

The University of Colorado at Boulder

STUDENTS' PERCEPTIONS OF THE SOCIETAL AND PERSONAL IMPLICATIONS
OF EDUCATION REGARDING CONCEPTS OF EVOLUTION

By

Samantha J. Steele

Defended 16 March 2018

A Thesis Submitted to the Honors College of
The University of Colorado at Boulder, To Fulfill Honors Requirements for Bachelor of Arts in
Ecology and Evolutionary Biology

Committee Members:

Lisa Corwin, PhD, Ecology and Evolutionary Biology, Thesis Adviser

Barbara Demmig-Adams, PhD, Ecology and Evolutionary Biology, Honors Council

Representative

Andrew Martin, PhD, Ecology and Evolutionary Biology

Joanna Lambert, PhD, Anthropology

Abstract

Evolutionary theory is a national learning priority in the United States. However, evolution is differentially taught and accepted by individuals across the nation depending on a variety of factors. Many studies have been conducted on academic populations and their acceptance and understanding or lack thereof of concepts of evolution. However, many of these studies were conducted on generalized populations. The University of Colorado at Boulder has a unique population of biology students with varying backgrounds, and we were curious as to how their perceptions of the impacts of teaching evolution might differ from other groups. In the research for this thesis, students from a population of introductory biology students and a population of an upper division evolution class were asked the question “If all individuals were required to learn evolution, how would it change the way society functioned?” Their responses were transcribed and coded using NVivo 11 software. Overall, students in both populations similarly reported positive implications of learning evolution in the cognitive, or knowledge-gain, domain. Students from both populations also related learning evolutionary theory to affective and behavioral gains. Responses from both populations were mostly positive, contrary to previous research. Students in the upper-division class also tended to address the concept of human evolution, whereas the general biology students did not cite human evolution in their responses.

Introduction

Possible Implications of Learning Evolution

The concept of evolution is a learning priority in biology curricula across the nation. Its significance is emphasized by organizations such as the American Association for the Advancement of Science, the National Science Foundation, and many others, and understanding and acceptance of evolution is a highly researched factor in science education (Konnemann *et al.*, 2016). Furthermore, complete and complex understanding of evolution encourages retention of the ideas and application to future problems. (Glaze *et al.*, 2015). However, evolution presented as “fact” is not universally taught across the United States’ education system, and the discussion of the idea continues to generate conflict in the public and with individual students (Brem *et al.*, 2003). Evolutionary theory is not universally accepted, and according to several studies, the resistance to or difficulty accepting the theory may influence and be influenced by poor understanding of the concepts of evolution. Teachers in U.S. school systems often feel pressure from parents and religious influences and dilute their teaching to avoid potential conflict.

Most commonly, relationships characterized by conflict develop between religious individuals and those who study and teach evolution—what scientific doctrine may refer to as Creationism versus Evolutionism. However, the perceived conflict or disagreement between firmly held religious beliefs and concepts related to evolution is only the tip of the iceberg in how students may be affected by learning evolution. In addition to the disagreement between these concepts, Brem and colleagues (2003) also found that learning evolution could provide rationale for racial differences, effect on an individual’s sense of purpose, and influence whether individuals see themselves as “in control” of their own destiny, et cetera. Brem’s 2003 paper

provides five potential ways in which learning concepts of evolution might affect individuals. Some of the proposed effects are religious in nature, while others are not. Brem's research hypothesizes that learning evolutionary concepts may affect students' a) perceptions of race, b) self-control and self-determination, c) spirituality, d) selfishness, and e) sense of purpose in life (Brem *et al.*, 2003). Hypothetically speaking, learning the concepts of evolution with poor understanding or a previously held bias might encourage or reinforce a student's racist mentalities, or it could disband them entirely resulting in greater acceptance of other races and cultures. The spectrum of potential effects is wide and largely undocumented outside the realm of religious conflict. The goal of this thesis is to explore, identify, and discuss these and other potential implications students expect to encounter from learning or not learning concepts of evolution.

Study Questions

The research for this thesis was conducted under the faculty advisory of Dr. Lisa Corwin of the University of Colorado's Ecology and Evolutionary Biology department as a follow-up to the evolution education study conducted by the RE³ACH Lab team in 2017. In that study, the research team hypothesized potential cognitive dissonance within students as concepts of evolution conflicted with their personal beliefs and doctrine. The goal of the original RE³ACH study was to identify student's perceptions of the societal and individual implications of evolution education. This thesis aims to:

- describe in detail students' thoughts and expectations about the implications that teaching evolution has for society,
- ascertain whether students believe that concepts of evolution have an impact on society and/or the individual beyond simple knowledge gain, and

-determine whether students report impacts that are cognitive, behavioral, or affective

The intent is to facilitate thoughtful, honest discussion with students in the sample population to discover what they think might be the most beneficial, neutral, or harmful aspects of learning evolutionary theory. This research will further target students' perceptions of how learning the concepts of evolution may or may not affect students' relationships with and understanding of the natural world and the way humans interact.

Literature Review

Prior and Current Research

Numerous studies have been conducted not only on students' understanding of evolutionary concepts, but few studies have been conducted on potential and observed effects of learning such concepts on the students and society. After interviewing a sample population of psychology students and using qualitative analysis to explore the opinions, affect, and observations of students regarding their experiences learning about the theory of evolution, prior research identified sources of conflict and observable effects on social and scientific perceptions (Brem *et al.*, 2003). Brem's research on students' perceptions of evolution also surveyed undergraduates from other disciplines. The populations included students from the humanities (24%), Engineering (22%), Social sciences (15%), Life sciences (11%), and who were undecided or other (28%). Students from these populations cited mainly negative and conflictual views on evolution. (Brem *et al.*, 2003). Notably, the population surveyed in this study drew mainly from fields outside the life sciences, in which one might not necessarily expect unanimous agreement on evolution or positive views about evolution. Another study conducted in 2003 by Sinatra and colleagues examined a similar population of individuals in a biology class for non-majors and found no correlation between students' understanding of evolution and their acceptance of

human or animal evolution (Sinatra *et al.*, 2003). Therefore, it is pertinent to examine students belonging to diverse groups. It may be important to understand how life science students, who are especially likely to discuss and interact with concepts of evolution in the future, perceive impacts of teaching evolution and society. A population of biology students has yet to be examined in this way, and this study targets that unexplored population to see whether their perceived implications of learning evolution are similarly negative and conflictual.

This study is a more in-depth look at a study conducted in 2017, where Corwin, Steele and Fried looked broadly at evolution education, and utilized a variety of interview questions to gain insight into the core beliefs and understanding of evolutionary concepts held by biology students at the University of Colorado, Boulder. These students were in the biology discipline and participated in interviews after completing Evolution (EBIO 3080) or General Biology (EBIO 1220). Those in General Biology were not necessarily part of the EBIO major. For this study researchers recruited a group of 26 students from the combined classes with which to conduct interviews and generated a qualitative codebook to be able to later analyze their transcribed responses.

For the smaller-scale study discussed in this paper, the focus is on one specific question from the interview: “If every student were required to learn about evolution, do you feel it would change the way society functioned? If so, how?” This question was selected to observe the implications students felt learning evolution might have on society, whether they have a great deal of personal experience learning about evolution or not. Interviewers prompted students to express positive, negative, or neutral effects they felt may have an impact on society.

