how your teacher introduced it?

Q: Do you remember in your science classes - did your teachers, when they taught about evolution, mention humans at all in the context of evolution?

Q: So the students who weren't comfortable with it were vocal about it?

Q: So did you talk about fossil human ancestors, like the fossil Lucy?

Q: Have you taken science courses in college? What have you taken?

Q: That's a lot of science for an English literature person. What's your motivation for taking a lot of science courses?

Q: How did your experience in middle and high school prepare you for taking BIO187, BIO188, ASM104, etc. Do you think you were prepared coming in?

Q: How do you think your performance in ASM104 would have been affected had you had some sort of introduction to the idea of human evolution in school?

Q: What was your experience in your family, growing up, in terms of your parents fostering scientific inquiry or, how would your family background affect how you felt about learning about evolution?

Q: Did your parents take you to natural history museums or the science center in Phoenix or anything like that? Or to the Phoenix Zoo?

Q: Do you remember your parents having any reaction to your learning about evolution when you started public school?

Q: So one of your parents had a stronger opposition to it than the other. What is the educational background of your parents?

Q: What about you and your family background?

Q: Do you have any memory of your parents reacting to your learning about evolution in 9th grade?

Q: Would you say it's more your academic experiences or your social/family experiences that made you interested in science and made you curious about going into a field of science? Was it more your teachers or your family influence?

Q: How do you feel personally about the idea that humans evolved, just like every other living thing on the planet and are the product of evolution over millions of years?

Q: How have classes at ASU influenced that?

Q: Any hands-on {activities} in high school?

Q: So, how did you feel in 9th grade when a lot of kids were acting up and speaking out against the teacher? How did you feel and what did you say? What did you do?

Q: Given that you have a background, an academic background in evolution, and a little or a lot in human evolution, do you think that having a concept or an idea that humans are just sort of one part of nature influences sort of how you live your everyday life? It could be something as simple as whether you recycle or how you vote, or how you look at health issues, global health issues. Does it make you more conscientious about issues of race? Is there anything you can reflect upon in that regard?

Q: Do you think if you didn't have a background in biology you would do things differently or do you think recycling, voting, charities, etc., is just part of who you are and separate from your education?

Q: Would you have made that decision {to be vegetarian} if you hadn't taken any biology since like 9th grade?

Q: You said you were "supportive of diversity" – do you think your background in biology has influenced your feelings about human diversity in general?

Q: So in AZ, and in other states, I'm sure, you can graduate high school without taking biology. Do you think it's important for students to have biology in 9th-12th grade?

Q: So what about health issues?

Q: Have you become friends with or met or talked to students in your classes here who have like no background in biology or have been really struggling with the material?

Q: So, how do you feel about difficulty of the intro courses - the 100 level courses? Are they appropriately challenging for incoming students at ASU?

Did it help to have BIO100 first?

Q: Could you have gone straight to BIO 187/188 or are you glad you had BIO100?

Q: Do you read newspapers either online or on paper? Like the New York Times or Daily News?

Q: Do you ever give money to any charity organizations or wildlife funds or anything like that, or have you in the past?

Q: Do you volunteer for any organizations or are you part of any student groups or anything like that?

Q: Do you have jobs?

Q: Do you plan on doing an internship or research before you graduate or an honors thesis?

Interview 2 (Round 2, Group 2)

Q: So why don't we just start by going around and just telling me a little about...just tell me where you went to high school (HS) and what you're majoring in here at ASU.

Q: So are you freshmen, sophomores, juniors...?

Q: Ok. So your memories of high school should be pretty fresh in your minds. So let's just talk a little bit about your science classes. You can include middle school as well as high school. Just tell me a little bit about what classes you took, and specifically any biology classes that you had.

Q: Was that your only biology class?

Q: I'm sorry, I should have asked; did you all go to public high school - graduate from public high school?

Q: Ok. Um, so, you just had one biology class in high school. Did you do a little biology in middle school, do you remember? Like dissecting grasshoppers or worms or anything like that?

Q: So that's what your class did for the whole year you worked on that?

Q: Ok. And again you said your major was...?

