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College students' use of science content during socioscientific issues negotiation: Impact of evolution understanding and acceptance

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College Students' Use of Science Content During Socioscientific Issues Negotiation: Impact of Evolution Understanding and Acceptance

by

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This work is dedicated to:

My Dad, Ray Fowler, for instilling in me the knowledge that I can accomplish whatever I set out to do, no matter how long it takes. Dad, I wish you were here to share this moment with me.

My Mom, Chris Fowler, letting me be myself and for teaching me to have an open mind.

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College Students' Use of Science Content During Socioscientific Issues Negotiation: Impact of Evolution Understanding and Acceptance

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ABSTRACT

The purpose of this study was to explore the evolution science content used during college students' negotiation of biology-based socioscientific issues (SSI) and examine how it related to students' conceptual understanding and acceptance of biological evolution. Specific research questions were, (1a) what specific evolutionary science content do college students evoke during SSI negotiation, (1b) what is the depth of the evolutionary science content reflected in college students' SSI negotiation, and (2) what is the nature of the interaction between evolution understanding and evolution acceptance as they relate to depth of use of evolution content during SSI negotiation? The Socioscientific Issues Questionnaire (SSI-Q) was developed using inductive data analysis to examine science content use and to develop a rubric for measuring depth of evolutionary science content use during SSI negotiation. Sixty upper level undergraduate biology and non-biology majors completed the SSI-Q and also the Conceptual Inventory of Natural Selection (CINS: Anderson, Fisher, & Norman, 2002) to measure evolution understanding and the Measure of Acceptance of the Theory of Evolution (MATE: Rutledge & Warden, 1999) to measure evolution acceptance. A multiple regression analysis tested for interaction effects between the predictor variables, evolution understanding and evolution acceptance. Results indicate that college students primarily

use science concepts related to evolution to negotiate biology-based SSI: variation in a population, inheritance of traits, differential success, and change through time. The hypothesis that the extent of one's acceptance of evolution is a mitigating factor in how evolution content is evoked during SSI negotiation was supported by the data. This was seen in that evolution was the predominant science content used by participants for each of the three SSI scenarios used in this study and used consistently throughout the three SSI scenarios. In addition to its potential to assess aspects of argumentation, a modification of the SSI-Q could be used for further study about students' misconceptions about evolution or scientific literacy, if it is defined as one's tendency to utilize science content during a decision-making process within an SSI context.

Chapter 1

Introduction

The purpose of this study was to explore the evolution science content used during college students' negotiation of biology-based socioscientific issues (SSI) and examine how it related to students' conceptual understanding and acceptance of biological evolution. The knowledge gained from this study has the capacity to enhance our understanding of the role science content plays during SSI negotiation. This in turn, could benefit the SSI movement by providing greater insight in how SSI are negotiated and identifying roles played by conceptual understanding and acceptance of evolution. This could ultimately add to the literature base on meaningful ways to facilitate scientific literacy for all people.

In this chapter, connections between evolutionary theory and SSI that focus on biological issues are made, including a discussion of the importance of evolution understanding and its connections to biologically-centered SSI research. Reasons why evolution content may or may not be addressed during contextually-based SSI negotiation are discussed and connections made between the use of science content and SSI negotiation. Finally, the research questions, their rationales and the significance of this study are discussed.

Evolution: Connections to SSI

Today's students are constantly exposed to scientific findings, much of it from the popular media, and an understanding of science is necessary in order to make thoroughly informed decisions about a myriad of important issues. Examples range from whether to eat genetically modified foods, to issues such as the political, economic, and environmental effects of off-shore drilling. These types of issues are termed SSI due to their societal and moral connections to science (Sadler & Zeidler, 2005; Zeidler & Sadler, 2008a). Because of the impact science has on students and society, it has been a longstanding goal of science education reform to achieve a scientifically literate population that consistently makes informed decisions (AAAS, 1990; NRC, 1996). More recently, Roberts (2007) has defined scientific literacy to include two general "visions": Vision I stresses the aspects of science content as they relate to goals within science, and Vision II is a broader functional approach. It has been argued that, with respect to Vision II, teaching within an SSI framework can enhance scientific literacy (Zeidler, 2007). Due to this, the SSI movement is rapidly becoming widespread in science education across the globe.

The socioscientific movement focuses on fostering students' thinking and discourse about the interaction between science and society while considering any moral and ethical issues that arise (Zeidler et al., 2005, Zeidler & Sadler, 2008a). In the words of Zeidler, Walker, Ackett, and Simmons (2002): "Socioscientific issues then, is a broader term that subsumes all that STS has to offer, while also considering the ethical dimensions of science, the moral reasoning of a child, and the emotional development of the student" (p. 344).

In addition to the SSI movement's broad connection to scientific literacy, SSI have proven to be versatile tools for studying a variety of science education topics including nature of science (Abd-El-Khalick, 2003; Sadler, Chambers, & Zeidler, 2004; Zeidler, Walker, Ackett, & Simmons, 2002), argumentation (Dawson & Venville, 2009; Zeidler, Osborne, Erduran, Simon, & Monk, 2003; Zohar & Nemet, 2002), informal reasoning (Dawson & Venville, 2009; Sadler & Zeidler, 2005), moral reasoning (Pedretti, 1999; Hogan, 2002), moral sensitivity (Clarkeburn, 2002; Fowler, Zeidler & Sadler, 2009; Sadler, 2004), teacher pedagogy (Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006), content knowledge (Sadler & Donnelly, 2006; Sadler & Fowler, 2006) and reflective judgment (Zeidler, Sadler, Callahan, & Applebaum, 2009). Furthermore, it has been argued quite convincingly that using SSI as a context in science education can also contribute to students' character education (Zeidler & Sadler, 2008b).

Evolution is not in itself a SSI because it lacks certain defining characteristics. Specifically, evolution is the biological change in populations of organisms over time and is explained by the scientific theory of natural selection. It is not an ill-structured controversial dilemma within the scientific community. However, there is a connection between evolution and SSI negotiation. For example, while examining informal reasoning with genetic engineering SSI scenarios, it was found that biology majors' understanding of evolution had a strong influence on their decision-making (Sadler 2005; Sadler & Zeidler, 2005; Sadler & Zeidler, 2004). The types of SSI scenarios that may involve an understanding of evolution science content include those related to the biological sciences such as cloning, stem cell research, gene therapy, and biodiversity. These types of issues are used in numerous studies related to decision-making (see

Dawson & Venville, 2009; Kolstø et al., 2006; Sadler & Fowler, 2006; Zohar & Nemet, 2002 for examples). If understanding of evolution in the context of commonly used SSI influences SSI negotiation, then it will also influence conclusions made from research that studies SSI negotiation in those contexts. Thus, the SSI movement would benefit from further studies on the relationship between understanding and acceptance of evolution and biology-based SSI.

The Evolution Polemic

In order to comprehend the connection between the understanding of evolution and biologically-based SSI, we need to explore reasons why students may not utilize evolutionary content knowledge during SSI negotiation. Three basic reasons why this may not occur are: (1) students do not learn the content; (2) they don't internalize what they have learned; and (3) they aren't taught how to use science content when making decisions. This section addresses the above three reasons with discussions of how the controversial nature of teaching evolution can prevent it from existing in state science standards; teachers' discomfort with teaching evolution; and the informal reasoning and argumentation involved in SSI negotiation.

Controversy in Our Nation

One reason why students may not utilize evolutionary content knowledge during SSI negotiation is because they may not have learned about it in school or in other contexts. Whether or not to teach evolution in school is a source of much debate, as noted by a history of courtroom battles. This controversy has its official origins in March of

1925 when Tennessee passed the Butler Act. Under this act, any pubic school or university that received funds from the state was prohibited from teaching any theory that "denies the story of the Divine Creation of man as taught in the Bible, and to teach instead that man has descended from a lower order of animals" (Tenn. HB 185, 1925). In response to this act, the ACLU issued a press announcement stating that it was willing to support any teacher who challenged the law's constitutionality. At the urging of his peers and with a desire to challenge the law, John Scopes was arrested in May of 1925 for discussing evolution with his biology class. After a trial with much media attention, Scopes was ultimately convicted and fined $100. The conviction was overturned two years later due to a technicality. The state of Mississippi was the next state to pass an anti-evolution law in 1926. Arkansas became the third and final state in 1928 (Linder, 2002).

Anti-evolution laws were repealed in the late 1960s, and in 1987 the United States Supreme Court ruled that requiring public school teachers to teach creation-science is an establishment of religion and therefore illegal (Edwards, governor of Louisiana vs. Aguillard et al., 482 U.S. 578, 1987). In 1994 a teacher attempted to sue his district, claiming that the district's requirement that he teach evolution violated his First Amendment right to free exercise of religion. The appeals court upheld the finding that the school district had merely required a science teacher to teach a scientific theory in biology class. (John E. Peloza v. Capistrano Unified School District, 37 F. 3rd 517, 194). Many states, such as Kansas and Kentucky, responded by removing or limiting the word evolution from their curriculums.

In response to the above mentioned court rulings, anti-evolutionists refined their strategy by attempting to remake creationism into scientific theory rather than a religious belief. They call this pseudoscientific theory intelligent design (Johnson, 1991). Intelligent design asserts that while some organisms may be under the influence of natural selection (i.e., microevolution), life and its various species were created by an "intelligent designer." In an attempt to lend scientific credence to intelligent design, it is based on the notion of "irreducible complexity," which states that certain structures within living things are too complex to have evolved gradually (Behe, 1996). However, a 2005 U.S. District Court ruling in Pennsylvania stated that intelligent design is a form of religion and not science (Kitzmiller vs. Dover Area School District, 04cv2688, 2005). Since then, anti-evolutionists changed tactics again and have been attempting to pass "academic freedom" bills which would allow teachers to present alternate "theories" of evolution in their biology classes. Thus far, such legislation has been attempted and failed in Alabama, Florida, Michigan, Missouri, and South Carolina, but has passed in Louisiana.

Teachers' Discomfort with Evolution

Even when the teaching of evolution is mandated by state standards, it still may not be effectively taught. Like many other members of the population, some science teachers experience discordance between teaching evolution and their own personal beliefs. Along with discordance come feelings of anxiety and a general mistrust of science, creating a barrier to learning evolutionary theory and to scientific literacy in general. It must be very difficult, at best, to effectively teach a subject one is not comfortable with, and this raises an important point for science educators. Though many science teachers have no problem with teaching evolution to their students, it is critical to keep in mind that at least 16% of biology teachers nationwide claim that it conflicts with their creationist beliefs (Berkman, Pacheco, & Plutzer, 2008). This may be a large contributing factor as to why one study finds that 20% of Florida biology teachers are uncomfortable with teaching evolution and its emphasis in the newly revised Florida science standards (Fowler & Meisels, in press).

Unease with teaching may be a negative experience on an emotional level for the teacher, but even more importantly, a teacher's poor attitude or discomfort can adversely impact students' learning in a number of ways. Many teachers either avoid teaching evolution altogether or decrease the amount of instructional time spent teaching it (Moore, 2008). As explained more fully in Chapter Two, evolution is the unifying theory of biology, and neglecting evolution instruction may lead to an incomplete understanding of biology and consequently hamper informed decision-making about a variety of issues. Perhaps even more damaging to students' learning is that some teachers teach evolution, but in doing so, perpetuate their inaccurate views on nature of science (Moore, 2008). For example, many will tell their students that evolution is "just a theory and not a proven fact" (Fowler & Meisels, in press). This leads students to believe that scientific theories are merely guesses and undermines the meaning of a scientific theory and the deep amount of evidence that supports it. Still others, including those in public schools, will include creationism or intelligent design when teaching evolution and present it as an alternate theory (Moore, 2008). Doing this does a disservice to students because it encourages them to blur the line between evidence-based reasoning and faith.

When considering reasons why teachers are uncomfortable with teaching evolution, conflict with religious beliefs is clearly a major reason (Aguillard, 1999; Griffith & Brem, 2004; Moore, 2008; Weld & McNew, 1999; Zimmerman, 1987). However, there is another, often overlooked reason why teachers are uncomfortable with teaching evolution: pressures from the community, administrators, colleagues, parents and students (Moore, 2001). Even teachers who accept the scientific validity of evolution and rank it as very important to understanding biology and nature of science may refrain from emphasizing it in their classes out of pressure from others and, in some cases, fear of losing their jobs (Fowler & Meisels, in press). Thus, both political implications and teachers' lack of acceptance of the scientific validity of evolution are impediments to teaching it in the science classroom.

Internalization of Evolution Content

Negotiation of SSI involves coming to a decision about or developing a position regarding a SSI. The decision-making process is influenced by cognitive, psychological, and social factors (Gordon, 1996). In this context, cognitive factors include reasoning and perception. Psychological factors include personality traits, such as identity, tendency to take risks, and effects from traumatic prior events, and societal factors include ethnicity, religion, and socioeconomic status. Due to their ill-structured nature, SSI are associated with an informal reasoning process rather than the formal, deductive reasoning process because they use evidence to create a conclusion or come to a decision. Kuhn (1991) and Means and Voss (1996) assert that issues which invoke informal reasoning are ones that require an individual to support a claim by building an argument. For that reason, measures of informal reasoning quality often center on the arguments used during the informal reasoning process (Kolstø, 2006; Means & Voss, 1996). In this case, arguments are defined as assertions accompanied by justification (Kuhn, 1991; Toulmin, 1958) and have often been used to examine argumentation quality (Driver, Newton, & Osborne, 2000; Erduran, Simon, & Osborne, 2004; Sadler & Fowler, 2006). A deeper examination of prior informal reasoning research in an SSI context will be made in Chapter 2.

It seems intuitive to think that if people are informed about content, then they will use it to make evidence-based decisions. Anyone who has served on a jury knows that they are told to consider the evidence and base their verdict solely on that. The jury's interpretation of the evidence presented in court deems a person guilty or innocent; yet there are instances of juries that cannot come to a decision even though all jurors were presented with the same evidence in court, resulting in a hung jury (see United States vs. Shirley Cunningham and William Gallion, 2008, for an example). This is because prior knowledge and beliefs affect how people interpret evidence laid before them.