Two Broad Sides

The basis for the focus on the question of learning about evolution and the effects of this on students' beliefs comes not only from interview findings in a previous study in the Corwin Lab, but from a report entitled "Perceived Consequences of Evolution" (Brem *et al.*, 2003.). Brem's abstract notes two main opposing viewpoints of evolution. One, the generally positive view that learning concepts of evolution can inspire wonder and appreciation for the natural world within the student. The other, a negative view that acceptance of evolutionary theories may result in justification of sin, abandonment of spirituality, and loss of purpose in life. These two broad categories span the gamut of the potential diverse effects on students when learning about evolution and they set the stage to develop more specific perceptions and criteria for identifying them. The most common area of research in which this divergence exists is the realm of religion "versus" evolution, as previously mentioned—belief in creation by God, and scientific reasoning for acceptance of evolution as the origin of all life, including human life. Not only will this study screen for this conflict within its unique population of biology students, it will enhance and add to existing literature by specifically exposing biology students' perceptions of evolution, which may be positive or negative.

A Framework for Potential Consequences

Brem's paper proposes a framework for five key areas of consequence in learning evolutionary theory:

1. Sense of Purpose in life. Concepts of evolution may suggest to some individuals that there is no "master plan," as Brem's paper says. Furthermore, individuals may adopt the impression that "survival of the fittest" is a key theme in understanding why certain humans or other organisms succeed over others (Brem *et al.*, 2003).

2. Perceptions of race and ethnicity. Individuals may utilize concepts of evolution to explain the physical differences between races and expose their insignificance next to the knowledge of humanity's shared traits.
3. Sense of spirituality. Evolution may be perceived by some as conflictual with their conception of religious ideas, such as the creation of the universe, an afterlife, or intelligent design.
4. Perceptions of selfishness. Individuals may utilize the idea of "survival of the fittest" to justify self-centered behavior, perhaps at the expense of others.
5. Sense of self-determination. Individuals may feel that since evolutionary processes are the basis for individuals' characteristics today, they have little or no control over their actions or events of their lives. Alternatively, evolution may provide individuals with an enhanced sense of control.

These five potential impacts of learning evolutionary theory are a basis for this study's qualitative codes (Brem *et al.*, 2003). There are individual and societal implications to adopting any of the five views presented in Brem's study, therefore asking students about societal implications of learning evolution will capture their broad thoughts on implications and applications of learning evolution.

Methodology

Sample Population

The population for this thesis includes students from Evolution (EBIO 3080) and General Biology (EBIO 1220) at the University of Colorado, Boulder. The research team recruited participants from both classes due to the variety in stages of learning, background knowledge, and investment in biology topics. Not all General Biology students are biology majors and may

have varying exposure to concepts of evolution, dependent on their previous education experience. EBIO 3080 students are frequently biology or environmental science majors and likely have previous exposure to concepts of evolution, presumably from introductory biology courses at the university. A sample-size of fifteen students per class was the goal sample size of this thesis, and 25 student interviews are transcribed (X from EBIO 3080 and X from EBIO 1220). This thesis aims to cultivate a representation of the CU Boulder population that is interested in concepts of evolution, and to look at how these subpopulations may differ because of their investment and time spent with concepts of evolution. In this sample selection the team chooses to incorporate representation from students with greater versus lesser background knowledge of concepts of evolution to generate a depiction of undergraduate populations who engage in biology courses early in their career (EBIO 1220) and those who choose to specifically study evolution (EBIO 3080). Indeed, EBIO 3080 students are the target of this thesis because of their voluntary participation in an evolution class, which may provide an interesting and different representation than previous studies. This study may offer insight into whether students who pursue evolution in their curricula perceive impacts of learning evolution differently than other populations.

Experimental Design

The portion of the interview transcribed and analyzed for this study is part of a longer, hour-long interview conducted with study participants for a previous study. Interviews were conducted by Dr. Lisa Corwin, Erin Fried, and Samantha Steele with approval from the CU Boulder IRB office. At the outset of the interview, students were asked to provide their personal definition of evolution. The interviewer offered no correction of misconceptions, and this question started the students thinking on their perceptions of evolution. The question used as the

focus for this thesis was the seventh of the ten questions from the original study. Question seven reads “If all individuals were required to learn evolution, do you feel it would change the way society functions? If so, how?” The question was chosen for analysis in this thesis because of its focus on the topic of evolutionary theory in an educational setting—the setting in which the sample group likely encountered the topic—and because it targeted students’ perceptions of the concept and its potential effect on society and individuals without insinuating a negative or positive response to the student. Students could also describe perceived impacts outside their own firsthand experiences. Researchers Steele, Corwin, and Fried utilized 26 interviews at the end of the data collection period. The research team transcribed only the segment of the interviews containing question seven.

Data Analysis

Transcribed data from the open-ended question “If all individuals were required to learn evolution, do you feel it would change the way society functions? If so, how?” was qualitatively coded and analyzed to generate a representation of the way students relate to the experience of learning evolutionary theory. The team utilized an inductive coding strategy, wherein a set of codes is developed based on a reading of the data after transcription but before final coding and refined based on findings. Analysis began with an initial framework of themes (drawing heavily from Brem’s research) to form a basic codebook, and then added themes and nuances based on any novel student perceptions identified in the transcribed interviews. This refinement based on results precipitated a highly specific codebook that reflected the ideas frequently expressed by students. Ultimately, thirteen codes were identified for describing students’ opinions on learning concepts of evolution. Table 1 displays the final codebook, organized into the three categories of

general psychology: cognitive, behavioral, and affective. Qualitative analysis of interview transcription results was synthesized into definitions for each of the 16 codes.

Cognitive	Behavioral	Affective
General Conflict (12)	Agency in Choosing What to Believe (5)	Feeling Connected (4)
Society's Knowledge (10)	Environmental Conscientiousness (2)	Shift in Morality (1)
Understanding Evolution (8)	Perceptions of Race (positive and negative) (3)	Sense of Spirituality (positive and negative) (6)
Understanding Human Behavior (10)	Selfishness (1)	Cooperation and Kindness (5)
Accepting and Understanding Change (2)	Sense of Self-Determination (2)	

Table 1: Table 1 shows the final codebook categorized into cognitive, behavioral, and affective. Parenthetical numbers represent the number of interviews in which the code appeared.

Code Definitions

General Conflict- Students express that everybody learning about evolution would create conflict between individuals, groups, or doctrines. Conflict with religion is a recurrent theme. This code has a generally negative connotation, although students sometimes discuss ways that learning evolution might relieve such conflict.

Society's Knowledge- Students express that learning about evolution generally increases society's knowledge, enhances skills and general knowledge of scientific processes, "scientific

literacy”, or critical thinking. This code is not necessarily specific to evolution or understanding of human behavior.

Understanding Evolution- Students express that learning the theory of evolution enhances understanding of evolutionary concepts and processes.

Understanding Human Behavior- Students express that understanding evolution allows them to understand the root of human behaviors, especially in a social and relational context.

Subcategory one: **Understanding Others’ Views-** Students feel that learning concepts of evolution may cause individuals to be more open toward the views of others (specifically on the topic of evolution, or not). Subcategory two: **Understanding Self-** Students see a link between their own behaviors or decisions and principles of evolution. Students express that evolutionary principles may act on or help determine their actions or decisions. All the above codes have a generally positive connotation.

Accepting and Understanding Change- Students express that evolution’s nature of constant change can help individuals become more accepting of the change in their own life—seeing it as a natural process. In a negative light, students may feel evolution debunks the idea of a “master plan.” (Brem *et al.*, 2003). Although expressed with a negative connotation in Brem’s paper, responses under this code are positive in this study.