Q: Did you take the AP Bio exam after that? The IB exam?

Q: Ok. Are you planning on...you have to take a science class for your general studies major obviously, a lab class. Did you take something that fulfilled that yet?

Q: And what about the geology class? Are you learning anything in geology about like fossils or, um, like the history of the Earth in terms of how old the Earth is and things like that?

Q: Is this historical geology?

Q: So introductory geology is mostly rock types and things like that?

Q: Ok. So, I'm going to be asking you lots of questions about evolution. So I will tell you that when I say evolution what I'm referring to is the theory that all livings things on the planet today descended from a common ancestor that lived millions of years ago, and that that process has occurred through natural selection, genetic drift, gene flow - mechanisms of evolution proposed by scientists. So that's the definition that I'm using for this group. Um, so having said that, can you give me just a reflection upon the first time that you were introduced to that idea, whether it was middle school, high school, or college...just, when you think the first time was that someone talked about that even if it wasn't something formal.

Q: So would you characterize your Dad as someone who is accepting of the idea of organic evolution?

Q: Ok, so he was engaging you in that and getting you interested in it in a positive light towards science?

Q: Right. And this was mostly in high school that you're referring to?

Q: Do you specifically remember your teacher saying "I can't teach you this?"

Q: Was that, um, a male teacher or a female teacher?

Q: Do you remember the first time you were introduced to the idea of evolution?

Q: What was your first formal academic experience with it? Middle school?

Q: Ok. And do you remember....so, it wasn't its own unit that you guys covered - I guess in your middle school science - it wasn't like, "Evolution is our next chapter or unit?"

Q: How have you been introduced to this idea since you haven't had any formal biology training? Obviously you're aware of the concept of evolution, so would you say that came through your parents or just tv shows, reading?

Q: Oh, ok. What class was that?

Q: So he talked about Charles Darwin a little bit and like...?

Q: Ok, good to know. Um, so, you already told us a little bit about what the attitude was in the classroom around teaching of evolution so, do you have any memories of there being, um, anything different about learning about evolution than when you were learning about parts of the cell, or something like that in your classroom? Did you teacher portray a particular attitude? Were the students acting up or have any particular attitude about it, or...?

Q: Ok. So do you remember any...did you personally have any reaction to that? Or did the other students talk about it outside of the classroom?

Q: So did any of you get, um, any instruction at all about where humans fit in to that picture of evolution and learn anything about like fossil human ancestors or any scientific evidence supporting the evolution of humans?

Q: What class did you take? Was that your IB class?

Q: Um, so tell me a little about how you guys feel about that. Just the idea that is supported by fossil evidence {and} presented by scientists that humans descended from other primates and are primates and are just evolved organisms like other living things. How do you...what do you guys feel about that personally?

Q: Ok. Do you think that, personally, do you feel that humans were created in their present form or are you accepting of the idea that humans evolved from a primate ancestor?

Q: Ok. So tell me a little bit about your spiritual and religious upbringing, um, if your parents were religious, did you go to church or temple or anything like that?

Q: Ok. About what age did you stop going?

Q: Ok. And so, but did religion remain a part of your household because of your mom as you grew older or was that just something your mom did, or...?

Q: What kind of church, was it a Christian?

Q: But it was a church?

Q: Are your parents very religious people?

Q: So did they teach you ... were they going to church?

Q: Yeah, ok. But so, they were willing to, um, like if you said you wanted to go to a different type of church or learn about a different religion they would have been ok with that?

Q: High school years tend to be the time when a lot of students really start thinking about issues like this and want faith do they belong in, what are their spiritual beliefs, how do I feel about how the universe came to be and all of that kind of thing. But it also happens to be the time when a lot of students are introduced to the idea of evolution, and so it can be very challenging for some students to reconcile the two. So, um, they'll be going to church or youth groups or things like that and thinking "ok, who am I spiritually?", but then they'll be in school being told "ok, you've evolved from a primate ancestor" and things like this, though a lot of people don't actually get that in school. But they learn about evolution and, some students are comforted by the idea that they can be a spiritual person and study science and listen to and accept what scientists say. Has anyone had that experience, of really getting to a point where you had to think, "Ok, is it alright for me to be a spiritual person and study science and accept evolution and be ok with that"?