Kolstø, Bungum, Arnesan, Isnes, Kristensen, et al. (2006) note that SSI decision-making involves scientific, political, and ethical dimensions. Science content or "facts" are only part of the equation when considering factors that influence decision-making. Another part of the equation consists of affective factors, such as concern for the way a particular decision may affect others or whether or not it is morally or ethically the "right" decision to make. Stated another way, in addition to using science content knowledge to support an argument and weigh a decision, people also consider how the issue will impact themselves and/or society and how that connects with their values (Sadler & Zeidler, 2005).

When studying SSI negotiation, it is important to examine factors other than science content knowledge that may play a role in the decision-making process. How a person interprets evidence is affected by prior knowledge and beliefs. It is not sufficient to merely show someone evidence; a person must incorporate that evidence into his or her preexisting knowledge base so that it can be applied to present and future situations. This is because once one is outside the context of a classroom, one may not think to consider science content when confronted with socioscientific situations. While this could be due to a lack of specific instruction on how to integrate content knowledge in the decision-making process, it may not be the only reason people separate their content knowledge from their everyday lives and decisions; emotive aspects and beliefs can also play a role. Chinn and Samarapungavan (2001) assert that though students can answer questions correctly on a test or tell a teacher what they think the teacher wants to hear, that does not indicate that students give validity to or have internalized the content. Unfortunately, the disparity often goes unnoticed by teachers and researchers and can result in a false sense of success with teaching. Additional support for the notion that students do not always consider scientific merit to be the convincing factor when reasoning through an SSI situation comes from Sadler, Chambers, and Zeidler (2004). Their study showed that students' decisions were based on personal relevance, information quality, and previous personal beliefs where an article that most closely aligned with their personal beliefs was deemed most convincing.

Connected to core beliefs and personal experiences are a person's moral considerations. In a study of informal reasoning patterns in a socioscientific context, Sadler and Zeidler (2003) gave special attention to how moral considerations play a role in patterns of informal reasoning. Their study found that there are three distinct patterns involved in informal reasoning: rationalistic, emotive, and intuitive. The rationalistic pattern is strictly cognitive wherein participants use reason and logic to support their position. The other two patterns, emotive and intuitive, are affective. With intuitive reasoning, students resolved scenarios based on their initial thought or feelings. Emotive reasoning, though containing some rational aspects, also displays empathy and sympathy towards others. Also noted was that many students used each of the three patterns in varying combinations and degrees in order to support their position on the socioscientific topics and that students' moral considerations were strongly embedded throughout the informal reasoning process.

At this point, one may wonder what beliefs and morals have to do with understanding evolution. After all, evolution is a scientific theory supported by a preponderance of data; it is not a faith-based belief system. However, as discussed above, a person’s core beliefs affect how a person internalizes science content. Many people view evolution as contradictory to their core religious beliefs and therefore do not accept evolutionary theory. In other words, there is a decision-making process involved with whether or not to accept the scientific validity of evolution, and, for some people, religion is weighed as a factor in that decision. Morals do not equate to religious beliefs in that many nonreligious or atheistic people exhibit strong moral reasoning and many religious people do not; however, most major religions do attempt to foster certain moral values. This makes it possible, in the instances of those who hold religious views, that whether or not a concept conflicts with core religious beliefs is an affective factor that affects decision-making. If one's strongly held religious beliefs conflict with the theory of evolution, the subsequent decision may be to reject evolution.

These studies point to the need for a solid content component in a science curriculum; however, science content has always been taught in the classroom, and people still may fail to draw upon content knowledge or scientific evidence when making decisions that should be informed by science (Perkins, Faraday, & Bushey, 1991). This implies that scientific content knowledge, while necessary, is an insufficient condition for reasoning out informed decisions in a socioscientific context. This could be explained by the role that prior beliefs play in learning content, as in the case where religious beliefs conflict with scientific evidence supporting evolutionary theory. In that case, a person's beliefs become a barrier to accepting scientific evidence. With respect to evolution, this belief barrier is well documented, and the leading cause is a perceived conflict with certain religious beliefs, specifically creationism (Pew Forum on Religion and Public Life, 2005).

Science and religion are two different epistemological systems of knowledge, one evidence-driven and the other faith-driven. While many people are able to demonstrate knowledge of evolution, it does not mean that those same people have internalized it into their personal belief systems and will use it in a decision-making processes. In other words, a person may have an understanding of evolution well enough to pass an exam or even an entire course, but this does not mean that the same person accepts evolution as a valid scientific theory.

Evidence-Based Decision-Making and Justification

Studies involving quality of arguments used in making a decision for or against an issue also show a relationship between quality of argumentation (i.e., use of facts to justify claims) and content knowledge in that students with less content knowledge demonstrate poorer argumentation skills in a SSI context (Sadler & Fowler, 2006; Sadler & Donnelly, 2006). However, studies also show that even when a person has considerable content knowledge, it is not always utilized in the decision-making process (Hogan, 2002; Zohar & Nemet, 2002). There is an implication that students must be explicitly taught to consider content knowledge when confronted with socioscientific issues. Furthermore, it has been shown that students do become more skilled with all aspects of arguing for or against a decision when argumentation is explicitly taught (Osborne, Erduran, & Simon, 2004).

Studies also show that people may attempt to apply science content knowledge but do so with less skill than educators hope for. For example, while students are largely epistemically dependent on experts (Norris, 1995), they do try to assess the soundness of justifications proposed for knowledge claims; however, they rarely crosscheck references (Kolstø et al., 2006). Students have a tendency to trust an article found in the popular media as long as it has the appearance of being trustworthy. Kolstø et al. (2006) demonstrated this in a study of preservice science teachers who judged the trustworthiness of Internet articles that they selected. Criteria used were quality of references, consistency of argumentation, face validity of argumentation, and compatibility with their own subject knowledge. Students also considered the possible underlying interest, personal value-related qualities, the author's or expert's competence, level of professional recognition, and level of expert agreement. Another study that points to students' lack of skill in applying science in argumentation shows that students will cite data, but not claims and often fail to articulate how specific data relate to particular claims (Sandoval & Millwood, 2005).

Not only are people less skilled at assessing knowledge claims, they themselves either knowingly or unknowingly may give faulty claims. There are times when students attempt to apply incorrect science content knowledge when negotiating SSI. For example, the Sadler (2005) study described earlier in this chapter found that while some students alluded to evolutionary perspectives when considering a genetic engineering issue, many of them had misconceptions about evolution.

A person must be shown how to incorporate scientific evidence into his or her preexisting knowledge base so that it can be applied to present and future situations. For example, Zohar and Nemet (2002) showed that when students are explicitly taught argumentation skills in the context of human genetic dilemmas, students were more apt to draw upon science content when formulating their arguments. However, students who were exposed only to the science content did not gain an increase in their argumentation skills. In a study of groups of 8th grade students' ideas and reasoning used to make a collaborative environmental management decision, Hogan (2002) found that across groups, students touched on themes scientists use to make similar decisions, and most focused narrowly on particular themes. Hogan asserts the need for fostering students' content knowledge *and* thinking skills for decision-making about complex environmental issues. With respect to evolution, even when taught evidence-based reasoning, students who do not accept or understand evolution may not use its content during SSI negotiation.

Research Questions and Rationale

RQ 1

As described earlier, a scientifically literate person is one who uses science content knowledge to make informed decisions, either personally or socially, about topics or issues that have a connection with science. However, because factors other than science content play a role in decision-making, this raises the question about the extent to which people use their content knowledge when making decisions. In order to answer this question, first it is necessary to characterize specific science content involved in various SSI contexts in terms of the types or taxonomies of content as well as the depth of content use. For that reason, the first set of research questions are:

1A. What specific evolutionary science content do college students evoke during SSI negotiation?

1B. What is the depth of the evolutionary science content reflected in college students' SSI negotiation?

Answering the above questions will result in the inductive generation of a rubric for quality of depth of content use during SSI negotiation. This rubric would potentially be useful to science educators with goals of examining the use of science content during SSI negotiation. For example, by knowing specific content likely to be addressed in various scenarios, results from this study can help both researchers and teachers in choosing an appropriate SSI scenario(s) for their purposes. Furthermore, this protocol for establishing a rubric could be used in future studies to examine use of science content in other SSI contexts, such as ones related to the ecology and the environment.

The rubric created by answering the first set of research questions also has the potential to be useful to classroom teachers. The course of a school year in a typical science class creates many opportunities for use of SSI as a pedagogical tool. For example, a high school biology course could use SSI about stem cell research in the fall, reproductive cloning in the winter, and global warming in the spring. From a teacher's perspective, it would be useful to have the ability to anticipate how students in a class might connect with specific SSI scenarios. A set of rubrics for multiple SSI scenarios can aide teachers in their decision about whether or not to use a particular SSI scenario.

RQ 2

Evolutionary theory is deeply embedded in the science of biology, and many national organizations are of the opinion that understanding it is a necessity for scientific literacy (see AAAS, 2008; NABT, 2008; NRC, 1996 for examples), as will be explained further in Chapter Two. However, while an understanding of evolution is critical for overall scientific literacy, many students do not accept it and/or are not comfortable enough with it to learn it, and many teachers are neither willing and/or able to teach it. This can be an impediment for those who use SSI in their research and/or teaching because many SSI, particularly those biological-based, such as cloning and gene therapy, involve concepts related to evolutionary theory in their underlying science content, and results can be affected by participants' knowledge and/or acceptance of evolution. Further study is needed to characterize the relationship between understanding and acceptance of evolution and the use of science content during SSI negotiation.

The literature suggests that informal reasoning and argumentation involved in SSI negotiation are influenced by factors such as emotions, beliefs, and moral development. The acceptance or lack of acceptance of evolution is often a highly charged topic. In other words, many people feel very strongly about evolution, and this includes both those who accept it and those who do not. For that reason, acceptance of evolution was identified as a potential emotive factor in the negotiation of SSI which may contain content with evolutionary aspects. The hypothesis is that the extent of one's acceptance of evolution is a mitigating factor in how evolution content is evoked during SSI negotiation. Therefore, those who do not accept evolution will either refuse to use its content during SSI negotiation or use it very poorly (possibly with misconceptions) even if they have a demonstrated knowledge of the concepts and are prompted to do so. Under this hypothesis, those who have knowledge of and accept evolution have the greatest likelihood of scoring highest on the rubric created from research question 1. Those who may not have as much knowledge of evolution, yet accept it, have the potential to score higher on the rubric than 1) those with neither high knowledge nor acceptance of evolution or 2) those with higher knowledge of but do not accept evolution (please see Figure 1.)

The following research question will test the above hypothesis:

2. What is the nature of the interaction between evolution understanding and evolution acceptance as they relate to depth of use of evolution content during SSI negotiation?

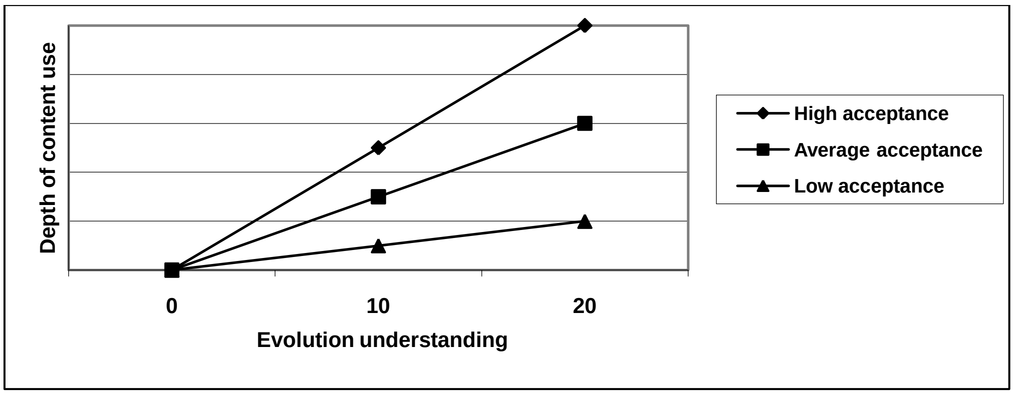

Figure 1. Hypothetical relationships among evolution understanding and acceptance and the depth of use of evolution content during SSI negotiation

The SSI movement will benefit from studies on the understanding and acceptance of evolution and the relationship between it and biology-based SSI. This is particularly salient with respect to high school and college students since that is with whom the majority of SSI research and teaching occur (Sadler & Zeidler, 2005 for example). The argument here is that acceptance and understanding of evolution may influence the types of science content as well as the depth of science content used during SSI negotiation, making this a study that will greatly enhance our literature base on the theory and practice of SSI instruction.

While answering the first set of research questions will aid science educators in understanding the use of science content within the context of certain SSI scenarios, the purpose of question 2 is to examine how the depth of evolution content used in the SSI scenarios relates to students' understanding and acceptance of evolution. This question is asked because of the possibility that while students may have knowledge of a subject, they may not have internalized it to a point where they can apply that knowledge to settings beyond their final exam. Answering this question will determine the extent to which internalization (or lack of internalization) of evolution content takes place in specific SSI settings.

Significance of the Study

Once factors that mitigate understanding and acceptance of evolutionary theory in the context of SSI are better understood, science educators will be better able to use SSI as a way to promote informed decision-making, a key part of scientific literacy. *Science for All Americans* defines scientific literacy as a multifaceted construct including "being able to use scientific knowledge and ways of thinking for personal and social purposes" (AAAS, 1990, pp. xvii-xviii). The National Science Education Standards define a scientifically literate person as someone who is able to "use appropriate scientific processes and principles in making personal decisions" and "engage intelligently in public discourse and debate about matters of scientific and technological concern" (NRC, 1996, p. 13). In other words, one who is scientifically literate uses science content knowledge to make informed decisions, either personally or socially, about topics or issues that have a connection with science. The problem is that these reform documents do not address the extent to which people ought to use their content knowledge when making decisions and what degree of influence affective factors, such as a person's beliefs, can have and still be considered an informed decision.

Not only is the use of SSI important in the U.S., but there are global implications as well. The field of science education is becoming an international community with an increasing amount of research about improving science teaching and learning (Duit, 2007). Research involving SSI occurs not only in the United States (e.g., Zeidler, Sadler, Simmons, & Howes, 2004) but also internationally, including countries such as Norway (KolstØ, 2006), Brazil (dosSantos & Mortimer, 2003), Portugal (Reis & Galvao, 2004), the United Kingdom (Hughes, 2000), Australia (Dawson & Venville, 2009), and Canada (Bingle & Gaskell, 1994; Pedretti, 1999), to name a few. Furthermore, many countries, such as Taiwan (Center for Science Curriculum Studies, 2006) and most of Europe (Eurydice, 2006) are incorporating SSI into their national curriculum. Because acceptance and understanding of evolutionary theory varies across the globe, it becomes even more important to study it within the context of SSI.