Agency in Choosing What to Believe- Students express learning about another way of thinking or other position on evolution gives them the choice to believe it or not. Students may express that not learning the alternate position on evolution (other than their own) may prevent them from fully understanding or empathizing with both sides. This code appears in five separate interviews and responses are positive in nature.

Environmental Conscientiousness- Student expresses that learning concepts of evolution may cause individuals to be more respectful and reverent of their natural environment. Students potentially mention investment in conservation and environmental protection. This code is generally positive.

Perceptions of Race Negative- Students express that evolution “proves” the superiority, inferiority, or relative fitness of different races. Students may feel that evolution could potentially lead others to believe this idea as well.

Perceptions of Race Positive-Students feel that learning evolution explains away or minimizes differences between races/ethnicities by placing them in a simple, physical context. Students may provide scientific explanations for why skin colors are different. Students express that evolution leads them to believe in equality between races.

Selfishness- Students express the potential for learning concepts of evolution to promote selfishness in individuals. The student may mention a need to “get ahead” or bolster one’s own fitness above a concern for one’s community. This code has a generally negative connotation.

Sense of Self-Determination (Self-Regulatory Behavior, Sense of Control Over Life)- Students express that learning concepts of evolution may promote or destroy an individual’s sense of control over one’s life and ability to affect their outcomes through decisions and actions. Students may mention genetic predisposition and “human nature.” Students may identify behavior or thought pattern that is rooted in evolution and talk about changing the behavior. This code may reflect change in reacting to others’ behavior, or empowerment in changing own behavior.

Feeling Connected (Appreciation and Humility)- Students express that learning about evolution highlights similarities between people. Potentially enhances connections between

individuals and understanding of one another's behaviors. Students may mention empathy for others and a sense of humanity's place in the scheme of nature, antagonistic to an anthropocentric view of the world. This code is generally positive in this study.

Shift in Morality (Social Darwinism)- Students express that learning about evolution may justify what we consider "immoral" actions if they benefit the majority. This may cover actions for the good of the many. Examples may include population control, eugenics, and "survival of the fittest." This code is expressed with a negative connotation.

Sense of Spirituality Negative- Students see potential for individuals to feel that individuals' religion or spirituality is incompatible with the concept of evolution. Students may mention a forcing-out of belief in an afterlife or higher power, potentially causing distress in the paradigm of an individual with a religious foundation for life.

Sense of Spirituality Positive- Student feels learning concepts of evolution will enhance individuals' understanding of and connection with their spirituality.

Cooperation and Kindness- Student feels learning concepts of evolution may increase individuals' desire to help one another, often through the passing on of helpful knowledge, and commit selfless acts to improve the survival or quality of life of others. This code appeared in five separate interviews and is generally positive in nature.

Results and Discussion

This section will begin with a discussion of results reported by the most students in the interview transcriptions: the codes that fall under the "cognitive" category. Afterward, this section we will discuss several interesting codes from the "behavioral" and "affective" sections.

Cognitive Codes

The most prevalent comments by students centered around both cognitive understanding gains when learning evolution or conflicts in society because of learning evolution. Overall, codes classified as cognitive receive the most attention from students. As knowledge gain is the

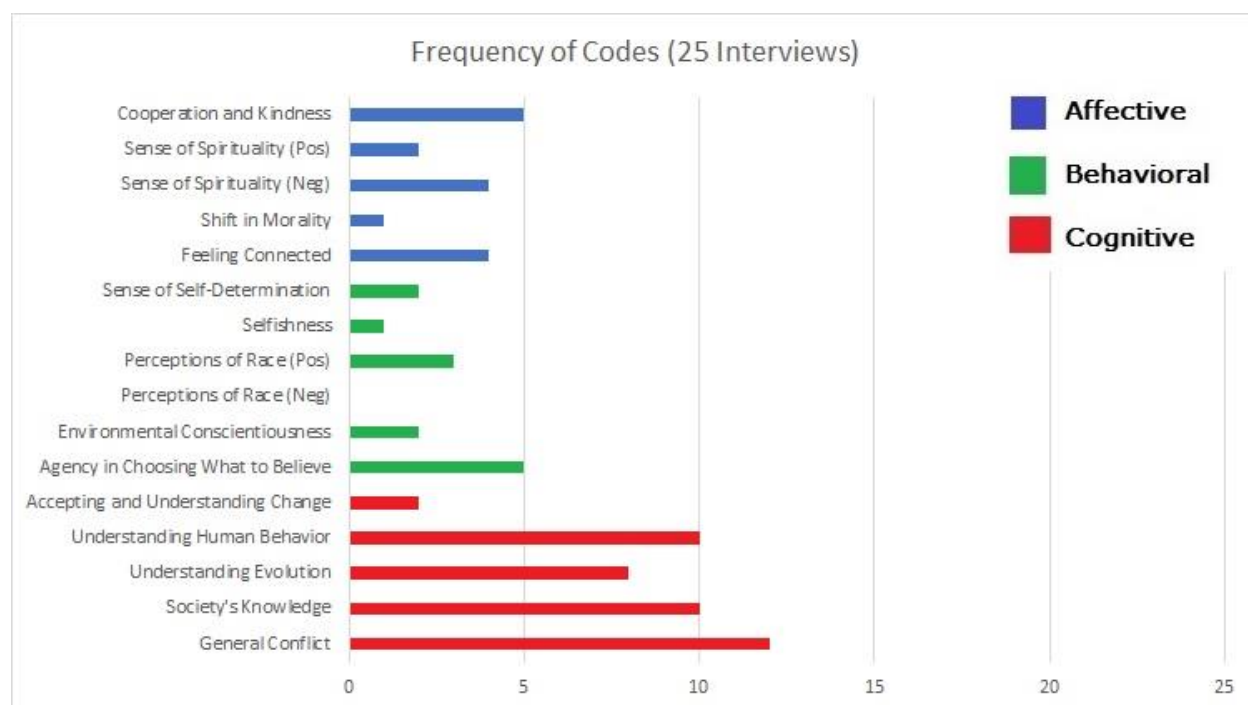


Table 2: This graph represents the number of interviews in which each code appears out of the 26 total interviews. “Cognitive” type codes are classified under the red bars and come up most frequently in student interviews, while “affective” and “behavioral” type codes appear less frequently but are similar to one another.

foremost goal of an educational institution, this is not surprising. Results from this study indicate that the unique population of students interested in evolution are also thinking about the cognitive impacts of learning evolution, as is typical of a student in an academic institution. However, a substantial number of students did cite behavioral and affective effects on society because of learning concepts of evolution.

General Conflict- The way students expressed potential conflict regarding learning evolution was highly variable. One of the principle themes within “General Conflict” was that such conflict may arise due to individuals’ misunderstanding of concepts of evolution. Additionally,

some students proposed that the act of forcing all individuals to learn about evolution would cause conflict in and of itself. However, students also described ways in which learning concepts might relieve that same conflict. One student said the following:

“I’m sure you’ll get a large kickback from the religious community, which has been going on for quite some time. I think there would be a little bit of an uproar, but at the end of the day everyone is entitled to their own opinions.”

This student introduces the frequently communicated idea that being required to learn evolution would cause conflict with certain groups who do not hold evolutionary theory as necessarily true. Indeed, students like the one quoted above believed it might be inappropriate to require all individuals to learn the concept. This tolerance and understanding for individuals of diverse backgrounds appeared in several interviews, where students mentioned ways in which certain groups might take offense or feel discomfort at the idea of being required to learn these concepts.

“Well, if everyone had a solid education and they didn’t just have the misconstrued depiction of evolution in their mind of us coming from chimps... I hope there would be less conflict in regards to religion and how that contradicts evolution or how people think that contradicts evolution... Maybe people would be more open to change, because that’s like a continuous thing...”