Q: But would you say that affects your view of science or how science is done in any way...the fact there aren't scientific explanations that are strongly held to about the original origins of life, like the very first living organisms? I mean there are a lot of hypotheses about how that happened, but not a well-structured theory about how that happened, so does that cause problems for you in terms of how you think of how science is done?

Q: So you've taken Bio 187? So BIO 187 is like general BIO 1 and it's a lot of evolution and environmental biology. Um, so since you didn't have a whole lot of evolution in school, do you think that that hurt you when you're taking BIO 187? Were there a lot of unfamiliar concepts in BIO 187 that you wish had maybe learned about in high school?

Q: So were there any other moments in your life where you'd recall when you were kind of struggling with the idea of what you're being maybe taught in church and your faith and then what you're being taught in school?

Q: Do you think like knowing that, or having an understanding of that, changes how you feel about evolution?

Q: Is that comforting to you?

Q: Any issues ever for you about trying to reconcile faith and science?

Q: Remind me of your major again.

Q: So just tell me a little bit about your opinion about where humans sort of fit in on the planet and what our role is in terms of taking care of the earth and protecting endangered species or whether you think humans are contributing to global warming. Like where do you think that we fit in that big environmental picture?

Q: Ok. What do you think, just where do we fit in within the whole global environmental picture?

Q: Ok. I mean you all generally have the same type of opinion about, you know, you want to take care of the Earth. Do you think that's more fostered by your experience with science and learning about chemistry and biology, or physics? Or do you think it's fostered more by your spiritual beliefs?

Q: So maybe more your faith is...fosters that feeling?

Q: Ok. Great. Anybody else go to zoos and museums much when you were a kid? Tell me about that a little bit.

Q: Did your parents take you or you went on school trips?

Q: Did you go regularly, though, with your family, or, would you say you just went a few times?

Q: Did your parents take you or did you go on school trips?

Q: When did you move here?

Q: Ok. So for you guys who are science majors, um, what do you think is the thing that most contributes to the fact that you are going to major in a science-related field? Do you think it was your academic background, good teachers, was it um, something just about you internally, was it your parents, you know, doing projects with you at home growing up or...or maybe a family member was ill and that caused you to be interested in it?

Q: So what experience do you think fostered that interest in you the most, your personal experience, or your academic experience?

Q: What is involved in that?

Q: Do you vote? Don't tell me how you vote. Do you vote in elections?

Q: Ok. Um, do you read newspapers, whether that's actual paper or on the internet, or news websites, I mean do you feel yourself inclined to check out what's going on in the world?

Q: Do you watch more local news or more world things would you say?

Q: Ok. Magazines, newspapers, websites, surfing the internet...?

Q: I'm just going to ask you...is there anyone in your family, and you don't have to tell me who in your family, but anyone in your family who you characterize as either racist or prejudiced against other individuals and if so why do you think that is and how do you feel about it?

Q: Do you have any memory of learning in your science classes at all about why people have different skin colors, why people look differently who live in different areas of the world?

Q: Ok. Anybody else learn about that in science or even history?

Q: Ok, but you haven't had any introduction to any scientific reasons why?

Q: Ok, but nothing specifically like "this is why"?

Q: Ok. Do you think that if people learned about that that would have an effect on how they view other people?

Q: So, do you think it'd be beneficial to you to have that knowledge to be able to say "This is the scientific evidence that supports that we're all...you know came from the same stock and this is why we have different skin colors and physical features?"