Finally, we know that affective factors such as emotions and intuition are used in reasoning out decisions in an SSI context (Sadler, 2004; Sadler & Zeidler, 2004, 2005). However, we do not know how the factors which affect acceptance of evolution relate to the extent of emotions and intuition used in decision-making. This will give science educators a more complete picture of how biology-based SSI are negotiated inside or outside of the classroom.

Chapter 2

Introduction

The purpose of this chapter is to examine the literature with respect to the proposed research questions. Because this study addressed the use of science content, and specifically evolutionary theory, in the context of socioscientific issues (SSI) negotiation, this chapter began with an overview of evolutionary theory and was followed by making the connection between evolutionary theory and the whole of biological sciences and scientific literacy. This study also addressed understanding and acceptance of evolution; therefore a review of relevant literature was examined and followed by a review of prior research on informal reasoning and argumentation within a SSI negotiation context.

The Centrality of Evolution to Scientific Literacy

Biological Evolution

While a full treatment of biological evolution can be found in countless books devoted to the topic, a brief overview is presented here. The initial 1859 publication of Charles Darwin's *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* (1979/1859) explains descent with modification by means of natural selection, the key concept of evolution. Darwin observed that (1) there is variation within populations of organisms; (2) that the variation is passed from parents to offspring; and (3) that some individuals within a population are more successful at surviving and reproducing than others. From these observations

Darwin concluded that survival and reproduction are not random; instead, those with more favorable variations are more successful at survival and reproduction. Darwin called this natural selection. In short, according to natural selection, those that are better adapted to their environment experience a greater probability of surviving to their reproductive years and producing offspring. Since Darwin's time, advances in science have supported and expanded on his theory. For example, the field of genetics has shown that DNA is the molecule of heredity, which explains why offspring are likely to show traits of their parents. Mendelian genetics and an understanding of meiotic cell division explain why offspring don't *always* show traits of their parents. The famous Hardy-Weinberg equation explains how changes in allele frequencies will cause entire populations of organisms to change over time. This equation holds true as long as there are no more than two alleles for a genetic trait, the breeding population is very large with no effects of genetic drift, mating is random, and there are no mutations, migration, or natural selection. In other words, a population can only remain in Hardy-Weinberg equilibrium if evolution is *not* occurring. Countless studies of a variety of populations of organisms have shown that Hardy-Weinberg equilibrium does not occur in nature (see Asami, Gittenberger & Falkner, 2008; Galindo-Sanchez et al., 2008 for examples). The advent of DNA sequencing technology has enabled biologists to compare gene sequences among species. The field of molecular phylogeny compares gene sequences and uses statistical computer modeling to demonstrate relationships between species and estimate how long ago they diverged from a common ancestor. Findings from such studies support existing and growing fossil evidence (Kittler, Kayser, & Stoneking, 2003, for example).

Knowledge of the molecular and physical mechanisms of evolution has applications within virtually every aspect of the life sciences. For example, it is because humans and other primates come from a common ancestor that medical trials of medicines and vaccines are able to be performed on laboratory animals. Another example of the applications of evolution understanding is found in the field of ecology. Molecular techniques combined with concepts related to evolution are used by ecologists for the purposes of conservation of plants and animals. For example, Walker (1997) compared DNA sequences of samples of *Chrysopsis floridana*, the endangered Florida Goldenaster, collected from various locations in Hillsborough County, Florida. She then compared the amount of genetic variation within populations to that of other populations. Her findings show that there is a barrier to gene flow between populations. Because the Goldenaster lives in a sand pine scrub habitat, which is highly valued for development, she concluded that habitat destruction is hindering the survival of this endangered native Florida plant. Other examples of the application of molecular techniques and evolutionary theory within Florida include the melaleuca trees (Cook, Morris, Edwards, & Crisp, 2008), anoles (Kolbe et al., 2007), tardigrades (Garey, McInnes, & Nichols, 2008), freshwater mussels (Turner et al, 2000), and sea turtles (Bowen & Karl, 2007).

In summary, instances of content related to evolutionary theory during SSI negotiation can include anything that refers to organisms' adaptation to their environment and/or ability to survive and create offspring. It includes genetic variation of populations of organisms, DNA or protein sequences, common ancestry, fossils, and plant and/or animal diversity. Specific examples of how these might occur as references to evolutionary theory during socioscientific decision-making will be given later in this chapter.

Evolution and Scientific Literacy

Scientific literacy can be viewed in terms of knowledge about science or from a more sociocultural perspective, wherein one has an understanding of the practice of science and its relevance to everyday life (Sadler, 2007). While Chapter One described the importance of SSI as a means to achieving scientific literacy within a more sociocultural perspective (Zeidler, 2007), many national and international organizations view scientific literacy as knowledge about science. In the latter view, as embedded as evolution is in the science of biology, many are of the opinion that understanding it is a necessity for scientific literacy. Regarding biology content knowledge, a scientifically literate person needs to have a basic understanding of biological principles and processes in order to make sense of the myriad of instances where they come in to contact with them in day-to-day life. The field of biology is made up of many broad topics threaded and held together by the theory of biological evolution. Because of this, many national organizations, several of whom are used by states to base their state science standards, assume that a prerequisite for an overall understanding biology is a thorough background in biological evolution. For example, the National Science Teachers Association's (NSTA, 2003) official position statement on the teaching of evolution states that it should be included in science education frameworks and curricula because it is a major unifying concept in science. It is further stated that learning evolution is necessary in order to achieve a sufficient level of scientific literacy. In their 1998 book, *Teaching About*

Evolution and the Nature of Science, the National Academy of Sciences (NAS) states, "Teaching biology without evolution would be like teaching civics and never mentioning the United States Constitution" (p. 7). Another example is Dobzhansky's (1973) famous quote, "nothing in biology makes sense except in light of evolution" (p. 125). The National Center for Science Education (NCSE, 2000) says this about evolution:

> It is the best, most accurate explanation we have for the variety we see in the living world, resulting from the research and experimentation of thousands of scientists for over a century. And, it is important. Children may not need to know what time of day George Washington was born, but they need to know he was our first president. In the same way, they may not need to know every detail of cell division, but they need to know about evolution because it is a key to understanding every aspect of the biological sciences, from genetics to animal behavior (NCSE located at http://www.ncseweb.org/resources/articles/3117_evolution_creation_and_scien_12_7_2000.asp).

The National Association of Biology Teachers (NABT) states that "teaching biology in an effective and scientifically honest manner requires that evolution be taught in a standards-based instructional framework with effective classroom discussions and laboratory experiences" (NABT statement on teaching evolution located at http://nabt.org/sites/S1/index.php?p=65).

In their National Science Education Standards (NSES), the National Research Council (NRC, 1996) considers evolution one of the major unifying concepts and processes in science: Beginning in grades K-4, the standards mention adaptation in response to a changing environment. Biological evolution is mentioned in more detail in grades 5-8 by giving a more in-depth treatment of adaptations. The grade 9-12 standards go into the greatest detail and treat biological evolution as a unifying concept. The American Association for the Advancement of Science (2008) views evolution as something beyond an important concept within biology and nature of science. It claims that one must also understand the physical sciences and mathematics in order to understand the evidence for evolution.

The importance of evolution to science understanding is also stressed outside of the United States. The national curriculum in the United Kingdom, for example, includes key evolutionary concepts as one of the major sections in science (Department for Children, Schools, and Families, 2008).

Acceptance and Understanding of Evolution

Major organizations such as the AAAS, NSTA, NAS, NABT, and NCSE recognize the importance of evolution to scientific literacy, yet many people do not accept it as a valid scientific theory and object to it being taught in science classrooms. When wondering why this might be the case, the answer may seem simple: Some perceive a conflict between evolution and certain religious beliefs. However, the stances of both theologians and clergy in many religions disagree. For example, Colburn & Henriques (2006) surveyed 53 clergy members from the following Christian religions including Catholic, Methodist, Lutheran, Presbyterian, Episcopal, United Church of Christ, and Disciples of Christ, to elicit their views about science, religion, and the evolution/creationism debate. They found that the majority of clergy find no conflict between evolution and creation, and most strongly disagreed that evolution is incompatible with God. Interestingly, when compared to results from a similar survey given to teachers, the clergy were most likely to accept evolution. When asked for their suggestions for how teachers might address the evolution/creation debate in the classroom, their suggestions included asking clergy to visit the classroom; having teachers use an "I used to think" approach to model how they accept science and religion; encourage students to think on their own and examine their beliefs; and not addressing religion at all since most science teachers are not trained or qualified to teach religion. The position of the Florida Catholic Conference states, "Evolution in its common understanding as a theory to explain the biological changes in organisms is not contrary to the Catholic understanding of creation, provided that any theory of evolution does not deny that God brought all things into existence and that He creates each individual soul" (http://www.flacathconf.org/LegReport.htm).

If evolution does not conflict with many religions, one might think that perhaps those that do not accept it simply do not have a good understanding of evolution (or possibly their religion); however the answer isn't that simple. Much work has been done on the relationship between understanding and acceptance of evolution. Nehm & Schonfeld (2007) investigated whether or not an increase in knowledge of evolution and nature of science was associated with a preference in teaching evolution in preservice secondary science teachers. Though significant gains were made in evolution knowledge and understanding nature of science, participants' preferences remain unchanged, and the majority preferred that creationist ideas be taught in schools.

Dedniz, Donnelly, and Yilmaz (2008) studied 132 Turkish preservice biology teachers' acceptance of evolution using the Measure of Acceptance of the Theory of Evolution (MATE: Rutledge & Warden, 1999) instrument. They also measured epistemological beliefs using a 38-item scale developed by Wood and Kardash (2002), and thinking dispositions using the Actively-Openminded scale (AOT: Sá, West, & Stanovich, 1999). Using a hierarchal multiple regression, they found that a significant correlation exists between knowledge and acceptance of evolution. In addition, participants with openness to belief change were more likely to accept evolution, as were those who have parents with a higher education level.

The differing results between the Nehm and Schonfeld (2007) and Dedniz, Donnelly, & Yilmaz (2008) studies described above makes one wonder which comes first, acceptance of evolution or understanding it. A study by Ingram & Nelson (2006) attempted to answer that question. They investigated the extent to which Midwestern biology majors accept evolution, whether or not instruction influences students' acceptance of evolution, and the relationship between acceptance of evolution and achievement in an advanced college evolution course. Over the course of three semesters (n = 255), a pre-post design was used to measure gains in acceptance of evolution by using a survey similar to the MATE (Rutledge & Warden, 1999) and to determine the relationship between students' acceptance of evolution and achievement in an upper-level evolution course. It was determined that almost 2/3 of students accepted evolution initially, whereas 3/4 accepted it by the end of the course. The greatest gains were noted for students who were initially undecided about whether to accept evolution. In addition, there was no strong relation between acceptance of evolution and achievement in the course.

Sinatra, Southerland, McConaughy, and Demastes (2003) measured understanding and acceptance of evolution in addition to epistemological beliefs and cognitive dispositions in 93 students enrolled in an undergraduate non-majors biology course. They found a strong correlation between understanding and acceptance of the noncontroversial topic of photosynthesis; however there was no correlation between understanding and acceptance of animal or human evolution. Epistemological beliefs were related to acceptance of human evolution but not animal evolution or photosynthesis. The authors conclude that knowledge may need to reach a critical level before it can influence acceptance. This makes sense given that detailed specifics on how evidence for evolution is collected often is not learned until upper level undergraduate or graduate level biology coursework.

If the goal of science educators is to achieve scientifically literate people, it begs the question, to what extent people are scientifically literate if they do not accept the fundamental unifying theme of biology? The corollary question to be raised is, are those who do not accept evolution capable of making informed decisions within a socioscientific context? The next section of this chapter takes a closer look at decision-making within an SSI context.

Decision-Making and SSI

For the purposes of this study, negotiation of SSI is defined as the process of coming to a decision about a specific socioscientific issue. Decision-making is the act of choosing a course of action when one is confronted with options. In order to effectively make decisions, one must be able to envision relevant choices, identify the potential consequences of each, and determine the likelihood that each would occur before choosing the most reasonable choice. This process is influenced by cognitive, psychological, and societal factors (Gordon, 1996). Cognitive factors include reasoning and perception. Psychological factors include personality traits, such as identity, tendency to take risks, and effects from traumatic prior events. Societal factors include ethnicity, religion, and socioeconomic status.

Reasoning occurs in one of two ways: deductive (formal) and inductive (informal). In the case of formal deductive reasoning, a conclusion is drawn based on a particular premise. This type of reasoning is typically associated with well-structured problems. Informal reasoning, on the other hand, is more often associated with ill-structured problems, such as SSI, because it uses evidence to create a conclusion or come to a decision. Kuhn (1991) and Means and Voss (1996) assert that issues which invoke informal reasoning are ones that require an individual to support a claim by building an argument. For that reason, measures of informal reasoning quality often center on the arguments used during the informal reasoning process (KolstØ, 2006; Means & Voss, 1996). In this case, arguments are defined as assertions accompanied by justification (Kuhn, 1991; Toulmin, 1958) and have often been used to examine argumentation quality (Driver, Newton & Osborne, 2000; Erduran, Simon, & Osborne, 2004; Sadler & Fowler, 2006).

Belief bias, the rejection or acceptance of an argument based on one's beliefs rather than a logical argument, indicates a person's difficulty with evaluating evidence that conflicts with his or her beliefs (Evans, 2002). This has been shown to be the case in studies of scientific thinking (Greenhoot, Semb, Colombo, & Schreiber, 2004), as well as in logic-based reasoning (deNeys, 2006). Belief bias is separate from confirmation bias, also known as myside bias, where a person seeks evidence that will confirm prior beliefs. When examining evidence used during SSI negotiation, one ought to also consider both how a person's beliefs might bias which particular evidence is being used, in addition to the amount of content knowledge a person has.