This student describes a potential positive consequence of requiring all individuals to learn concepts of evolution. They imply through their description of “misconstrued” ideas that the initial misunderstanding of concepts of evolution might cause backlash from certain communities—mainly religious ones—might be lessened with a more informed population.

Other students did not specify a positive or negative outcome, but implied that the consequences of requiring everyone to learn concepts of evolution could cause either positive or negative outcomes depending on how the concepts were taught. Overall, students' perceptions of potential conflict arising from requiring individuals to learn concepts of evolution were both positive and negative, depending on the circumstances and approach.

Society's Knowledge- The "Society's Knowledge" code falls under the cognitive category of codes in this thesis. Student responses classified under this code may describe how learning concepts of evolution increases knowledge of scientific processes in general, and often invoke the idea of scientific literacy. In the following excerpt, a student describes in detail the way individuals may be able to apply concepts of evolution to their holistic scientific knowledge and problem solving.

"The knowledge that you gain from learning about evolution is not just knowledge of evolution. It's knowledge of these larger scale concepts, and to understand evolution you have to understand a much broader, you have to have a broader understanding of science in general, and scientific method and methods of that sort of thing. and I think having the background leading up to evolution and then understanding the evolutionary concepts would produce a more informed population.

And therefore maybe if everyone was informed about these things we wouldn't have problems with, you know, antibiotics. So I think it would be beneficial because we would have...if more people were informed about these things people would understand why these problems are so pressing."

Students also described that learning concepts of evolution might increase knowledge of scientific concepts in general and potentially promote critical thinking.

“I think a lot of people would, I mean, just making sure people study more science in general would probably make people a little better at sniffing out BS and better at critical thinking, which is always good.”

Overall, students brought this code up frequently, and acknowledged consistently positive cognitive gains for society as a result of learning evolutionary theory.

Understanding Evolution- Many students expressed the idea that if all individuals were required to learn concepts of evolution, understanding of the concepts, processes, and applications of evolution would increase in a beneficial manner. Although this seems simple and straightforward, understanding the concepts and processes of evolution is a basis for scientific and general knowledge, in and outside biology. This idea appeared in the following excerpt:

“I think that it would definitely have a positive effect on the way that people approach science. I think that, especially with evolution, a lot of people say “oh well, it’s just a theory like, you can’t actually prove it.” But I think if people were really well educated about it they would kind of have a better—more appreciation for science and the work that goes into mapping evolution of species and humans, because there’s so much work and effort that goes into it and it crosses over into so many different fields, and I don’t think people really realize that. So I think that if everyone had to take an evolution course, they would really see how broad of a topic it is and how so many disciplines interact to go into research in evolution and just have a greater appreciation and understanding of the science that is behind it.”

This student introduced a notion that education on concepts of evolution might cause a general, positive increase in appreciation for and understanding of scientific processes and foundational concepts. This excerpt as well as many similar quotes from students took on a

generally positive tone regarding the increase in information among individuals learning concepts of evolution. Additionally, several students moved beyond general knowledge to emphasize an increase in understanding of practical applications of evolutionary theory.

“But I do think it is important, at least in, uh, describing certain things to people. Like why we should be interested in protecting, uh, genomic variation. Just like, why are certain things important? Why is inbreeding bad? I feel like people have a sense of it, but they don’t know, like, mechanisms.”

“The way we deal with problems. The way we deal with—I feel like evolution forces us to look at how things got there, and that is a very important—that is very important in dealing with problems as they arise. Um, not just how you got there, like, you know, from place to place or point A to point B, but like, what’s changed? What now is this organism, now that it’s had all these influences? For example conservation problems I feel like are greatly impacted by an increased understanding of evolution.”

In these two excerpts, students cite specific ecological issues and suggest that increased knowledge and understanding of evolutionary concepts, and therefore an understanding of their implications, might generate a more informed perspective on contemporary issues.

Understanding Human Behavior- Students in our study frequently expressed “Evolution’s” potential impact on the way they or their peers understand human behavior. This code is broken down into several segments, including “Understanding Human Behavior,” “Understanding Others’ Views,” and “Understanding Self.” We initially designated these as separate topics, but clear similarities between the three prompted us to combine them into an over-arching theme of understanding humanity and its motives. One student articulated the foundation of this argument by describing the way learning concepts of evolution might direct individuals away from an idea

of “manifest destiny” or “extraction from the natural environment,” highlighting our place in ecology and vulnerability, even as humans, to evolutionary forces.

“I do think everyone should learn about evolution. I think it’s a really important, framework for understanding the world and a lot of things we do. Especially...the statistic we were shown in the very beginning of class where it was like 50% of Americans basically don’t believe in evolution was kind of scary and frightening... maybe in the past we’ve had this idea of manifest destiny...extraction from the natural environment.”

Students who expressed this theme had the common underlying idea that humans were not “extracted” from the nature and evolution, so they frequently described ways in which human behavior may have been influenced by evolutionary forces. For instance, one student highlighted survival as the foundation for human behavior in the following excerpt:

“I mean you learn that like, the foundational, like, driving force is this, you know, desire to survive, right? This natural selection. So I think that’s obviously what you learn through evolution, and then you see that it applies to humans. And I think then you can understand, you know, everyone’s working for this universal goal.”

Another excerpt exhibits a similar chain of reasoning—acknowledging that humans are animals, driven by survival and subject to the selective forces of evolution.

“It helps understand why people do the things they do. I think understanding humans on a fundamental level is super important just in terms of relations, and it helps, like, why we’re always warring with each other, because of competition for resources, and so it plays a huge role in that. So I think if everybody had a foundation in why humans are the way they are—like acknowledge that we’re animals too, which I think evolution also

helps with—I think it would make people think more critically about why we do the things we do and the way society interacts.”

Additionally, students acknowledged a genetic component to human behavior. Students often expressed the way in which individuals might utilize the idea of evolution-linked behaviors in humans to better cooperate and improve society. The first subcategory, “Understanding Others’ Views,” is characterized by the student’s expression of openness and understanding directed toward others, with concepts of evolution as the guiding basis for this openness. Both students who expressed this concept did so in the context of religious tolerance and understanding. One student said;

“I think it would definitely be positive if everyone learned evolution. I mean, I know for me, growing up, I grew up in a fairly religious family. And I was taught that evolution, you know, was just trying to disprove God. But from the time I can remember...I’ve always been fascinated about it and regardless wanted to learn about it. I think it’s really changed my viewpoints on life. I think it could hopefully help, you know, disagreements we have about religious values. And kind of realize that we’re all similar and just trying to find solace in life.”

This interviewee described a potential realization in individuals learning concepts of evolution—that all humanity is seeking the same comfort and have boundless similarities to one another. Another student concisely stated the following—that learning concepts of evolution would increase tolerance due to the expression of multiple views.

“I think religion would change too, and the intolerance of some people. I think there would be a lot more understanding among individuals.”

The second subcategory, “Understanding Self,” appeared once in the sample interviews—however, researchers found this was a distinct theme and determined it had the potential to occur more frequently within a larger sample size. The student who expressed this idea demonstrated a strong association between their own actions and traits and evolutionary concepts.

“And I think it’s always, you know, important for people to know their own history. Whether it be like an ancestor thing, or like, a really, really old ancestor thing. I think people would understand themselves a bit better.”

Through this statement, the student expressed a general notion of the importance of understanding one’s background. This idea is distinct from the “Sense of Self-Determination” code and does not necessarily include any mention of behavioral changes after gaining this knowledge.