APPENDIX F

ATTRIBUTES ASSIGNED TO CASES IN NVIVO

Attribute	Value (default value = NA)
Gender	Male/Female
Age	Age
Class Year	Freshman/Sophomore/ Junior/Senior/Post-bac
High School City	City
High School State	State
High School Type	Public/Private/Home school
High School Regular Biology	Yes/No
High School Honors Biology	Yes/No
High School Adv Honors Bio Dual	Yes/No
High School AP Biology	Yes/No
High School IB Bio	Yes/No
High School AP or IB Bio	AP or IB/No AP or IB
High School Anatomy & Physiology	Yes/No
High School Exercise Physiology	Yes/No
High School Forensics	Yes/No
High School Microbiology	Yes/No
High School AP Environmental Science	Yes/No
AP or IB Bio exam score	1/2/3/4/5
SATII Biology exam score	Score
Major	Major
STEM major	STEM/Not STEM
ASU BIO 100	Course grade
ASU BIO 187	Course grade
ASU BIO 188	Course grade
ASU BIO 201	Course grade
ASU BIO 202	Course grade
ASU BSHE	Course grade
ASU BCLT	Course grade
ASU HESF	Course grade
ASU IGH	Course grade
ASU REL 100	Course grade
University - other biology courses	Number of courses
GPA	GPA
GPA range	2.00-2.49/2.50-2.99/ 3.00-3.49/ 3.50-3.99/ 4.0
Ethnicity	Ethnicity as reported
Religion - questionnaire	Student's religion
Religious services attendance – questionnaire	Never/Rarely or holidays/Once per week/Multiple times per week/Practice in home/NAG
Science career desire	Yes/No
Evolution acceptance - questionnaire	Score (0 least – 35 most)
Human evo. acceptance - questionnaire	Score (0 least – 5 most)
HS evolution exposure - questionnaire	None/Minimal/Moderate/ High

Attribute	Value (default value = NA)
HS HEBEd exposure - questionnaire	None/Minimal/Moderate/ High
Other high school enrollment	Yes/No
Public and private school – mix of both	Yes/No
K-8 evolution exposure - interview	Minimal/Yes/No
HS evolution exposure - interview	Minimal/Yes/No
HEBEd exposure in non-science class	Yes/No
Time spent on evolution	None/1 class period or day/2 days to 1 week/1 to 3 weeks/throughout course
Teacher disclaimer	Yes/No
Teacher religious views	Yes/No
K-12 HEB general exposure - interview	Minimal/Yes/No
K-12 HEB fossils exposure - interview	Minimal/Yes/No
Total K12 HEB Exposure	None/Minimal/Moderate/
Home science attitude	High
Family member STEM career	Positive/Neutral/Negative
Zoos and museums - family	Mom/Dad/Both/Extended
Zoos and museums - school	Yes/No/Yes a little/Yes a lot
Religion – community	Yes/No/Yes a little/Yes a lot
Religion – school	Yes/No
Religion – Mom	Yes/No
Religion – Dad	Religion
Religion – raised interview	Religion
Religion – attend CCD or Sunday school	Religion
Religious service attendance – interview	Yes/No
HEB education appeal	Yes/No
Preparation for college	Yes/No
Evolution acceptance – interview	Somewhat/Yes/No
	Undecided or I don't know/ Yes/Yes with questions/ No/Combination Sci and Rel/Undecided twd religion/Undecided twd science
Human evolution acceptance – interview	Undecided or I don't know/ Yes/ Yes with questions/ No/Combination/Undecided twd religion/Undecided twd science/Indifferent/I do not want to answer
Conflict between science and religion	Yes/No
News exposure	Limited/Yes/No
Voting activity	Yes/No
Evolution makes sense statement	Yes/No
Human evolution makes sense statement	Yes/No
Biology Makes Sense statement	Yes/No

Attribute	Value (default value = NA)
Diversity – expression of judgment	Yes/No
Diversity – attitudes of family	One parent/Both parents/Extended
Diversity – knowledge	None/Minimal/Moderate/ High
Diversity – desire to learn more	Yes/No
Diversity – explanation	Scientific/Religious/Combo
Environment – recycle	Yes/No
Environment – global issues statement	Thoughtful/Somewhat thoughtful/Not thoughtful
Environment – endangered species attitude	Doubt/No doubt
Environment – global warming statement	Mentioned
Motivation – natural inclination toward science	Yes/No
Motivation – illness, self or family	Yes/No