Informal Reasoning

One's prior beliefs and opinions are not always swayed by content knowledge, even if a person has learned the content well enough to recall it on an exam. For example, in a study of Indian children's knowledge of astronomy (Samarapungavan, Vosniadou, & Brewer, 1996), one 7-year-old girl was interviewed and gave answers that consistently indicated a belief in the heliocentric model of the universe. The next day at lunchtime, the girl approached the interviewer and asked whether the earth really moved or whether the sun and moon moved around the earth. The interviewer asked her what she really thought. She responded that according to her teacher, the earth spins on its axis to cause the day/night cycle, but that she thought that the sun and moon went up and down, from ocean to sky and back, to cause the day/night cycle.

Beliefs and opinions also play a role in how one determines the validity of evidence during decision-making. In a study done by Sadler, Chambers, and Zeidler (2004), students were given two conflicting articles about global warming and asked to decide which of the two had the most scientific merit. Students' decisions fell into four categories: (1) personal relevance, (2) better data and interpretation, (3) better explanation, and (4) equally meritorious. Students were then asked to discern which was the most convincing and provide a rationale. In this case, students' decisions were based on personal relevance, information quality, and previous personal beliefs wherein the article most closely aligned with their personal beliefs was deemed most convincing. An interesting pattern that emerged was that many students did not agree with the same article for both questions, implying that a large number of students do not consider scientific merit to be a convincing factor when considering socioscientific issues. This supports previous findings by Zeidler, Walker, Ackett, and Simmons (2002) that students often separate scientific knowledge and personal opinion. This phenomenon was also noted by Zeidler, Applebaum, & Sadler (2006). They found that when high school students were confronted with SSI that conflicted with their core beliefs or personal experience, the data were often dismissed. When students were compelled to defend their opinions (i.e. argue), they included their core beliefs and personal experiences. Thus, beliefs and opinions play a role in argumentation and subsequent decision-making.

In addition to using science content knowledge to support an argument and weigh a decision, people also consider how the issue will impact them and/or society and how that connects with their moral values (Sadler & Zeidler, 2005). This is not a new idea. In book III of his *A Treatise of Human Nature* (1740), David Hume states in part I, section I:

> Since morals, therefore, have an influence on the actions and affections, it follows that they cannot be derived from reason; and that because reason alone, as we have already proved, can never have any such influence. Morals excite passions, and produce or

> prevent actions. Reason of itself is utterly impotent in this particular. The rules of morality, therefore, are not conclusions of our reason (p. 5).

In a study of informal reasoning patterns in a socioscientific context, Sadler and Zeidler (2004) gave special attention to how moral considerations play a role in patterns of informal reasoning. In this study, college students (15 biology majors and 15 non-science majors) were given a brief description of gene therapy and then were given a prompt, such as a description of Huntington's disease, for example, and asked if they approve or disapprove of gene therapy in that context. Students were then asked questions designed to elicit a rationale for that position followed by a request to give a counter-argument and a rebuttal to the counter-argument. This process was repeated using a cloning scenario. Students then underwent a second interview designed to elicit personal experiences, social considerations, and morality used in the overall informal reasoning pattern. Following a thorough qualitative analysis, it was found that there are three distinct patterns to informal reasoning: rationalistic, emotive, and intuitive. The rationalistic pattern is strictly cognitive wherein participants use reason and logic to support their position. The other two patterns, emotive and intuitive, are affective. With intuitive reasoning, students resolved scenarios based on their initial thought or feelings. Emotive reasoning, though containing some rational aspects, also displays empathy and sympathy towards others. Also noted was that many students used each of the three patterns in varying combinations and degrees in order to support their position on the socioscientific topics and that students' moral considerations were strongly embedded throughout the informal reasoning process.

While exploring informal reasoning patterns in the context of SSI in the study mentioned above, Sadler (2005) took a closer look at the types of comments made by students. He noted that 8 of the 15 biology majors made comments indicative of an evolutionary perspective. In these cases, many responses equated evolution to a natural order of life that should not be disrupted. It was also noted that many comments revealed the misconception that evolution has a purpose or predetermined outcome. On the other hand, while many non-science majors also rejected genetic engineering on the grounds that it disrupts a natural order, they did not explicitly mention that the natural order is generated by evolution. Sadler found that biology students based decisions on either of the two genetic engineering scenarios given but that the evolutionary consequences differed by scenario. For example, with respect to gene therapy, the focus was on altering human evolution, while with cloning the focus was on genetic diversity. Sadler concludes that the misconceptions about evolution displayed by college biology majors is a cause for concern and that additional studies with a larger sample are needed to further study this. He further adds that assessing student understanding of evolutionary theory in the context is possible and that “such studies may significantly enhance the picture of student conceptions of evolution” (p. 72).

Argumentation

There is much science education research on students' argumentation skills and their influence on decision-making. According to the *Oxford English Dictionary,* an argument is a "statement of the reasons for and against a proposition; discussion of a question; debate." Though this meaning has been interpreted by some as rhetorical or didactic (e.g., Kuhn, 1992; Boulter & Gilbert, 1995), others interpret it as multivoiced in that the argumentation process can occur within a social group. It is the second interpretation that many science educators interested in argumentation find alluring because the practice of argument in groups can be a tool for scaffolding individual student's argumentation and subsequent decision-making (Driver, Newton, & Osborne, 2000).

Studies of argumentation in the context of science classrooms are generally regarded as a valuable contribution to research in science education (Driver, Newton, & Osborne, 2000). For one thing, there is the belief that practicing argumentation in the classroom will enable students to critically examine scientific claims and be better equipped to confront and make informed decisions about issues that appear in daily life (Norris & Phillips, 1994). Second, because scientists use argumentation in the form of weighing evidence, publishing in peer reviewed journals, and presenting at conferences, it is argued that exposing students to the norms of scientific argument will give them a better understanding of scientific claims and reduce the positivist view of science that is taught in the classroom (Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002). Third, Driver, Newton, and Osborne (2000) argue that argumentation will help students develop conceptual understanding, investigative competence, and understand science as a social process. Related to this, Zeidler and Sadler (2008) promote argumentation in an SSI context as a vehicle for citizenship education.

Given the three reasons mentioned above, it can be assumed that studying how students use argumentation will better equip science teachers to use it in the classroom. It might also be assumed that this will give students not only a better understanding of the nature of science, but also help them to become scientifically literate citizens capable of making informed decisions by using scientific knowledge to support their arguments. However, this is not always the case.

In science education, studies of argumentation center around Toulmin's (1958) model. In this model the main components of an argument are:

- Data: The facts surrounding the argument, establishes the basis of the argument
- Claim: The part of the argument the arguer wants to prove. It is the purpose behind the argument.
- Warrant: Logical connection between data and claim.
- Backing: Basic assumptions that provide support for the warrant
- Qualifier: Limitations of the claim
- Reservation: Exceptions to the claim

Using Toulmin's model, there appears to be a solid connection between logic and argument. Logic provides the rules for relating premises to conclusions, while argument is the practice of it. Because of this, it would be easy to assume that argumentation and its subsequent decisions are rational. Indeed, many studies on argumentation use Toulmin's argumentation pattern to provide a basis for developing tools to analyze arguments (see

Erduran, Simon, & Osborne, 2004). While these studies are worthwhile for gaining an understanding of which components of an argument people are likely to be weak, the assumption that arguments are constructed around scientific facts prevents researchers from completing the connection of how one's process of argumentation leads to making a specific decision. As described in the informal reasoning section of this chapter, students do not always or exclusively use content knowledge when reasoning out their decisions. Beliefs, opinions, and moral considerations play perhaps an even larger role.

When examining how the quality of argumentation in a genetic engineering SSI context is affected by content knowledge and morality in 56 high school students, Sadler and Donnelly (2006) found no statistically significant differences between the three variables. They suggest that this could be due to a lack of background knowledge in genetics and propose that there could be a non-linear relationship between content knowledge and argumentation quality. Sadler and Fowler (2006) tested the Sadler & Donnelly (2006) Threshold Model of Content Knowledge Transfer (TMCKT) by examining content knowledge and argumentation quality in a genetic engineering SSI context in college undergraduate biology majors and non-majors. Data from their study support TMCKT in that biology majors demonstrated much higher argumentation quality than did the non-majors or the high school students from the Sadler and Donnelly (2006) study.

Dawson and Venville (2009) examined 30 Australian high school students' argumentation and informal reasoning about biotechnology. Groups of 2-3 students underwent semi-structured interviews during which they were asked about their understanding and views on various types of biotechnology, including cloning, genetic testing for diseases, paternity, and forensics. These topics were chosen because they are SSI underpinned by an understanding of genetics, and a variety of issues was used in order to observe a range of reasoning patterns. Students were not prompted to offer rationales or counter-positions. Using two researchers to code student responses, informal reasoning patterns were categorized as rationalistic, intuitive, emotive, or a combination of those as described by Sadler and Zeidler (2005). Argumentation quality was analyzed in a manner similar to Sadler and Fowler (2006) where student statements were categorized into levels. Level 1 was a claim only; level 2 statements contained a claim plus data and/or warrants; the third level also included backing or a qualifier, and level 4 contained all of the above mentioned elements. Results show that the patterns of informal reasoning most often used by students across SSI topics were intuitive and emotive. This differs from patterns observed by Sadler and Zeidler (2005) where rationalistic reasoning was more common. The authors explain that a possible reason for this is that that older students in the Sadler & Zeidler (2005) study were better able to articulate their emotive and rationalistic reasoning due to the Threshold Theory of Content Knowledge Transfer (Sadler & Donnelly, 2006; Sadler & Fowler, 2006) described earlier.

Argumentation quality was at a level 2 for the majority of students across the topics. When examining informal reasoning patterns together with argumentation quality, it was noted that level 2 arguments coincided with intuitive and/or emotive informal reasoning, and level 4 arguments contained rationalistic informal reasoning, either alone or in some combination with emotional and intuitive informal reasoning. The authors claim that rationalistic informal reasoning is required to make a connection between students' science understandings and skills and the SSI under discussion, but that a complex reasoning pattern (combination of rationalistic and emotive and/or intuitive) is essential for students to be scientifically literate, informed decision-makers in an SSI context.

This study is unique in that it examines informal reasoning and argumentation quality with the same data set in the context of SSI; however, one weakness is that, while the authors mention a similarity of informal reasoning and argumentation patterns across the issues, they did not examine the students' comments for patterns of types of science content used. Given that they used these particular SSI because they all have ties to genetics and biotechnology, an exploration of genetics content stated by students across scenarios would have strengthened their study. One interesting thing to note which may be pertinent to this proposed study is that, when looking at the examples given for rationalistic reasoning patterns, there is a clear connection to natural selection (evolution). For example, when discussing genetically modified foods, one student said "if you make it so it's too specific for the environment so it grows really well and the environment changes it won't grow well at all" (pg. 11). Another states, "If they genetically modify these crops so they're pest resistant, all the pests would die out and you're changing the ecosystem" (pg. 11).

Summary

This chapter explored what evolution is and why it is important to scientific literacy. It showed that the role of content knowledge, including evolution content, on evidence-based reasoning is not as great as was once thought within the context of SSI scenarios with a biological context. Though students can be taught to rationally utilize science content in a decision-making process, their core beliefs, personal experiences, and affective factors continue to play a strong role. This includes acceptance or rejection of evolution. A better understanding of the interplay between the understanding and acceptance of evolution and SSI negotiation is essential for gaining a clearer picture of how to achieve a population of informed decision-makers.

Chapter 3

Introduction

The focus of this study was to examine the use of evolution science content and the roles of understanding and acceptance of evolution on the use of content during socioscientific issues (SSI) negotiation. The following research questions collectively addressed the use of evolution science content during SSI negotiation and interactions between understanding evolution, acceptance of evolution, and how deeply students use evolution when negotiating SSI.

1A. What specific science content do college students evoke during SSI negotiation?

1B. What is the depth of evolutionary science content reflected in college students' SSI negotiation?

2. What is the nature of the interaction between evolution understanding and evolution acceptance as they relate to depth of use of evolution content during SSI negotiation?

This chapter gives an overview of the design of the study, a description of the target and accessible populations, instruments used in the study, and a description of data collection and analysis by research question.

Overview

Participants in this mixed methods study were students enrolled in senior level college courses taught through the Integrated Biology and Geography departments during March and April of 2009. The primary investigator visited each of the classes, informed the students about the study, and invited them to participate. Those who chose to participate completed a four-part survey. The first part was the Socioscientific Issues Questionnaire (SSI-Q). This used three different scenarios, which were given in random order. The second part of the survey was an assessment of conceptual understanding of evolution, and the third part was an assessment of acceptance of evolution. The instrumentation section of this chapter (pp. 49 - 57) describes each of these assessments in detail. The fourth part of the survey asked for demographic information where participants were asked to fill out an information sheet with open-ended questions asking for their major, gender, age, number of college level biology courses, ethnicity, religious affiliation, and whether or not they would be willing to participate in a follow-up interview. Please see Appendices A - E for each part of the survey and the interview protocol. Participants typically completed the survey within 30 – 60 minutes (average 45 minutes). Figure 2 shows a flowchart of the overall study design.