Accepting and Understanding Change- Students also expressed—on a positive note—that learning concepts of evolution might alter an individual’s sense of self-determination to make them more accepting of change in their lives. The student utilizes acceptance of death in the context of nature to show how understanding the concepts and natural progression of mechanisms of change such as evolution might alleviate one’s difficulty in accepting change in all areas of life.

“Mr. Rogers died, I was just freaked out about death and my mom (the biologist that she is) would just tell me “it’s okay, because life will continue to exist even when you die, and even when I die!” And it wasn’t that comforting at all, but it gets you—you’re part of life that’s going to adapt and it’s going to go through change and it’s going to evolve.”

Indeed, students applied this idea of accepting change to occurrences beyond evolution and even beyond the field of science.

“Even just understanding the concepts that things change—I think it can apply to tons of things. It can apply to programs, it can apply to plans or homework—they change, they evolve, they adapt. I don’t know, I think it can be applied to a lot of things. It’s also just super cool because you can look at a plant and ask why it has purple flowers and learn that it’s the frequency of some specific DNA and that’s why it’s purple.”

This student used the frame of evolution to illustrate potential takeaways for individuals studying evolutionary theory.

Behavioral Codes

Codes were classified under “behavioral” when students described ways in which learning concepts of evolution may influence their behavior or the behaviors of others. This could involve changes in beliefs resulting in altered behavior or behavioral changes due to understanding of what motivates human actions.

Agency in Choosing What to Believe- The code “Agency in Choosing What to Believe” encapsulates a student’s feeling that learning about alternative positions and opinions other than their own provides the student with a choice in how to form their own beliefs. “Agency in Choosing What to Believe” appeared in two separate interviews for a total of seven references. While relatively few students mentioned this idea, the two interviewees who did expressed its potential significance and link to an individual’s upbringing and deep-seated beliefs. Students expressed a sense of empowerment tied to this ability to choose. One student commented in the following way:

“I really strongly believe that people should be taught a lot of different things—whether

that be evolution and buddhism or cath—yeah. Every different way, and then it all goes down to what they choose.”

As shown in this subject’s response, students often expressed that learning about another way of thinking or other position on evolution empowers them with the choice to believe it or not. Students also expressed that not learning the alternate position on evolution (other than their own) may prevent them from fully understanding or empathizing with both sides or from fully understanding the context of their knowledge. The following student commented that even those who are deeply set in their views can benefit through the agency to choose, as it would bring a “scientific,” or more objective, element to conversation.

“I feel like even if there were a select few people who had just become entrenched in the opposite view it would still at least bring like, a somewhat scientific side to the discussion for anyone who’s questioning it in the first place. At least that opportunity to discuss it, I think would be really valuable for anyone.”

Perceptions of Race Positive- Several students introduced the idea that, in their opinion, concepts of evolution could “explain away” the beliefs held by contemporary society on race due to the objective, simplified nature of these genetic factors. One student introduced the concept by addressing its simplicity and physical nature in the first segment of their interview:

“There was a whole incident with students throwing bananas at an African-American Greek organization, and stuff like that. So I feel like...learning evolution in that regard would kind of point out the fact that there’s no evolutionary difference in that regard, they’re just all at the same ‘level.’”

This student’s response exemplifies the occasional societal perception that certain races are on different tiers of humanity. In this student’s opinion, concepts of evolution break down

that idea by limiting the implications of race to the physical domain. Other students utilized more scientific detail to explain “race” itself. Another interviewee expressed the way the biological differences between people originating in other parts of the world, through mechanisms of evolution, can provide a simple explanation for racial differences independent of politics or social structure.

“I think the evolution of race is really interesting. And so how it has evolved from just melanocyte production into complete constructs and actions and behaviors. I think that would have changed. If like, they realized ‘oh, well you have evolved as a black person because you lived in a, like, sub-Sahara.’ Right? Where the sun is so powerful that you can’t—black skin would reflect more light and so they wouldn’t have something like a vitamin D toxicity. Versus white skin color may have, or did theoretically, evolved in northern countries. Norway, Finland, all those northern latitudes.”

And so that’s kind of where there’s less sun. and that’s kind of where I’m getting at with that. How that has genetically evolved and yet it has evolved a different and even social craziness. And how you see similarities of actions between races, or similarities of likes and dislikes, and, and similarities of interactions.”

Finally, the regions from these interviews coded under “Perceptions of Race Positive” showed an observable positive emphasis on the results. One student clearly expressed this effect by elaborating on the way this understanding could potentially enhance compassion between human beings.

“Maybe there would be less, like, prejudice, racism, that, like—hate...there would be just more understanding and maybe more interest in learning about our other friends on the planet and each other. So there would maybe be more compassion.”

Perceptions of Race Negative- None of the students in this interview pool mentioned a negative impact on perceptions of race. Although this is the antithetical concept to the “Perceptions of Race Positive” code, students will not necessarily express it in conjunction with or as frequently as that code. The two sides of the perceived impact do not necessitate the appearance of the other.

Although the code did not appear in our interviews, previous studies have demonstrated its potential to describe the way students are affected by learning concepts of evolution.

Sense of Self-Determination (Self-Regulatory Behavior, Sense of Control Over Life)- Students who expressed a potential impact of learning evolution on individuals’ sense of self-determination often expressed a shift in their sense of control over life. One student expressed a negative impact, stating that individuals might try to fight against mechanisms driving evolution. The student utilized the example of antibiotic resistance to illustrate humanity’s desire to control nature.

“If everyone had a solid grasp of evolution, they realize all the mechanisms driving it and all the concepts, I feel like some people may try and kind of...defeat it. And try and like, go against the grain, and...maybe that could be a good thing or a bad thing, in terms of like, drug resistance. People could just like, keep making these drugs to someday counteract the resistance, and there will be no resistance. But that could also be a bad thing because maybe that resistance is what is supposed to be in society in the first place, and we’re kind of interacting with that and messing with it.

Another student acknowledged the potential negative impact on sense of control as well as a potential positive impact. The student expressed that learning concepts of evolution early on might alleviate the fear of the unknown and desire to control nature.

“I think if you don’t believe in evolution, you might feel more in control, or you would be nervous to learn about evolution because it would make you feel less in control. But I think if they had learned about evolution from, like, their entire lives growing up, then I think they would—I don’t think they even would think about it as much. Like they wouldn’t be afraid to be not in control, they would just be how they are and feel fine learning about it. I don’t know. That’s just for me personally, so I don’t know how other people would be affected by it.”

Some students communicated an idea that if all individuals were required to learn concepts of evolution, individuals might be able to identify evolutionary roots of their thoughts and actions and perhaps empower change in their behaviors.

“It might not necessarily change the way you act, but it might help inform you about why you act that way. And you might be able to self-reflect a little bit. About like, “that’s a stupid way to act. That doesn’t apply anymore. I’m not getting chased by tigers anymore. I can stop that train of thinking because it’s not useful anymore,”

In this excerpt, the student outlines a potential thought process in which an individual might see evolutionary roots in their behaviors (such as avoiding predators) and alter the train of thought leading to those behaviors due to their understanding of evolutionary theory. Taking evolutionary theories then manipulating one’s behaviors comes again in another response:

“I think being able to see “no, we could really better ourselves,” could—I don’t want to say create evolution—but in a way, kind of create evolution. Like manipulate it, kind of. It would be really...a good thing to see.”