APPENDIX G

FINAL VARIABLES USED IN THE QUANTITATIVE ANALYSIS

Variable Name	Label	Values[a]	Measure[b]
PARTICIP	Case number (unique identifying number for each case)		Nominal
ACADAPT	Academic aptitude	1 SAT score < 1000 or ACT score < 20 2 SAT score 1000-1099 or ACT score 20-22 3 SAT score 1100-1199 or ACT score 23-25 4 SAT score 1200-1299 or ACT score 26-28 5 SAT score 1300-1399 or ACT score 29-31 6 SAT score 1400-1499 or ACT score 32-34 7 SAT score 1500-1600 or ACT score 35-36 999 Not answered -1 Not applicable	Ordinal
ADVBIO	Number of advanced biological science classes completed in high school		Scale
AGE	Participant's age		Scale
AGEEARTH	View on the age of the Earth	1 The age of the Earth is less than 20,000 years 2 I don't know 3 The age of the Earth is at least four billion years 999 Not answered	Nominal
ANTIBIOT	Q: Do antibiotics kill viruses as well as bacteria?	1 Yes 2 I don't know 3 No 999 Not answered	Nominal
APES1	Q: It is wrong for humans to poach (hunt) and eat monkeys and apes.	1 Completely disagree 2 Mostly disagree 3 I don't know/Neutral 4 Mostly agree 5 Completely agree 999 Not answered	Nominal/ Ordinal

Variable Name	Label	Values[a]	Measure[b]
APES2	Q: It is important to preserve the forests where chimpanzees, gorillas and orangutans live.	1 Completely disagree 2 Mostly disagree 3 I don't know/Neutral 4 Mostly agree 5 Completely agree 999 Not answered	Nominal/ Ordinal
APES3	Q: Scientists should not use chimpanzees for drug testing.	1 Completely disagree 2 Mostly disagree 3 I don't know/Neutral 4 Mostly agree 5 Completely agree 999 Not answered	Nominal/ Ordinal
APES4	Acceptance of humans' biological relationship to other primates (composite variable).	1 No or low acceptance 2 Minimal acceptance 3 Moderate acceptance 4 High acceptance 999 Not answered	Ordinal
BABEL	Q: The scattering of peoples from the tower of Babel across the Earth is the cause of modern races of humans.	1 Completely disagree 2 Mostly disagree 3 I don't know/Neutral 4 Mostly agree 5 Completely agree 999 Not answered	Nominal/ Ordinal
BIOLOGY	Completed more than 2 biological science classes including 1 or more advanced biological science classes in high school.	0 No 1 Yes 999 Not answered	Nominal
BIOSCI	Number of biological science classes completed in high school		Scale
BIRTHCON	Views on birth control use	1 It is wrong to use birth control 2 I don't know 3 Birth control should be used to prevent unwanted pregnancy 999 Not answered	Nominal

Variable Name	Label	Values[a]	Measure[b]
BOOKS	Influence on STEM career desire - Books	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
CEAWARE	Current event awareness (awareness of oil spill in Gulf of Mexico)	1 No 2 Yes 999 Not answered	Nominal
CLASSYR	Participant's undergraduate class year	1 Freshman 2 Sophmore 3 Junior 4 Senior	Ordinal
CLIMATE	Exposure to climate change science in high school science class	0 No 1 Yes 2 I don't know 999 Not answered	Nominal
CLONING	Q: Technology used to clone or genetically alter non-human animals should be used for humans.	1 Strongly oppose 2 Somewhat oppose 3 I don't know/Neutral 4 Somewhat favor 5 Strongly favor 999 Not answered	Nominal/ Ordinal
CURIOUS	Influence on STEM career desire - Own curiosity	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
DIVINE	Q: Divine creation is the best explanation for the existence of humans.	1 Completely agree 2 Mostly agree 3 I don't know/Neutral 4 Mostly disagree 5 Completely disagree 999 Not answered	Nominal/ Ordinal
DOCTEL	Influence on STEM career desire - Nonfiction television	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal