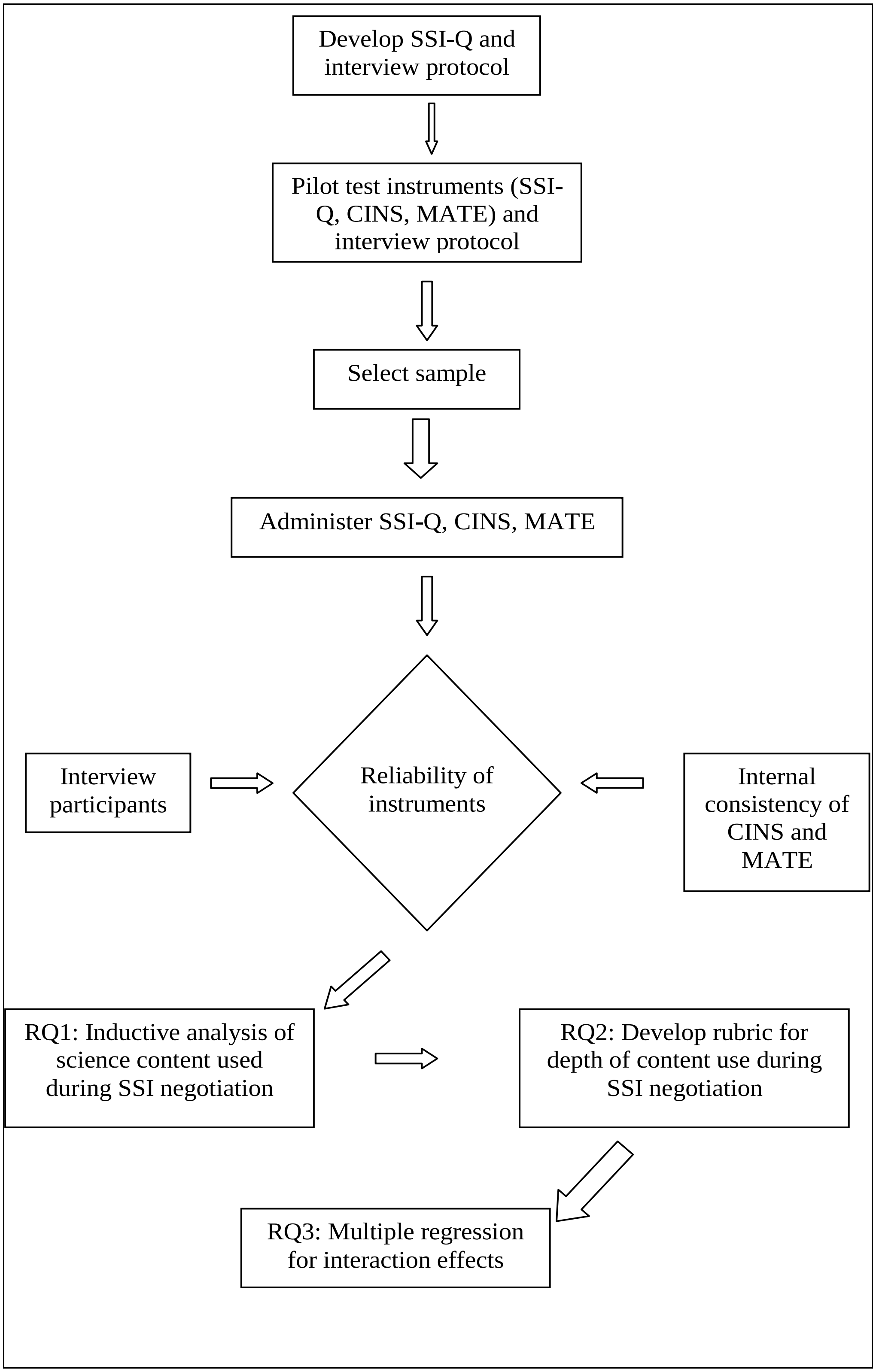

Figure 2. Flowchart of the study design

Sample

Target Population

The population of interest in this study was undergraduate college students enrolled at the University of South Florida. While much SSI research has been done with high school students, the threshold theory content knowledge transfer (Sadler & Donnelly, 2006; Sadler & Fowler, 2006) gave the expectation that both evolution understanding and the use of science content to make informed decisions would yield a greater range of data in college students than would be gained by examining high school students.

The University of South Florida (USF) is one of the nation's top research universities and offers 219 undergraduate, graduate, and specialist degree programs to over 46,000 students at campuses located in Tampa, Sarasota, St. Petersburg, and Lakeland, Florida. Of the over 35,000 undergraduate students enrolled, nearly 25,000 are considered upper level with over 60 credits hours of coursework (20,000 at the Tampa campus).

Participants

Because many people may not use or only minimally use science content during SSI negotiation it was important that the sample included those who we could reasonably expect to have advanced knowledge in the sciences as well as those who may not have as much knowledge. For that reason, the sample consisted of upper level undergraduate students from a range of backgrounds, including biology and biomedical science, in addition to those from other majors, including philosophy, environmental science, psychology, anthropology, and criminology.

Participants included students enrolled in either a 4000 level biology course (Animal Behavior or Organic Evolution) or 4000 level non-majors course (Florida Ecosystems or Environmental Issues) at the USF Tampa campus during the spring semester of 2009. With the permission of the course instructors, their department chairs, and approval of the USF Institutional Review Board, the principal investigator went to each individual class and invited students to participate in the study. Of the 110 students asked, a total of 60 students participated in the study, making a response rate of 55%. The total number of students present in class and the number who participated in the study appear in Table 1 along with a brief description for each course.

Table 1

Courses from which participants were sampled

Course number and title	Course description	Number of students enrolled	Number of students asked to participate	Number of students who participated
ZOO 4513C: Animal Behavior (3 credits)	For advanced biology majors with prior coursework in Biology I & II, General and Organic chemistry, Genetics, Ecology, and Cell Biology. It is an introduction to comparative animal behavior with analysis of types of animal behavior, their function and evolutionary origin.	61	50	40
PCB 4674: Organic Evolution (3 credits)	For advanced biology majors with prior coursework in Biology I & II, General Chemistry, and Genetics. It is an introduction to modern evolutionary theory focusing on population genetics, adaptations, speciation theory, phylogeny, human evolution and related areas.	44	19	3

Table 1 (Continued)

Course description	Number of students enrolled	Number of students asked to participate	Number of students who participated	Number of students who participated
BSC 4057: Environmental Issues (3 credits)	This course is open to all students and has no required prerequisite coursework. The course fulfills a USF exit course requirement. It is a study of biological, economic, ethical, legal, political and social issues relating to current environmental problems.	11	5	1
EVR 4930: Ecosystems of Florida (3 credits)	This course is open to all students and has no required prerequisite coursework. It is a survey of the diversity of ecosystems found in Florida.	49	36	16

Participant Demographics

Participants included 36 females and 24 males ranging in age from 19 to 37 years old (mean age = 23.2 years). Most of the students were White (n = 42), and the remainder were African American (n = 1), Hispanic American (n = 3), Middle Eastern (n = 2), Indian (n = 1), Asian American (n = 3), and no response (n = 8) (see table 2). Participants represented a variety of religious backgrounds including Catholic (n = 12), Protestant Christian (n = 14), Agnostic/Athiest (n = 3), Islam (n = 4), Hindu (n = 2), Buddist (n = 1), Judiasm (n = 2), Wiccan (n = 2), no particular religion (n = 13). Seven participants did not respond (see Table 3).

Table 2

Participant demographics by race/ethnicity

Race or ethnicity	Number of participants
White	42
African American	1
Hispanic American	3
Middle eastern	2
Indian	1
Asian American	3
No response	8

Table 3

Participant demographics by religion

Religion	Number of participants
Catholic	12
Protestant	14
Christian	
Islam	4
Hindu	2
Buddhist	1
Jewish	2
Wiccan	2
Agnostic/Atheist	3
No religion	13
No response	7

Instrumentation

Pilot Study of Instruments

Pilot testing of the SSI-Q, Conceptual Inventory of Natural Selection (CINS), and Measure of Acceptance of the Theory of Evolution (MATE) instruments and the interview protocol was done during January and February of 2009 with 11 students enrolled in a Cellular, Molecular, and Microbiology Department capstone course titled

"The Scientific Processes in Biology." All participants were biology majors, ranged in age from 21 to 34 years old, and consisted of 6 females and 5 males. Participants represented a variety of religions, including Hindu, Wicca, Catholicism, Protestant Christianity, and Atheism or Agnosticism. Most identified with a White or Caucasian ethnicity, with one Asian American and one Hispanic.

The primary investigator approached participants during their class time and gained their permission to pilot test the instruments and interview protocol for this study. Participants first completed the CINS and MATE, and then meeting times were arranged for each to visit the primary investigator to complete the SSI-Q and a follow up interview. Descriptions of results from the pilot testing of each instrument appear next in their respective sections.

SSI Questionnaire (RQ 1)

As described in Chapter 1, negotiation of SSI involves coming to a decision about or developing a position regarding an SSI. In this study a written questionnaire was used to examine SSI negotiation where students were given several SSI scenarios and asked to come to a decision or resolution about each.

Due to the nature of this study, it was important to choose scenarios which were likely to incorporate basic evolutionary concepts and have the potential to give a diverse range of responses for each of the variables. Because contexts involving genetic engineering and medicine have been shown to be ideal for this situation (Dawson & Venville, 2009; Sadler, 2005; Sadler & Fowler, 2006), these types of scenarios were chosen for the study. The initial version of the SSI Questionnaire consisted of four scenarios: reproductive cloning, gene therapy for intelligence, use of preventative antibiotics, and use of the MMR vaccine in small children.

The questionnaire was based on the interview protocol developed by Sadler (2003) based on Kuhn's (1991) framework. This protocol was used to study SSI negotiation and adapted to include additional prompts to elicit use of science content, particularly evolutionary content, and with fewer SSI scenarios. Participants read a brief description of gene therapy and were then asked to offer a position on whether or not they approve of gene therapy for a scenario involving the improvement of intelligence in humans. A series of questions designed to elicit a rationale to support the position, pose a counter position, and a rebuttal to the counter position were asked in order to allow participants multiple opportunities to utilize science content in their SSI negotiation. An additional question designed to prompt students to relate the scenario to evolution was added. This procedure was repeated with the remaining scenarios.

During pilot testing, participants were given each of the scenarios in random order. Time to complete the entire set of scenarios ranged from 15 – 40 minutes. After examining the initial scoring rubric, which is described in greater detail later in this section, it was noted that participants consistently scored poorly on the fourth scenario, no matter which scenario it was. It was also noted that the vaccination scenario did not elicit as much depth of evolutionary content use as the other three scenarios. For these reasons, the primary investigator decided to remove the vaccination scenario from the SSI-Q instrument in order to prevent the above mentioned problems and to shorten the overall instrument. The final version of the SSI-Q is located in Appendix A.

Conceptual Inventory of Natural Selection (RQ 2)

Participants were assessed for their understanding of evolution using the Conceptual Inventory of Natural Selection (CINS: Anderson, Fisher, & Norman, 2002). This instrument was made up of 20 multiple choice items designed to measure conceptual understanding of the following evolutionary concepts: biotic potential, population stability, natural resources, limited survival, variation within a population, variation inheritability, differential survival, changes in populations, origin of variation, and speciation.

Items were developed based on scenarios selected from evolutionary biology literature and students' responses to open-ended questions about natural selection. Initial field testing was done with four groups of 100 students each at ethnically diverse community colleges in Southern California.

Validity. In order to determine whether the instrument was measuring the desired construct, seven students were interviewed about their understanding of natural selection. In addition, three university and two community college biology professors reviewed the instrument for content validity. Items were revised based on feedback from student interviews and professors' comments. The revised instrument was administered to biology and non-biology majors. Following an item analysis, the instrument was revised again and administered to 206 students enrolled in one of two non-majors biology courses.

Reliability. An item analysis showed the difficulty of items had an average of 46.4%, which is close to the typical average difficulty suggested by Gronlund (1993). Internal consistency was measured using the Kuder-Richardson 20 (KR_{20}) and resulted in

.58 for students enrolled in one class and .64 for students enrolled in the other class. This is an acceptable reliability coefficient according to Gronlund (1993). A principal components analysis supported internal consistency in that items measuring the same concept co-varied highly with each other and loaded on the same component, whereas items that did not measure the same concept loaded onto other components. The internal consistency of this instrument is supported by other studies as well including Nehm and Schonfeld's 2008 study of biology majors ($\alpha = .78$) and a pilot study of 52 undergraduate biology majors and non-majors ($\alpha = .81$) conducted by the primary investigator.

The CINS instrument was scored by assigning one point for each correct answer. Because the instrument is made up of 20 items, the possible score range was 0 – 20. During pilot testing, scores on the CINS ranged from 11 to 20 with a mean of 16.6 and a standard deviation of 3.7. The internal consistency measured by Cronbach's alpha was .83. Because this is above the predetermined threshold of .79, it was decided the study could proceed without modification to the CINS instrument. Please see Appendix B for the complete instrument.

Measure of Acceptance of the Theory of Evolution (RQ 2)

Participants' acceptance of evolution was assessed using the Measure of Acceptance of the Theory of Evolution (MATE: Rutledge & Warden, 1999). This instrument contained 20 Likert-scaled items designed to assess the processes of evolution, available evidence of evolutionary change, the ability of evolution to explain phenomena, human evolution, age of earth, validity of science as a way of knowing, and the current status of evolutionary theory within the scientific community.

Validity. Items were reviewed by five university faculty with expertise in evolutionary biology and science education and rated for validity on a scale of 1-5 (1 is invalid and 5 indicates a high confidence that the item measures the construct). Items with a minimum scale of 3.5 were used, and the average rating of items in the instrument was 4.7. A principal components factor analysis revealed a single factor and all items achieved loading values greater than .65. This indicated that the instrument has construct validity in that each item contributed significantly to a single factor.

Reliability. The authors of the MATE established reliability by administering the instrument to 552 Indiana high school teachers. The Cronbach alpha was .98, and item analysis showed that each of the 20 items had a corrected item total correlation greater than .65. Though this instrument was originally created for high school science teachers, reliability of the MATE instrument has since been established for other samples including college non-science and biology majors (test-retest $r = .92$; Cronbach $\alpha = .94$) (Rutledge & Sadler, 2007) and preservice science teachers (Cronbach $\alpha = .92$) (Dedniz, Donnelly, & Yilmaz, 2008), making it a suitable instrument for this study.

Scoring of the MATE was as follows: The 20 items were rated a 1-5 Likert scale. After reverse scoring negatively phrased items (#2, 4, 6, 7, 9, 10, 14, 15, 17, & 19), possible scores ranged from 20 to 100. During pilot testing, scores on the MATE instrument ranged from 49 – 100 with a mean of 86.6 and a standard deviation of 15.3. The internal consistency for the sample in this study as measured by Cronbach's alpha was .97. Given that the internal consistency was above a predetermined threshold of .79 and that students did not report difficulty understanding the questions when asked, it was decided that the study could proceed without modification to the MATE instrument. The complete instrument is located in Appendix C.

Semi-Structured Interviews

The purpose of the semi-structured interviews was to verify findings of data collected by the SSI-Q, CINS, and MATE instruments. The interview questions fell into three categories. The first was a series of questions similar to those from the cloning scenario in the SSI-Q. The second category was a set of four questions from the Oral Response Instrument (ORI) described by Nehm and Schonfeld (2008) as a measure of evolution understanding. The third category asked students “Do you accept the theory of evolution? Please explain why or why not.” and “Are there some parts of the theory that you agree with and other parts that you do not, such as human evolution, the age of the earth, or the validity of the scientific evidence, for examples?”