This student mentions a powerful implication of this sense of self-determination and control over one’s behavior due to understanding of its roots in evolution. Students with

responses coded under “Self-Regulatory Behavior” generally expressed that individuals might gain a positive ability to manipulate and assess their behavior due to learning concepts of evolution. Other students, however, identified negative consequences of this idea of manipulating evolution. Those consequences are identified below under “Social Darwinism.”

Selfishness- The “Selfishness” code appeared in only one interview in this sample. However, we believed the idea was strongly expressed by the interviewee and had the potential to appear more frequently in a larger sample size. The student expressed examples of how individuals utilize evolutionary concepts to validate themselves in the following segment:

“I think the positive ways would be...like, before you’d probably get less, you know, assholes going “survival of the fittest means survival of the strongest” and I should, you know, not care about people less strong than me. It’s like...screw you, buddy. You’d probably maybe get less of that, but also people are jerks. So, you know, maybe not.”

The student in this interview qualifies her statement with the idea that there are exceptions to the rule—she explained her view that most individuals studying evolution might feel less need to “get ahead” of individuals they perceive as weaker than they, but then they mention how some people might still use an evolutionary justification for selfish behavior.

Environmental Conscientiousness- While “Environmental Conscientiousness” appeared in only two interviews, students who utilized this language portrayed the concept as a potentially significant result of learning concepts of evolution. Students who expressed this idea spoke of a general sense they had that evolutionary theory might cause individuals to have a greater concern or appreciation for the environment. One student said:

“And like, I feel like we’d all have more consciousness before we act, and like, how our roles as humans are having negative ecological impacts. So like, from an environmental standpoint, I think it would be really beneficial.”

This excerpt shows the way the interviewed students thought individuals’ perspectives on ecology and environmental responsibility might shift because of education in evolution.

Affective Codes

Codes were classified under “affective” if students described ways in which learning concepts of evolution might affect the way individuals feel about themselves or the world around them. Students may have identified positive or negative affect in themselves or individuals because of ideas extrapolated from evolutionary concepts.

Shift in Morality (Social Darwinism)- A “Shift in Morality” due to individuals being required to learn concepts of evolution came up in relatively few interviews but with a great deal of thought and explanation. Individuals who assessed this topic in their interviews brought up ideas like population control, eugenics, and social Darwinism or a modern “survival of the fittest” attitude.

“I do know that certain aspects of and certain religious group—you know, they preach this morality and ethics of a certain type, depending. And I wonder if those types of things were lost in a society, if we would, for example, lose some aspect of this morality. But let’s say everybody understands that the population is increasing exponentially, and we have a huge problem with that. And everybody tries to correct that, and we have this giant societal overcorrection and you know, something really major happens. And I’m thinking just very broadly here. You know, do we have a moral obligation to not reproduce because we have this giant population that continues to increase?”

In this interview a student proposes the idea that if all individuals were required to learn concepts of evolution, certain groups (religious groups, in this example) might be lost or invalidated through the common acceptance of evolutionary theory. With those groups gone, the student postulates that there might be a loss of a certain morality within the population, leading individuals to engage in Darwinist behavior to preserve the species, morality aside.

Another excerpt brings eugenics and genetic manipulation into the mix. This was a common theme under “Shift in Morality,” as continued by the following excerpt:

“Do we have an obligation to—for lack of a better word, because of our scientific knowledge, do we have an obligation to have a “perfect” species, because we know...we could get rid of problems in the gene pool, that’s what I’m trying to say. We understand how. But is it an ethical thing? And if we think like robots, it makes sense to do certain things like that. But we think like humans and we have this obligation to take care of each other.”

This interview brought in another perspective that learning concepts of evolution might compel humanity to pursue the “perfect species,” knowing it has the technology to do so. Without predicting an outcome, students who mentioned this theme acknowledged a temptation or possibility for survivalist tactics to raise the fitness of the species at the expense of some of its individuals.

Sense of Spirituality Negative- Students brought up the potential effect of learning concepts of evolution on spirituality in two distinct ways. The first was in a primarily negative context, proposing a negative impact. One key component of the proposed negative affect was a potential for concepts of evolution to uproot deeply held beliefs. One student introduces the concept through this excerpt:

“It definitely can undermine a lot of people’s religious beliefs if they believe in, you know, the really strict literal translations of certain texts, which can be pretty awful for them. At least, you know, it kind of uproots an entire belief system.”

Students tended to provide anecdotal evidence for this prediction, as well. Another student in the following interview gave an example of an impact observed at home.

“I think that is really hard to say, because I think that in areas still coming from a weird religious background—‘cause the whole “grandfather is a crazy pastor” is just the tip of that iceberg—I probably spent hours and hours and hours and hours just trying to get my grandfather to accept microevolution as something that happens. And I think that if-I think that people who are less strong-willed than me...which isn’t...in the great scheme of things isn’t saying all that much. I mean, I think I’m a fairly strong-willed person but that’s beside the point. I think if you take a 13y year old kid, rural Georgia, who was brought up in a strict Baptist household—if you start teaching him evolution and telling him that what he’s believed his entire life, and then low-key indoctrinated in isn’t entirely true, I think you’re gonna get a lot of lash back. Not only from that kid, but from his parents and teachers are gonna get backlash, the other kids in the class are gonna get backlash, it’s gonna---it’s hard to convince people that their foundation of thinking isn’t entirely true. So I think in some areas it would really be helpful. So if you take a super urban area, I think there’s gonna be a lot less backlash. But when you’re getting a little bit more rural and a little bit more religious, it will really drive people against evolution.”

As demonstrated in the above excerpts, several students expressed a concern that learning concepts of evolution might have a negative effect on spirituality through the uprooting of previously held beliefs, which individuals might perceive as contrary to evolution. Another facet

of negative impact on spirituality students described was a conflict with the “big why” idea within individuals.

“And be able to think about future and past. And I think that allows us to try and conceptualize why we’re here, and so I think a lot of people need reassurance that there’s something more than this. Other than just taking in what this is. So I think evolution has had an effect on that just because of our ability to conceptualize and try and explain away everything.”

Some students whose responses were coded under this category expressed that learning concepts of evolution might conflict with the spiritual idea of a greater purpose in life, or “the big why,” through quantifying and explaining mechanisms previously thought to be divine or mystical. Students perceived this as a potentially harmful or negative consequence of learning concepts of evolution.

Sense of Spirituality Positive- Although most students who mentioned spirituality in the context of requiring all individuals to learn concepts of evolution held a negative connotation, some students postulated positive impacts on spirituality as a result of learning evolutionary theory. One student broached the subject through citing the personal benefit they felt when a teacher explained Evolution in conjunction with Christian ideas. This student therefore saw a positive connection between understanding both evolution and one’s own spiritual doctrine.

“I feel like there might be less argument. Because when you’re studying evolution, there’s not anything that says, “god doesn’t exist,” that’s not saying that, you know, any of the stuff in the bible’s not true or any of those things. It’s just saying that things happen that make populations change, whether it’s good or bad, and it’s—you know—it’s a real thing that’s happening and I feel like if somebody who was really religious was

required to learn about it that they might be more open to the scientific community and not so shut down about the whole subject.”

Indeed, another student suggested that evolutionary theory and religious ideas need not be portrayed as contradictory. These students commonly suggested that learning concepts of evolution could have a positive effect on an individual’s spirituality, depending mostly on the presentation and delivery of the information.