Variable Name	Label	Values[a]	Measure[b]
ENVIRO	Engagement in pro-environmental activities and behaviors (composite variable)	1 Least engaged 2 Somewhat engaged 3 Moderately engaged 4 Most engaged 999 Not answered	Ordinal
ETHNIC	Participant's self-identified ethnicity (categories are based on 19 possible survey response options)	1 Non-white, non-Hispanic, non-Asian 2 Asian 3 Hispanic, Latino, Spanish, Mexican, Chicano 4 Mixed ethnicities 5 Caucasian or white 999 Not answered	Nominal
GENACCEP	Acceptance of general evolution	1 Living things have existed in their present form since they came into being. 2 I don't know 3 Living things have evolved over time	Nominal
GODINVOL	Views on role of a supernatural being in evolution	1 A supreme being guided the evolution of living things 2 I don't know 3 Living things have evolved due to natural processes	Nominal
GOVFOLLO	Frequency of following events in government and public affairs	-1 I don't know 1 Hardly at all 2 Only now and then 3 Some of the time 4 Most of the time	Ordinal
GPA	Participant's undergraduate GPA	-1 I don't know 1 <2.0 2 2.0-2.49 3 2.5-2.99 4 3.0-3.49 5 3.5-3.99 6 4.0	Ordinal
HEACCEP	Acceptance of human evolution	0 No or low acceptance 1 Minimal acceptance 2 Moderate acceptance 3 High acceptance	Ordinal

Variable Name	Label	Values[a]	Measure[b]
HEBEXP	K-12 human evolutionary biology exposure	0 None 1 Low 2 Moderate 3 High	Ordinal
HEBEXP2	HEBEXP recoded into 2 categories	0 No or minimal K-12 HEB exposure 1 Moderate or high K-12 HEB exposure	Nominal
HELPANIM	Influence on STEM career desire - A desire to help animals	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
HELPPEOP	Influence on STEM career desire - A desire to help other people	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
HSREGION	U.S. region where participant graduated from high school	0 South 1 Northeast 2 Midwest 3 West	Nominal
HSSCI	Completed 3 or more science classes including 1 or more biological science classes in high school	0 No 1 Yes	Nominal
HSSCIHI	Completed more than 4 science and 1 or more advanced biological science classes in high school	0 No 1 Yes	Nominal
ILLFAM	Influence on STEM career desire - Illness or death of family member	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
ILLSELF	Influence on STEM career desire - Own illness	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal

Variable Name	Label	Values[a]	Measure[b]
IMMIG	Views on U.S. immigration	1 Least favorable view 2 Somewhat favorable view 3 Moderately favorable view 4 Most favorable view 999 Not answered	Ordinal
JOB	Influence on STEM career desire - Own job experience	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
K12CLASS	Influence on STEM career desire - K-12 class	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
K12TEACH	Influence on STEM career desire - K-12 teacher	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
MOVIES	Influence on STEM career desire - Movies	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
MUTATE	Q: All DNA mutations are harmful.	1 Agree 2 I don't know 3 Disagree 999 Not answered	Nominal
NATHIST	Influence on STEM career desire - Natural history museums	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
NEWS	Frequency of engagement with general news media	0 Not regularly 1 I don't know 2 Regularly	Nominal
NSHEVOL	Exposure to scientific explanations for the origin of humans in non-science classes	0 No 1 Yes 999 Not answered/I don't know	Nominal

Variable Name	Label	Values[a]	Measure[b]
OTHERINF	Influence on STEM career desire - Other	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
OVERPOP	Q: Indicate the degree to which you think human overpopulation is a problem.	1 Not a problem 2 Not too serious a problem 3 I don't know/Neutral 4 A somewhat serious problem 5 A very serious problem	Nominal/ Ordinal
PARNTHOB	Influence on STEM career desire - Parent hobby	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
PARNTJOB	Influence on STEM career desire - Parent job	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
PRINTMED	Influence on STEM career desire - Print media	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
PTIMETEL	Influence on STEM career desire - Primetime fiction television	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
RELFACT	Religion factor	0 None 1 Low 2 Moderate 3 High 999 Not answered	Ordinal
SAMESEX	Views on same sex relationships	1 Least favorable view 2 Somewhat favorable view 3 Moderately favorable view 4 Most favorable view 999 Not answered	Ordinal
SCIMEDIA	Frequency of engagement with science news and media (composite variable)	0 No or low engagement 1 Minimal engagement 2 Moderate engagement 3 High engagement	Ordinal