Interviews were conducted individually by the primary investigator and took place in a private office in order to help make participants feel more at ease during the interview process. Participants were reminded of the purpose of the study and told that the purpose of the interview was to verify data previously collected from the SSI-Q, CINS, and MATE and to further explore how individuals thought about and made decisions regarding issues that involve applications of science. They were encouraged to ask for clarification at any time during the interview and to answer honestly. They were assured of the confidentiality of their responses.

Each interview was audio-recorded and later transcribed. Analysis of interview transcripts was conducted to determine whether data collected from the SSI-Q, CINS, and MATE were consistent with what participants said during the interview.

During the pilot testing, it became obvious that a revision of one of the questions was necessary. The question was,

> "A number of mosquito populations no longer die when DDT (a chemical used to kill insects) is sprayed on them, but many years ago DDT killed most mosquitoes. Could you explain why many mosquitoes don't die anymore when DDT is sprayed on them?"

Since DDT is no longer legal to use in the United States, this question did not seem relevant to the participants. Therefore, it was changed to read,

> "A number of mosquito populations no longer die when pesticides are sprayed on them, but many years ago pesticides killed most mosquitoes. Could you explain why many mosquitoes don't die to the same extent anymore when pesticides are sprayed on them?"

Participants for semi-structured interviews were selected for maximum variation of evolution content knowledge and acceptance of evolution, as well as willingness to participate. While collecting participant data, students were asked whether or not they would be willing to participate in a follow up interview. The sample began with four sets of participants randomly selected from those who indicated that they would be willing to undergo an interview. The first strata consisted of those with the upper half scores on the measures of both understanding and acceptance of evolution. The second consisted of the lower half of understanding and upper half of acceptance. The third was made up of the higher half of understanding and lower half of acceptance, while the fourth came from the lower half of both understanding and acceptance. A total of twelve students were contacted regarding a follow-up interview, and eight students participated. Table 4 shows the number of participants for each category. The final interview protocol appears in Appendix E.

Table 4

Participants interviewed by category

	Lower half of acceptance	Upper half of acceptance
Lower half of understanding	2	3
Upper half of understanding	3	4

Analysis of the interviews was designed to be used to validate the results from the SSI-Q, CINS, and MATE. As such, the intention was to score each section of the interview and test for statistically significant correlation. However, the number of students who participated in the interview was too small to conduct a meaningful statistical analysis.

Data Analyses

This section describes how data were analyzed to answer each research question. Analysis for the first research questions was done in a qualitative manner with the ultimate result being a description of science content used during SSI negotiation and rubric for scoring how deeply evolution content is used.

Research Question 1

The first research question and its sub-questions examined the use of science content during SSI negotiation. Responses to the SSI Questionnaire were transcribed and used to explore the following two questions: What specific science content do college students evoke during SSI negotiation? And, what is the depth of evolutionary science content reflected in college students' SSI negotiation?

Science Content

Participants' responses to each scenario were examined for references to content related to both evolutionary theory and content that does not relate to evolutionary theory. The primary investigator had a strong background in the biological sciences including a Bachelor of Science degree in Biology and over 21 credits of graduate level coursework in biology, including several evolution courses, and has taught general biology, microbiology, and genetics at the university level. She worked closely with an expert in biological evolution who conducted dissertation research on an evolutionary topic and had extensive experience in teaching evolution as well as a host of other topics related to biology.

An initial list of references to content was compiled by the primary investigator using data from the pilot study and presented to the biology expert for her review. The final list was created as follows: The primary investigator and the biology expert independently examined 15 transcripts to identify categories of science content participants' referred to during negotiation of each of the SSI scenarios. They then discussed their findings and grouped the categories into themes, and reached agreement for a list of evolutionary science categories. The primary investigator then analyzed the remaining transcripts, and any new categories were discussed with the biology expert on a case-by-case basis. The last 15 transcripts analyzed produced no new categories, and it was assumed that redundancy had been reached.

Six themes of science content were found in each of the three scenarios. Four of the themes related specifically to evolutionary theory: Variation, Inheritance, Differential Success, and Change. A fifth theme was described as Misconceptions related to evolution. The sixth theme, designated as "Other" was categorized as science that wasn't explicitly tied to evolution. Because characterization of the different themes is important to describing the creation of the depth of content use rubric, each of the six themes is described below and again in greater detail in Chapter 4.

Theme One – Variation. References to variation included acknowledgement that phenotypic and/or genetic variation exists in a population of organisms and/or is necessary for evolution to occur. Also included were references to a population's gene pool. Please see Table 5 for references and examples.

Table 5

References and examples for the Variation theme

Reference	Example
Necessity of variation /genetic diversity for evolution to occur	My position is pro-cloning only in that I support liberty, so an argument in opposition could be that cloning should be made illegal due to the lack of genetic diversity. If cloning became a common place practice then human beings as a species would be slowing evolutionary progress by reducing genetic diversity.
Effect on gene pool or on genetic diversity	This could enter some redundancy into the gene pool of a population and this would not allow the population to evolve as rapidly because the same genes just be repeated over and over again Some think that cloning could have an effect on the human gene pool.

Theme Two - Inheritance. This theme included references to the inheritance of traits or the passing of genes from parent(s) to offspring. Also included were responses that referred to the notion that not all traits are passed on because some are due to environmental effects (i.e., nature versus nurture) and general references to reproduction. Table 6 outlines references to this theme and gives examples.

Table 6

References and examples for the Inheritance theme

Reference	Examples
Pass on traits/genes	They could hypothesize that a couple that is not 100% healthy that chooses reproductive cloning could being into the world a child that is unequally healthy
	An argument would be that couples who can't have children naturally have an option to continue to pass on their genes (although not combined genes with the partner's genes to the "clone" offspring. In this way his/her genes are not lost.
Nature/Nurture; environmental effects	This scenario connects to evolutionary theory via the nature versus nurture argument. One side argues that it is solely the genes that result in an organism being what it is, while the other side argues that it is the environment that shapes an organism. In this scenario, the hypothesis is that changing a gene would make potential offspring smarter, but I believe it will not work unless changes are made to the environment as well.
	I would tell them that making a clone is not a good option because even though they look alike they will not have the same personality.
Reproduction	The <varcomycin> resistance of *Staph. aureus* was obtained via lateral gene transfer from *Enterococcus faecalis*. Bacteria can pass genes even between species which means that these resistance genes could ultimately make antibiotics useless anyway.
	That is being selfish and changing the natural chances that come along with reproducing.

Theme Three - Differential Success. The differential success theme relates to the concept that some individuals in a population are more successful than others at surviving and reproducing. Specific references include fitness, competition for survival, production of offspring (or inability to), and selective pressures, and natural selection. Table 7 describes this theme.

Table 7

References and examples of the Differential Success theme

References	Examples
Fitness	I would say that if you are sterile by nature your fitness is zero, evolutionary speaking.
	Evolutionary theory says that organisms that are the most "fit", survive, and fitness is a measure of an organism's reproductive success. In Darwin's terms, a couple that could not have children naturally would not be fit, and thus, their genes would not survive. However, reproductive cloning would allow them to bypass that definition.
Produce offspring	I guess everyone has the right to raise children or to fulfill their evolutionary purpose, which is to reproduce.
	In addition, humans are not much different from the other organisms on Earth – in the sense that reproducing and getting your genes into the next generation is (usually) an innately important event for which we strive. Cloning would be a way to achieve this when it is otherwise not possible.
Not all should reproduce	No. There is obviously a genetic reason why they are unable to produce a child.
	There is a reason that the couple is infertile. They aren't meant to reproduce. There could be a genetic defect in one of the parents that should not be carried on to another generation.

Table 7 (Continued)

References	Examples
Natural selection/selective pressures	It is not evolutionary fair to people who have not been engineered.
	When selective pressures are placed on the body's flora by antibiotics, the ones that best tolerate them will survive, and ultimately multiply to fill the empty niches that were formerly occupied by those that were not so well adapted. Thus, next time the antibiotic is used, only those with were more resistant will be present and the drug may not work.
	Intelligence could be a way that nature weeds out the weak genetically.
	Well, if people can't reproduce, that's natural selection. But now we can get around that with cloning. I love science, but there is a strong ethical side to this argument.
Competition for survival	The lack of competition alone will make the resistant strains stronger.

Theme Four - Change. Responses that fell into this theme relate to how populations of organisms change through time. Specific responses that were included in this theme referred to new traits or characteristics arising from mutations and genetic recombination resulting from sexual reproduction. Also included were responses relating to a change in the characteristics in a population of organisms due to either adaptations or deleterious changes. Speciation and extinction events were also included in this theme. Please refer to Table 8 for examples of responses related to change.

Table 8

References and examples for the Change theme

Reference	Example
Faster generation time leads to faster evolution	because they reproduce so rapidly it could take very little time for the disease to become more immune to the antibiotic.
Mutations lead to change	Cloning can disrupt this natural process and cause mutations, that can accumulate themselves, and cause debilitating consequences.
	also accumulate mutations which are deleterious.
Sexual reproduction leads to different/new characteristics	Sexual reproduction is the only reproduction humans are involved in. Given, it is more costly and it takes longer time to produce a set of offspring compared to asexual species, but it helps the humans to develop new characteristics (long term!).
Adaptations and/or deleterious changes/extinctions and/or just plain change/evolve	If humans as a population are unable to adapt, they will eventually become extinct.
	All of the other genes would not exist anymore and these new engineered genes would be the equivalence of an "adaptation" resulting in the new human population.
	Overtime, people adapted to their environment and their intelligence changed overtime as well
Stopping or preventing evolution	If we produce clones, we are therefore putting a momentary freeze on evolution.
Change in a population, speciation, or extinction	I would tell them that even though it may help in stopping the spread of the disease, there may be a horrible strain that arises from all the resistance and they might not be ready for it in time.
	That over time, if people employed this type of therapy, there would be no "bad" genes and there would be a race of 'intelligent' healthy humans, all the same.

Theme Five - Misconceptions. Several misconceptions about evolution were revealed in participants' responses. These included that evolution occurs on purpose or because it is "needed," that evolution has a plan or goal toward having things evolve to become "better," that asexually reproducing organisms do not evolve, and that individuals evolve or adapt (instead of populations). Table 9 includes references and examples for this theme.

Table 9

References and examples for the Misconceptions theme

References	Examples
Changes occur on purpose or because it's needed	well in order to evolve genes change to better adapt to the surroundings to make life easier. However evolution occurs when organisms need to change in order to survive and happens over generations.
	It shows that something can change its nature in order to make survival better.
	Things are constantly evolving to survive.
Evolution has a "plan"	If we enhance intelligence using gene therapy we would be completely foiling evolution's plan.
	The gene pool is being altered and Mother Nature did not intend for that to happen.
Evolution toward being "better"	The point of natural selection is to create better and better individuals in a population
	By changing they are evolving to their success.
Individuals evolve/adapt (rather than populations)	your body is always evolving and reacting to change.
	That as people came to different medical obstacles they adapt to different problems like infertility.

Theme Six – Other. Some participants mentioned other types of science content that was not explicitly tied to evolutionary theory. These included genetics, immunology, physiology, animal behavior, the process of science, and physical science. Specific examples are given in Table 10.

Table 10

References and examples for the Other Science theme

Reference	Examples
Genetics	I would say that the alteration or deletion of one gene won't affect just one trait, but could potentially cascade and affect many others for better or for worse.
	No, because the clone's lifespan would have half of the adult's, because they have less telomeres.
	telomeres are these little molecules at the end of spindle fiber in a cell which are lost little by little every time a cell divides. if you have a clone, it comes from a cell which has already undergone some division, and so the telomeres are less to begin with (from my understanding).
Immunology	You must be aware though that antibiotics do not treat or kill viruses.
	I would explain to them how the immune system works, and how a body could become immune to an antibiotic through a biological standpoint.
Process of science	Every cure for a disease has started as an experiment in animal models and then it has been tried on people with their consent.
	Look at Lucy. Successful cloning...then it died. If this process cannot be perfected with animals why attempt it with humans.

Table 10 (Continued)

Reference	Examples
Physiology	Now I don't know for sure, but one would probably expect that cloning would have a higher success rate because you don't have to hope that the egg in any method was fertilized since here it is only one set of genetic material so it is fertilized. You would just have to hope that the egg that is implanted is "accepted" in the uterus and starts to grow.
	The human is not a static organism. It is changing at all times to keep homeostasis. If it gets use to something, they over time the thing in question will not effect it in the same way. It is a built in defense mechanism to keep the body healthy.
Behavior	It is biologically natural for a woman to want to have a child and if it is the same genetic material, why not?
Non-biology	For anything that is set into motion, there is also an equal and opposite reaction.

Depth of Science Content Use

Once participants' responses had been placed into their appropriate themes, a rubric (see Table 11) was created to measure the depth of use of evolutionary science content. Working together, the primary investigator and the biology expert used five transcripts to create an initial rubric. During this process, it was noted that some students would give a response utilizing a term but without explaining what the term meant. For example, when asked how a topic related to evolutionary theory, a student replied, "It's natural selection." While this is not a particularly deep statement, it was used in the proper context. On the other hand, when asked the same question of another student, the response explained natural selection without using the term, "natural selection" as follows: "Basically according to evolutionary theory, the one that is stronger and more fit than the rest will survive and will pass its genes on. Bacteria that have the resistance genes will continue to live and reproduce." In order to accommodate both types of responses, the original rubric contained separate sections for proper use of terminology and for accurate explanations. While a third section was created to distinguish between students who mentioned content related to evolution before the last question, which prompts them to do so. The terminology and explanation sections were each scored on a scale of -1 (for misconceptions) to 3 (for use of multiple terminology or concepts) for an entire scenario, while evolution use was an extra point. Thus, with the initial rubric each scenario had a possible score range of -2 to 7.