Cooperation and Kindness- Students’ responses were coded under “Cooperation and Kindness” if they demonstrated ideas of communicating helpful knowledge or cooperating for the sake of community wellbeing. Students under this code emphasized impacts of learning evolution as positive for society over the individual. Students frequently described ways that learning concepts of evolution might expose ways in which human needs are similar across all or most human beings. One student summarized their ideas in the following way;

“Having all the same needs like we need food, water, and shelter to survive. Basic resources to be healthy. And I think for some people to be able to see that, they would be able to understand that some people are just struggling to have that and they would empathize with them saying—hey, I understand that you have these needs too...”

Some students also thought that, in a very literal sense, understanding concepts of evolution might highlight the way humans can benefit from cooperation in the form of shared knowledge and progress. These excerpts highlight ways in which humans might physically benefit from cooperation and kindness, enhancing their fitness and survival. The students quoted here expressed that learning evolution might benefit humankind in such a way.

“Evolution betters each other because we’ll think of “hey, what’s the best way to create reproductive success?” by helping each other. By eating healthier foods. By exercising

more. Not smoking. You know, tricks like that. That benefits each other as a whole if you learn how to work with each other and keep that same kind of mentality going. Whereas if you don't work with each other, I mean yeah, they can be explored, they can go off into exploration and find that exercising is good for you, or eating healthy foods is good for you, but the other person might not. So I think that kind of plays a big role in why it's actually beneficial to learn evolution, because it'll teach people to learn how to be more congruent than divergent, I guess."

These examples highlight potential survival benefits that students believe may come from learning concepts of evolution. Some students also approached the idea of cooperative and altruistic thinking through the lens of intellectual cooperation, citing a culturally significant benefit from learning the theory of evolution on the cooperative nature of society.

"There would be more understanding. Maybe they would realize how everything is kind of interconnected and they would be more willing to, like, I guess...help others, understand others, do things for others, and not just like, the human race, but like...other creatures and organisms and stuff on the planet."

Both students cited here mention openness, understanding, and a sense of care for human and nonhuman organisms. Overall, students in this study tended to express that learning concepts of evolution might enhance cooperation and kindness across humanity.

Feeling Connected (Appreciation, Humility)- One of the fundamental tenets of the "Feeling Connected" code included exposure to and connections between individuals of all species due to understanding of behaviors and origins. One student exemplified this idea by describing how exposure to concepts of evolution might cause one to feel appreciation for the complexities of nature.

“I think it would change society for sure. I think that it would be probably for the better in a lot of ways because just the nature of studying evolution exposes you to, I think, the incredible beauty and intricacies of species in the natural world, and like just having that exposure would lend a lot of gratitude and appreciation to where we are today and how amazing those species are, you know, that are being threatened.”

This student’s excerpt demonstrates the feeling of connectedness to the natural world that several other students mentioned in altered forms. Other students described an increase in connectedness and appreciation through a sort of humility—stating that studying evolution might inform humans of their place within nature, thus generating an increased appreciation for it and connectedness to it.

“I’m also taking an ethics class talking about—well, it’s called “environmental literature,” and I guess one of the big themes was Christianity’s influence on society. And it’s pretty controversial but Christianity kind of has this anthropocentric view of the world, and through learning evolution I think you get the idea that humans are not superior to other things—like, other beings and creatures. So once you get that past your head I think there’d be a bigger appreciation for the rest of the world.”

Students who expressed ideas that fell under “Feeling Connected” described ways in which humans might see themselves as more a part of nature than as its masters.

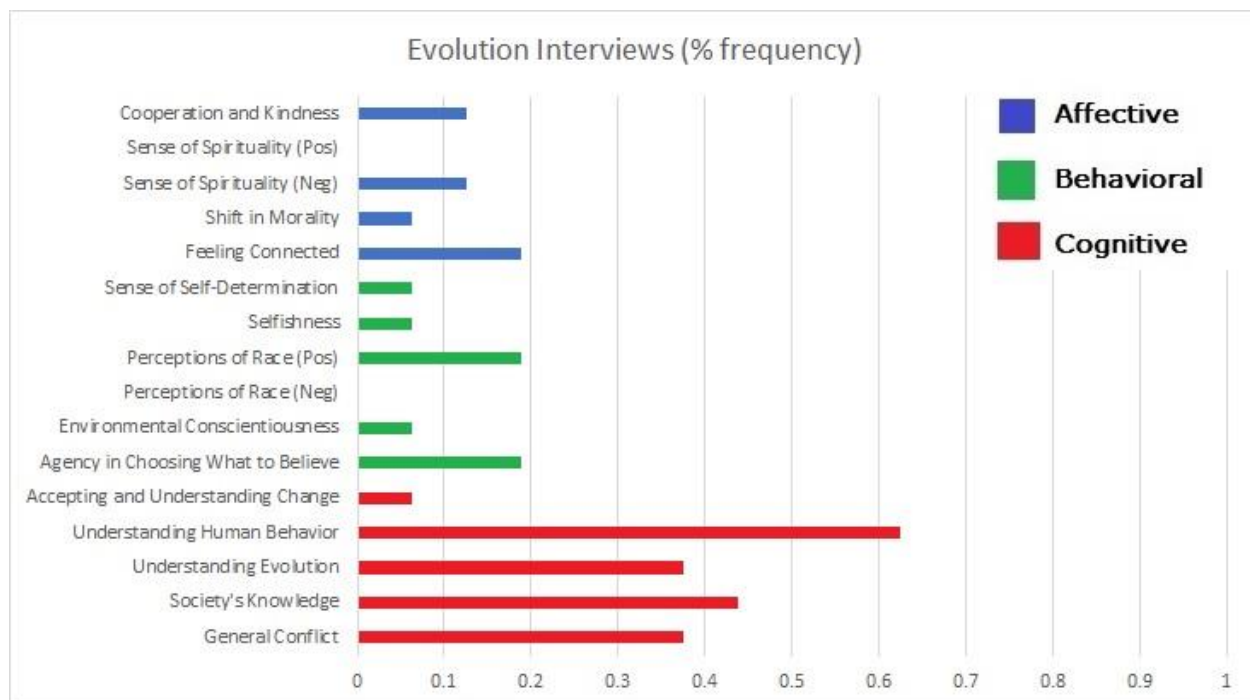
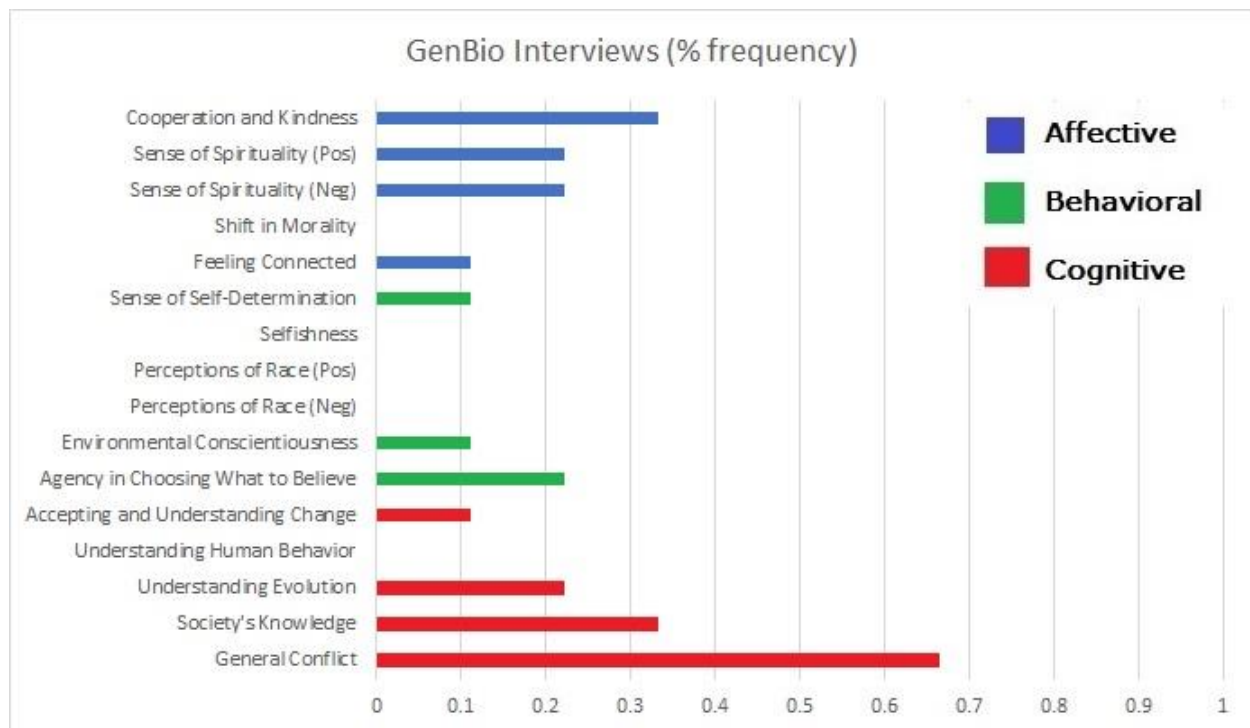