Variable Name	Label	Values[a]	Measure[b]
SCICENT	Influence on STEM career desire - Science centers	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
SCIEASE	Q: All in all, how would you describe your science coursework at ASU?	1 Extremely challenging 2 Somewhat challenging 3 Somewhat easy 4 Extremely easy -1 Not applicable 999 Not answered	Ordinal
SCIENCE	Number of science classes completed in high school		Scale
SCICAT	SCIENCE recoded into categories	0 0 classes 1 1-2 classes 2 3-4 classes 3 5-6 classes 4 7-8 classes 5 9-10 classes	Ordinal
SCIFAIR	Influence on STEM career desire - Science fairs	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
SCIHEVOL	Exposure to scientific explanations for the origin of humans in high school science class	0 No 1 Yes 999 Not answered/I don't know	Nominal
SCIPREP	Q: How well did your high school prepare you for your university science courses?	1 Extremely unprepared 2 Somewhat unprepared 3 Somewhat prepared 4 Extremely prepared -1 Not applicable 999 Not answered	Ordinal
SEX	Participant's self-identified sex	0 Female 1 Male 2 Other	Nominal

Variable Name	Label	Values[a]	Measure[b]
SKINSCI	Q: Differences in human skin color can be explained by science.	1 Completely disagree 2 Mostly disagree 3 I don't know/Neutral 4 Mostly agree 5 Completely agree 999 Not answered	Nominal/ Ordinal
STEMCELL	Exposure to the science of stem cells in high school science class	0 No 1 I don't know 2 Yes 999 Not answered	Nominal
STEMDEG	Majoring in or wants to major in a STEM degree program (coded based on multiple responses)	0 No 1 Undecided 2 Yes	Nominal
STEMCAR	Q: Are you interested in pursuing a science, technology, or engineering-related career (including medical, teaching, research, or industry jobs)?	0 STEM 1 I don't know 2 Not STEM	Nominal
STEMRES	Views on federal funding for stem cell research	1 Oppose 2 I don't know/Neutral 3 Favor 999 Not Answered	Nominal
SURVEY	Influence on STEM career desire - This survey	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
TOTALHEB	Total human evolutionary biology exposure	0 None 1 Minimal 2 Moderate 3 High	Ordinal
UNDEVOL	Number of undergraduate courses completed that addressed evolution		Scale

Variable Name	Label	Values[a]	Measure[b]
UNICOUR	Influence on STEM career desire - A university course	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
UNIPROF	Influence on STEM career desire - A university professor	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal
VACCINES	Q: Do you favor or oppose required vaccinations for all children?	1 Oppose 2 I don't know/Neutral 3 Favor 999 Not Answered	Nominal
VOTEPRES	Q: Did you vote in the 2008 U.S. Presidential election?	0 No, though I could have voted 1 Yes -1 No, I was too young to vote at the time 999 Other/Not answered	Nominal
VOTEREG	Q: Are you registered to vote in the U.S.?	1 Yes 2 I can register, but have not -1 I cannot legally register/I don't know	Nominal
WARMING	Q: Which comes closer to your personal view [of global warming]?	1 The Earth is not getting warmer 2 The Earth is getting warmer mostly because of natural changes in the atmosphere 3 The Earth is getting warmer mostly because of human activity such as burning fossil fuels 4 I don't know	Nominal
WARMPROB	Q: Indicate the degree to which you think global warming is a problem.	1 Not a problem 2 Not too serious a problem 3 I don't know/Neutral 4 A somewhat serious problem 5 A very serious problem	Nominal/ Ordinal

Variable Name	Label	Values[a]	Measure[b]
ZOOAQU	Influence on STEM career desire - Zoos and aquaria	1 No influence 2 Some influence 3 A lot of influence 999 Not answered -1 Not applicable/skipped	Ordinal

[a] Values -1 and 999 defined as missing

[b] Some nominal measures can be ordinal if the category for "I don't know/Neutral" is defined as missing.