After creating the initial rubric, the primary investigator and biology expert independently scored an additional ten transcripts. During the independent scoring process, both the primary investigator and biology expert came to a similar conclusion that some participants were giving multiple deep explanations throughout a single scenario. However, based on the initial rubric, this was worth the same three points as a participant who gave not-so-deep explanations in three separate places within a single scenario. Therefore, it was decided that scores for each explanation throughout a scenario would be added up so that the upper maximum had no set limit. In addition, with the initial rubric, participants who gave explanations using proper terminology were given a higher score due to the use of terminology. Because the intent of the SSI-Q is to measure depth of use of evolution concepts and not whether or not a student has an advanced vocabulary, it was agreed that the rubric could be simplified by merging the terminology and explanation sections and awarding a single point for the use of terminology within the proper context but with no further explanation. Points for an explanation would be based on the number of different concepts accurately used regardless of the presence of specific terminology. Responses with inaccurate explanations or ones that revealed a misconception resulted in the subtraction of a point from the overall score for each occurrence. Concepts that were repeated during a scenario did not receive any additional points.

In order to establish that the rubric was conceptually sound and establish its consistency, a third researcher with expertise in SSI and biology was asked to examine the rubric and go over the scores of one to score five, randomly selected transcripts with the primary investigator. Five transcripts was not a large enough number to calculate interrater reliability; however, a consensus was reached for all five transcripts, and it was determined that the rubric was an appropriate measure of depth of content use during SSI negotiation. The final rubric and detailed examples from participants' responses occur below in Tables 11 - 15. The rubric in Table 11 was designed to be general enough to adapt to various SSI scenarios.

Table 11

Socioscientific Issues Questionnaire rubric

Score	Explanation
-1	Inaccurate explanation or reveals misconception
0	No explanation or explanation too vague to determine its accuracy
1	Explanation incorporates 1 concept or term
2	Explanation somewhat deeper by incorporating 2 concepts
3	Deep explanation incorporates 3 or more concepts
+1	Add a point for use of evolutionary concepts before being prompted to do so
Total	Add up the score for participant's responses to questions within each scenario.

The following three tables provide selected examples of scoring for each of the three scenarios. The first table (Table 12) details scores from the cloning scenario. A justification for each example is also provided.

Table 12

Examples from Cloning Scenario

Score	Scenario question	Example
-1	Should individuals who want to carry and have their own children be able to choose cloning as an option?	I am not sure if it would be a good idea, because the whole point of reproduction is to mix genes and create a greater human population. (***Misconception that evolution has a purpose and that the purpose is to create "better"***)
0	In what ways does the above scenario connect to evolutionary theory?	In evolution you need a continuous flow of genes constantly changing. (***Meaning is unclear***)
1	How would you convince a friend or acquaintance of your position?	Maybe there won't be as large of a gene pool one day and this could cause bad results in reproduction. (***Refers to genetic variation***)
2	Is there anything else you might say to prove you are right?	As stated above, genetic variation is the basis for natural selection. There must be a variance for selection to place pressure on. ***(Refers to variation and differential success***)
3	Using as much scientific evidence as possible, how would you convince a friend or acquaintance of your position?	Since the majority of people are able to reproduce, the use of cloning as a means of reproduction wouldn't be too frequent, so I feel like it might not have too great of an effect on the gene pool of the population. Also – there are many other organisms that reproduce asexually, in a similar manner to cloning. In addition, humans are not much different from the other organisms on Earth – in the sense that reproducing and getting your genes into the next generation is (usually) an innately important event for which we strive. Cloning would be a way to achieve this when it is otherwise not possible. (***Refers to variation with respect to the gene pool and to asexual reproduction, inheritance of genes***)

This next table shows specific examples of scoring from the intelligence scenario. An example with a justification is provided for each possible score. Note that the justifications for examples are similar to those in the Cloning scenario.

Table 13

Examples from Intelligence Scenario

Score	Scenario question	Example
-1	In what ways does the above scenario connect to evolutionary theory?	well in order to evolve genes change to better adapt to the surroundings to make life easier. However evolution occurs when organisms need to change in order to survive, and happens over generations ***(Misconception that organisms "make" themselves evolve it that is happens because they "need" to***)
0	Can you think of an argument that could be made against the position that you have just described?	Natural selection. (***Uses the correct buzzword, but no explanation***)
1	In what ways does the above scenario connect to evolutionary theory?	Overall the populations will gravitate toward one of super intelligence. (***Refers to change in a population over time***)
2	How could someone support that argument?	If everyone were intelligent there would be no diversity in the genes. Eventually there would be a super intelligent population outshining the rest. (***Refers to genetic diversity and change in a population through time***)

Table 13 (Continued)

Score	Scenario question	Example
3	Using as much scientific evidence as possible, how would you convince a friend or acquaintance of your position?	If natural selection acts on genes and their frequencies in a population, then they require certain things like variety and differential reproductive success to function properly. If genes are controlling some portion of intelligence, then natural selection should act on intelligence just like any other trait. Thus, we need variety in the genes for intelligence among the human population. (***Refers to differential success, variation, differential success again***)

Table 14 shows examples of scoring of responses from the antibiotics scenario. Note the similarities between justifications for this scenario and the Cloning and Intelligence scenarios.

Table 14

Examples from Antibiotics Scenario

Score	Scenario question	Example
-1	In what ways does the above scenario connect to evolutionary theory?	Your body is always evolving and reacting to change. ***(Misconception that organisms "make" themselves evolve it that is happens because they "need" to***)
0	In what ways does the above scenario connect to evolutionary theory?	In terms of evolution, antibiotics will literally have no use because everyone's illnesses will eventually become resistant to every type of antibiotic. (***unclear***)

Table 14 (Continued)

Score	Scenario question	Example
1	Using as much scientific evidence as possible, how would you convince a friend or acquaintance of your position?	Even without antibiotics, bacteria would be evolving into harder to beat diseases. (***Refers to change over time***)
2	Using as much scientific evidence as possible, how would you convince a friend or acquaintance of your position?	Since antibiotics are not always 100 % effective, some bacteria will survive and reproduce, passing antibiotic resistance on to their offspring. (***Refers to differential success and inheritance of traits***)
3	In what ways does the above scenario connect to evolutionary theory?	This scenario is looking at adaptations that increase the organism's survival fitness. Those that survive the antibiotics can reproduce and pass on the trait that increases survivership, thus the resistant strain. ***(Refers to differential success, inheritance of genes, and change (e.g., new strain))***

Table 15 demonstrates how a depth score was made for an entire scenario. In this case, the cloning scenario was used. Subscores are given for participants' responses to each of the seven questions on the SSI-Q. In addition, an extra point is given if the participant mentioned evolutionary content before the prompt question. The seven subscores and extra point, if applicable, are then summed up to give a total depth score for a scenario.

Table 15

Example of a depth score

Scenario question	Participant's response	Explanation	Score
Should individuals who want to carry and have their own children be able to choose cloning as a reproductive option? Why or why not?	Yes, I believe that could be a choice that couples can make if they are unable to have children normally.	No evolutionary science content	0
Using as much scientific evidence as possible, how would you convince a friend or acquaintance of your position?	I would say that if the couple was unable to have children any other way, and were mentally and financially able to support a child, then it should be allowed, although they should be made aware of the success rate that cloning has achieved thus far.	No evolutionary science content	0
Can you think of an argument that could be made against the position that you have just described?	Some would argue that it's morally wrong to allow reproductive cloning that is a couple couldn't have children naturally, then perhaps they shouldn't try as there might be something wrong with them physically that cloning themselves would only exacerbate the problem.	Too vague to determine	0
How could someone support that argument?	They could hypothesize that a couple that is not 100% healthy that chooses reproductive cloning could being into the world a child that is unequally healthy	Refers to inheritance of traits	1

Table 15 (Continued)

Participant’s response	Explanation	Score	
If someone confronted you with that argument, what could you say in response? How would you defend your position against his/her argument?	I would say that I would not support reproductive cloning if the parents were not healthy and disease-free. If a couple was healthy, however, I would not see a problem.	No evolutionary science content	0
Is there anything else you might say to prove you are right?	<blank>	No response	0
In what ways does the above scenario connect to evolutionary theory?	Evolutionary theory says that organisms that are the most "fit", survive, and fitness is a measure of an organism's reproductive success. In Darwin's terms, a couple that could not have children naturally would not be fit, and thus, their genes would not survive. However, reproductive cloning would allow them to bypass that definition.	Refers to differential success and inheritance of genes	2
Use of evolution content before prompted?	They could hypothesize that a couple that is not 100% healthy that chooses reproductive cloning could being into the world a child that is unequally healthy	Yes	1
Total			4

Research Question 2

The second research question, “What is the nature of the interaction between evolution understanding and evolution acceptance as they relate to depth of use of evolution content during SSI negotiation?”, tested the hypothesis that the nature of one’s acceptance of evolution is a mitigating factor in how evolution content is used during SSI negotiation. Answering this question required the examination of participants’ evolution understanding, evolution acceptance, and average depth of use of evolution content during negotiation of the three SSI scenarios.

A multiple regression analysis was done using average depth of evolution content as the criterion variable and evolution understanding and evolution acceptance as the predictor variables, which are described in Chapter 4. In addition, these two variables were centered, and their product used as a third predictor variable so that the interaction effect between the two could be analyzed (Jaccard & Turrisi, 2003). Using this method to examine interaction effects in a multiple regression determined whether or not the effect of evolution understanding on depth of content use during SSI negotiation was mediated by evolution acceptance.

Summary

This chapter described the methods that were used to explore the relationship between acceptance and understanding of evolutionary theory during SSI negotiation in terms of depth of evolution content used. It explained how participants' responses were analyzed to give a clear picture of science content used during SSI negotiation. It also the development of the SSI-Q and how responses were scored to give a rating for depth of content use during SSI negotiation. Finally, the multiple regression method used to explore the relationship between depth of content use, evolution understanding, and evolution acceptance was described. The following chapter presents results on the types of science content and depth which was utilized used during SSI negotiation, descriptive statistics for evolution understanding and evolution acceptance, and an analysis of how understanding and acceptance interact to influence depth of evolution used during SSI negotiation.

Chapter 4

Introduction

The purpose of this chapter is to present the results of this study. Because the method for answering the first part of research question one involved an inductive data analysis, a detailed account of participants' use of science content during socioscientific issues (SSI) negotiation is given in a descriptive manner. Results from the second part of research question one, "How deeply do students use science content during SSI negotiation?" are reported next. The method for answering the second research question was quantitative, and the results are presented accordingly with descriptive statistics on evolution understanding and evolution acceptance, reported results from the multiple regression analysis, and the relationship between the variables, depth of content, evolution understanding, and evolution acceptance.

RQ 1A: Science Content Evoked During SSI Negotiation

Research question 1A was "What specific science content do college students evoke during SSI negotiation?" Students utilized science content during negotiation for each of the three scenarios: gene therapy for intelligence, reproductive cloning, and the use of preventative antibiotics. Science content found in each of the three scenarios fell into six themes. Four of the themes related specifically to evolutionary theory (variation, inheritance of traits, differential success, and change through time), and a fifth was described as misconceptions related to evolution. The sixth theme was categorized as other science that wasn't explicitly tied to evolution. A brief description of each theme is below. Please refer to Chapter Three (pp. 56 - 61) for a fuller description.

Four themes related to evolution were variation, inheritance, differential success, and change. The variation theme included acknowledgement that phenotypic and/or genetic variation exists in a population of organisms and/or is necessary for evolution to occur. Also included were references to a population's gene pool. The inheritance theme included references to the inheritance of traits or the passing of genes from parent(s) to offspring. Also included were responses that referred to the notion that not all traits are passed on because some are due to environmental effects (i.e. nature versus nurture) and general references to reproduction. Differential success related to the concept that some individuals in a population are more successful than others at surviving and reproducing. Specific references include fitness, competition for survival, production of offspring (or inability to produce offspring), and selective pressures, and natural selection. Responses that fell into the change theme relate to how populations of organisms change through time. Specific responses that were included in this theme referred to new traits or characteristics arising from mutations and genetic recombination resulting from sexual reproduction. Also included were responses relating to a change in the characteristics in a population of organisms due to either adaptations or deleterious changes. Speciation and extinction events were also included in this theme.

Because several misconceptions about evolution were revealed in participants' responses, a separate theme for misconceptions was made. These included that evolution occurs on purpose or because it is "needed," that evolution has a plan or goal toward having things evolve to become "better," and that individuals evolve or adapt (instead of populations). Finally, a theme for other science content included genetics, immunology, physiology, animal behavior, the process of science, and physical science.

The SSI-Q first asked participants for their reason for or against the issues presented in the scenario. Next, they were asked to give a potential counterargument, followed by a rebuttal to that counterargument. Due to the order of the questions, results are presented in terms of the main argument (participants' initial reason for or against an issue), counterargument, and supporting or additional evidence for their main argument (rebuttal). The SSI-Q also asked participants to relate the scenario to evolution. In cases where responses recapitulated a prior response, results are incorporated with that. Responses that revealed a misconception are reported with other misconceptions. Participants used science-based ideas in each of these three major ways; however, there were differences in how each was expressed due to the situation-specific nature of each scenario. For that reason, the descriptions of content evoked during SSI negotiation are given by scenario.

Cloning Scenario

The cloning scenario (see Appendix A) asked participants if they felt that infertile couples should be allowed to utilize reproductive cloning if that technology were available. Science content employed during negotiation of this scenario was used in a variety of ways: as a main argument against cloning, a main argument in favor of cloning, a counterargument, and as support for an argument. The content fell into each of the six themes and is described in further detail below and in Table 16.

Variation. Content within this theme was used as a main argument against reproductive cloning or as support to a possible counterargument. It was not used as a main argument for cloning or as supporting evidence for a main argument. The most common main argument was against reproductive cloning with the claim that, as a form of asexual reproduction, its widespread use would decrease genetic variation within the human population. However, some students counter-argued that this would not be the case, while others used the counter argument that cloning is not unnatural because asexual reproduction occurs in nature. Please see Table 16 for specific examples of how participants' used this theme during the reproductive cloning scenario.

Inheritance. Participants used science content related to inheritance as a main argument against reproductive cloning, a main argument for it, or as a potential counter-argument. It was not used as supporting evidence for a main argument. Science content within this theme related to cloned offspring being identical to the parent. In many cases this was used as an argument against reproductive cloning because of the potential to perpetuate undesirable or deleterious traits. Others used inheritance of traits as an argument in favor of reproductive cloning because it gives a person an opportunity to pass on traits or genes. Table 16 shows examples of how participants' used this theme during the reproductive cloning scenario.