Table 3: A comparison of the two classes using percent of interviews in which a code arises. Percentage was used because this study collected 9 interviews from Gen Bio and 16 interviews from Evolution

Due to the notion that students may react differently to concepts of evolution depending on how much interest they display in the topic, comparative graphs comparing the code

frequencies in samples from each class were generated. Although the distributions are slightly different, there is no apparent significant difference in how students addressed affective, behavioral, and cognitive ideas. However, differences were observed in the two classes regarding their discussion of topics regarding human evolution. Human evolution is a topic frequently excluded from the theory of evolution by individuals who selectively accept the theory based on their own beliefs (BouJaoude *et al.*, 2011). Students in the Evolution class frequently responded under the codes “Understanding Human Behavior” and “Perceptions of Race,” whereas General Biology students did not broach these topics. Since General Biology students are often not biology majors, and several of them self-identified as religious or not having been taught evolution in high school or prior, this finding is interesting. There are several potential reasons General Biology students would not mention this topic. One may be that the class talked about it less, since evolution occupied its own unit and the curriculum included only so much time to discuss the concept. Another reason may be that, since conflict surrounding concepts of evolution often include human evolution, students were choosing to talk about less controversial topics given their diverse class demographic. Finally, General Biology students might be selectively accepting evolution, but excluding its human applications. These could be topics of investigation in future studies.

Conclusions

Although prior studies conducted on generalized populations, such as Brem’s 2003 study, yielded mostly negative results and conflicting ideas regarding concepts of evolution, the populations used for this thesis do not follow the trend. One may expect from prior studies on more generalized populations that students with less affinity for the concept of evolution may not

express the same affective, behavioral, and cognitive gains as peers with greater interest and exposure in the topic. Not only is there a great frequency of codes with a positive connotation, there is also a substantial portion of these populations which applied concepts of evolution beyond the cognitive dimension, citing positive outcomes for society in both behavior and affective domains.

Additionally, based on prior research some difference in perceived impacts between General Biology students and Ecology students was expected. Results yield suggestions that they may not be. Although some students self-identified as coming from religious backgrounds, educational backgrounds wherein evolution was not commonly accepted, and households in which evolutionary theory was disputed, and had varying levels of interest in evolution or biology in general, their response content did not differ significantly. Furthermore, all populations mentioned positive impacts on society. It appears, based on the frequency of positive codes in some of the student interviews, that students maintain positive attitudes about learning evolution regardless of their interests depending on how the subject is taught. Students of varying backgrounds seem open to discussion regarding behavioral and affective gains because of learning concepts of evolution. Students in these populations had much more to say about potential impacts of learning evolution than negative perceptions and conflict. Positive ideas like those expressed by students in this study could potentially be discussed in a classroom setting, which might expose some positive societal implications of the concept. Could students' application of concepts of evolution to behavioral and affective ideas in their lives hold the key to acceptance of evolution in other populations?

Overall, students in this unique population very frequently acknowledged that learning concepts of evolution contributes to positive cognitive gains in society. Students also recognized

with some frequency that learning concepts of evolution may have (mostly) positive behavioral and affective impacts on individuals. Perhaps we can engage instructors of all disciplines in discussion regarding the behavioral and affective implications of learning evolution for society and how this may influence students' engagement and contribute to their acceptance and rationalizations of conflict.

Works Cited

- Ashong, C. (2016, February 20). Brazilian and Nigerian International Students' Conceptions of Learning in Higher Education. *Journal of International Students*. 7:2, 163-187.
- BouJaoude, S. and Asghar, A., Wiles, J.R., Jaber, L., Saredidine, D., and Alters, B. (2011). Biology Professors' and Teachers' Positions Regarding Biological Evolution and Evolution Education in a Middle Eastern Society. *International Journal of Science Education*. 33:7, 979-1000, doi: 10.1080/09500693.2010.489124
- Brem, S. K., Ranney, M., and Schindel, J. (2003, January 24). Perceived Consequences of Evolution: College Students Perceive Negative Personal and Social Impact in Evolutionary Theory. *Science Education*. 87:2, 181-206. doi: 10.1002/sce.10105/pdf
- Glaze, A. L., and Goldston, M. J. (2015, April 15). U.S. Science Teaching and Learning of Evolution: A Critical Review of the Literature 2000–2014. *Science Education*. 99:3, 500-518. doi: 10.1002/sce.21158/abstract
- Hokayem, H., and BouJaoude, S. (2008, March 04). College Students' Perceptions of the Theory of Evolution. *Journal of Research in Science Teaching*. 45:4, 395-419. doi: 10.1002/tea.20233/pdf
- Ingram, E. L. and Nelson, C. E. (2006), Relationship Between Achievement and Students' Acceptance of Evolution or Creation in an Upper-Level Evolution Course. *Journal of Research in Science Teaching*. 43:1, 7–24. doi:10.1002/tea.20093
- Konnemann, C., Asshoff, R., and Hammann, M. (2016, March 16). Insights Into the Diversity of Attitudes Concerning Evolution and Creation: A Multidimensional Approach. *Science Education*. 100:4, 673-705. doi:10.1002/sce.21226/abstract

- Larkin, D.B., Perry-Ryder, G.M. (2015, March 02). Without the Light of Evolution: A Case Study of Resistance and Avoidance in Learning to Teach High School Biology. *Science Education*. 99:3, 549-576. doi: 10.1002/sce.21149
- National Academy of Sciences. 1999. Science and Creationism: A View from the National Academy of Sciences, Second Edition. Washington, DC: The National Academies Press. doi:10.17226/6024.
- Sanders, M., and Ngxola, N. (2009). Addressing teachers' concerns about teaching evolution. *Journal of Biological Education (Society of Biology)*. 43:3, 121–128.
Doi: 10.1080/00219266.2009.9656166
- Sanders, M. and Makotsa, D. (2016). The Possible Influence of Curriculum Statements and Textbooks on Misconceptions: The Case of Evolution. *Education as Change*. 20:1, 216.
- Sinatra, G. M., Southerland, S. A., McConaughy, F. and Demastes, J. W. (2003), Intentions and Beliefs in Students' Understanding and Acceptance of Biological Evolution. *Journal of Research in Science Teaching*. 40: 510–528. doi:10.1002/tea.10087