Differential Success. The notion of differential success was used as a main argument or in support of a main argument against reproductive cloning. It was not used to argue in favor of reproductive cloning. The majority of content that fell into this theme related to the idea that people who are sterile have zero reproductive fitness and that reproductive cloning would interfere with natural selection. In other cases, students used the content related to differential success as part of other points in their argument. Please see Table 16 for specific examples of how participants' used this theme during the reproductive cloning scenario.

Change. The notion of change in a population over time was only used as a main argument against reproductive cloning or as supporting evidence against it. Content related to change in a population through time was used to argue against reproductive cloning based on the notion that widespread use of this technology would greatly reduce the rate at which human evolution occurs. There were also cases where the concept of change in a population through time (evolution) was used in a broader context to support a main argument. Table 16 shows examples of how participants' used this theme during the reproductive cloning scenario.

Table 16

Examples of participants' uses of science content for the reproductive cloning scenario

Theme	Main argument against cloning	Counterargument	Main argument for cloning	Support for an argument
Variation	No. The offspring would then have the same genetic material of one of the parents which would decrease the genetic variation and not be beneficial to the population.	It wouldn't be going against nature because nature has asexual reproduction so it is relatively the same things just humans doing it.	<not used>	<not used>

Table 16 (Continued)

Theme	Main argument against cloning	Counterargument	Main argument for cloning	Support for an argument
Inheritance	A couple that is not 100% healthy that chooses reproductive cloning could bring into the world a child that is unequally healthy There could be a genetic defect in one of the parents that should not be carried on to another generation.	An argument would be that couples who can't have children naturally have an option to continue to pass on their genes (although not combined genes with the partner's genes to the 'clone' offspring.) In this way his/her genes are not lost.	Having children spreads your genes and in turn furthers your evolutionary history.	<not used>

Table 16 (Continued)

Theme	Main argument against cloning	Counterargument	Main argument for cloning	Support for an argument
Differential success	Cloning could also be considered interfering with natural selection (and thus evolution), since you'd technically be adding another set of genes to the population that didn't come about on their own.	Well, if people can't reproduce, that's natural selection. But now we can get around that with cloning. I love science, but there is a strong ethical side to this argument. If a person has 'good' genes to survive well enough, they can pass on their same exact genes through their clone but this would result in a bottleneck effect where the variation in genes of a population will drastically lower if enough people clone themselves instead of reproducing.	<not used>	Natural selection demands variation in the population. Varying children as much as possible gives children a better chance of surviving and having an exceptional genetic composition. Cloning eliminates this genetic advantage.

Table 16 (Continued)

Theme	Main argument against cloning	Counterargument	Main argument for cloning	Support for an argument
Change	This would not allow the population to evolve as rapidly because the same genes would just be repeated over and over again. If enough people do this, the human population will take a halt in diversity and the whole population would virtually stay the same If a group of humans are unable to reproduce and instead they just clone themselves, then that group will never again be able to proceed with evolution If everyone just cloned instead of reproducing naturally evolution wouldn't occur.	<not used>	<not used>	Genetic variation is the basis for natural selection. There must be a variance for selection to place pressure on. With this our population will cease to evolve, and will eventually loose all plasticity, and a decline in longer term population growth will be seen

Misconceptions. In some cases, students revealed misconceptions regarding evolution. Misconceptions fell into two categories. The first was that asexually reproducing populations do not evolve, and the other was that evolution has some sense of purpose or design. Examples of misconceptions for all scenarios can be found in Table 19.

Other Science Content. Science content not explicitly related to evolutionary concepts was occasionally used to support an argument. In all instances, these were related to some aspect of genetics. Sometimes this included the notion of dominant and recessive genes. Other times it included inbreeding or a general knowledge of reproduction. Several students argued against reproductive cloning based on molecular genetics evidence regarding telomeres or in favor of based on the concept of nature vs. nurture. Examples of how other science content was used in this scenario are found in Table 20.

Intelligence Scenario

The intelligence scenario (see Appendix A) asked participants if scientists were able to isolate a single gene that contributes to intelligence, did they feel that gene therapy for intelligence should be allowed. Responses fell into each of the six themes and are described in further detail below and in Table 17.

Variation. This theme was used most commonly as a main argument against gene therapy for human intelligence or as supporting evidence for a potential counterargument. Many students argued against gene therapy, claiming that it would reduce genetic variation within the human population or alter the gene pool. However, some students counter-argued this by considering mutations as a source of genetic variation. Specific examples are given in Table 17.

Inheritance. This theme was not as commonly used when negotiating the intelligence scenario. In those instances in which it was used, it was to point out that germ line gene therapy would affect future generations. Please see Table 17 for specific examples.

Differential Success. This theme was used as a main argument by some participants to argue against gene therapy for intelligence and by others to argue in favor of it. In addition, it was used by many participants as support for a main argument. Please see Table 17 for specific examples.

Change. Some participants used this theme as a main argument in favor of gene therapy for intelligence, claiming that it would change the frequency of intelligent people in the human population. However, in most cases this argument was used against gene therapy for intelligence because it could potentially marginalize those who did not receive it enough to cause a speciation event. Other students argued that if an intelligence gene were beneficial for survival, there would already be a selective pressure for that gene and a change in the population would occur anyway. Specific examples are given in Table 17.

Table 17

Examples of participants' use of science content for the intelligence scenario

Theme	Main argument against gene therapy	Counterargument	Main argument for gene therapy	Support for an argument
Variation	If everyone were intelligent there would be no diversity in the genes We need the variety in intelligence to maintain the diversity of the human population. if our human population all contained genes for increased intelligence, there would be less variety in the population.	Perhaps this can give rise to mutations in that gene that can increase intelligence even more, so it has the potential of increasing genetic diversity even though you are changing it to some specific gene.	<not used>	<not used>

Table 17 (Continued)

Theme	Main argument against gene therapy	Counterargument	Main argument for gene therapy	Support for an argument
Inheritance	<not used>	<not used>	<not used>	The genes in question will be passed down from generation to generation and a sort of artificial evolution will be created in order to form the super intelligent individuals
Differential success	This would be just another form of eugenics just instead of not allowing the weak to breed, the stronger breed stronger than before. Think of all the arguments made for eugenics and there you go	<not used>	More intelligent people can come up with better ideas to help the masses.	It could potentially screw up the whole competition for better jobs. Survival of the fittest. We would still have crime, and prisons, etc. Only now they are really smart criminals that could take advantage of the normal people who weren't born with gene selection

Table 17 (Continued)

Theme	Main argument against gene therapy	Counterargument	Main argument for gene therapy	Support for an argument
Change	Eventually there would be a super intelligent population outshining the rest. Indigenous people would not benefit and become more marginalized. They would become a different species eventually if they didn't integrate into modern society.	<not used>	It would create a super intelligent society I believe yes because more intelligent people will reproduce and thus create a population of smart people.	Genes that are necessary for survival undergo evolution and modifications from generation to generation. According to the above scenario, if the gene for intelligence is not replaced, this gene naturally can undergo evolution or modifications from generation to generation, but more slowly than it could happen with the gene therapy

Misconceptions. The majority of misconceptions that emerged from the data either related to the notion that there is a purpose or plan behind evolution or that adaptations arise from an individual's desires or needs. One notably interesting response was one student who used evolutionary concepts to argue against gene therapy by stating:

> No, because we don't need smarter criminals and terrorist in this world. It could also potentially screw up the whole competition for better jobs. Survival of the fittest/smartest.

When asked how the scenario relates to evolutionary theory, this same student answered "It doesn't". This is a clear indication of the possibility that a person can utilize evolutionary concepts without even realizing it. Examples of misconceptions for all scenarios can be found in Table 19.

Other Science Content. Some students used other science content not explicitly connected to evolution to support an argument. Like the cloning scenario, this use of content was related to genetics. In some instances, it was related to pleiotropy, where a single gene can have multiple effects on the body. In other instances, the use of content was related to genetic linkage. Other genetics concepts included polygenic traits (where multiple genes contribute to a single trait) and the notion of nature vs. nurture. Examples of how other science content was used in this scenario are found in Table 20.

Preventative Antibiotics Scenario

The preventative antibiotics scenario (see Appendix A) asked participants for their opinion on the use of preventative antibiotics. As with the other two scenarios, science content used during negotiation of this one fell into each of the six themes and was used as either a main argument against the use of preventative antibiotics or as supporting evidence for the main argument as described below and in Table 18.

Variation. Variation was not a very commonly used theme, and in all instances was only used as support for a main argument rather than the main argument itself. The instances where content was used referred to sources of genetic variation, such as mutations, or in reference to variation within a population. Examples occur in Table 18.

Inheritance. Like variation, content related to inheritance was only used to enhance or support a main argument rather than as a stand-alone main argument. Please see Table 18 for specific examples.

Differential Success. The concept of differential success was the most commonly used theme in this scenario. Most used content within this theme to argue that the use of antibiotics creates an environment that allows only resistant bacteria to survive. However, the concept of differential success was also used to argue that antibiotics should not be used because they cause humans' immune systems to weaken due to a lack of selective pressure. Table 18 contains examples.

Change. Like the differential success theme, that of change in a population through time was also commonly used for this scenario as a main argument against the use of preventative antibiotics. In almost every case, this referred to the development of an antibiotic resistant strain of bacteria. Please see Table 18 for specific examples.

Table 18

Examples of participants' use of science content for the antibiotics scenario

Theme	Main argument against preventative antibiotics	Support for an argument
Variation	<not used>	Resistance can also occur due to genetic mutations within individuals.
		This could drastically change the frequency of certain diseases in a population.
Inheritance	<not used>	Bacteria that have the resistance genes will continue to live and reproduce
		An even greater threat is that the bacteria produce offspring that are able to survive the antibiotics.

Table 18 (Continued)

Theme	Main argument against preventative antibiotics	Support for an argument
Differential success	When selective pressures are placed on the body's flora by antibiotics, the ones that best tolerate them will survive, and ultimately multiply to fill the empty niches that were formerly occupied by those that were not so well adapted. Weeding out individuals with weak immune systems will only leave the fittest to reproduce, thus it will improve our population rather than keeping those who are weak alive in order to reproduce and increase their chances to be susceptible to disease.	<not used>
Change	This is the reason why more aggressive, resistant diseases are emerging.	<not used>

Misconceptions. There were two types of misconceptions revealed by participants' responses to this scenario. The first was that evolution arises from a desire or need. The second type of misconception was that individuals evolve (as opposed to populations evolving). Please see Table 19 for examples.

Other Science Concepts. There was a wider variety of other science concepts used by participants for this scenario than for the cloning and intelligence scenarios. Some participants mentioned prokaryotic genetics, while others used immunology content by differentiating between viruses and bacteria and how antibiotics are not effective with viruses. Still others used biochemistry. Finally, some students made reference to the process of science or nature of science." Please see Table 20 for examples.

Misconceptions

As mentioned during the descriptions of science content used for SSI negotiation for each of the three scenarios, misconceptions were revealed by nearly one-third of the participants. These misconceptions fell into four categories: that asexually reproducing populations do not evolve, that there is a purpose or design to evolution, that adaptations arise from an individual's desire or need, and that individuals, rather than populations, evolve. While the number of misconceptions was equally distributed among the three scenarios, none of these categories appeared in all three scenarios. The misconception that asexually reproducing populations do not evolve was only noted in responses to the scenario. That there was a purpose or design to evolution was noted in responses to the cloning and gene therapy for intelligence scenarios. The misconception that adaptations arise out of a need or desire emerged from the gene therapy for intelligence and preventative antibiotics scenarios, while the misconception that individuals, rather than populations, evolve was only noted in the preventative antibiotics scenario. Please see Table 19 for examples.

Table 19

Misconceptions for all scenarios

Scenario	Asexually reproducing populations do not evolve	Purpose or design to evolution	Adaptations arise from an individual’s desire or need	Individuals evolve
Cloning	It bypasses any form of selection since there is no assortment or even partner. It is asexual reproduction.	Evolution as far as natural selection goes has built in mechanisms which is why people may not be able to have children in the first place The whole point of reproduction is to mix genes and create a greater human population If it were a favorable option for natural selection, it would have already occurred. It has not for a reason	< no examples>	< no examples>

Table 19 (Continued)

Scenario	Asexually reproducing populations do not evolve	Purpose or design to evolution	Adaptations arise from an individual's desire or need	Individuals evolve
Intelligence	< no examples>	Intelligence could be a way that nature weeds out the weak genetically. If we enhance intelligence using gene therapy we would be completely foiling evolution's plan The gene pool is being altered and Mother Nature did not intend for that to happen. The point of natural selection is to create better and better individuals in a population	Well in order to evolve genes change to better adapt to the surroundings to make life easier. However evolution occurs when organisms need to change in order to survive, and happens over generations.	< no examples>

Table 19 (Continued)

Scenario	Asexually reproducing populations do not evolve	Purpose or design to evolution	Adaptations arise from an individual's desire or need	Individuals evolve
Antibiotics	< no examples>	< no examples>	Bacteria and diseases have the ability to evolve and protect themselves from us killing them to ensure the future of their existence. It shows that something can change its nature in order to make survival better.	The human body is not a static thing. It is always evolving and changing and that is how the body becomes immune to the antibiotics, via evolution

Other Science Content

Table 20 shows examples of science content not directly related to evolution. In the reproductive cloning and gene therapy for intelligence scenarios all science content not directly related to evolution was related to some aspect of genetics. The antibiotics scenario, on the other hand, contained a greater variety of responses with non-evolution science content. This is not surprising given that reproductive cloning and gene therapy are types of biotechnology, while the issue of the use of preventative antibiotics is more of a medical issue.

Table 20

Science content other than evolutionary topics utilized during SSI negotiation

Topic	Subtopic	Example	Scenario
Genetics	Dominant and recessive genes	I would say that there is no genetic combination and if the father had a genetic disease then it passed on to his child, but if there was a reproduction, then it would result to a recessive allele which could not express the disease if the gene was dominant.	Cloning
	Inbreeding	Look at inbreeding. The more closely related two people are, the higher the chance for genetic mutations and complications for the offspring.	Cloning
	General reproduction	I would respond in saying that cloning, parthenogenesis, and hermaphroditism is present in many species and works successfully for them.	Cloning

Table 20 (Continued)

Topic	Subtopic	Example	Scenario
Genetics	Telomeres	Telomeres are these little molecules at the end of spindle fiber in a cell which are lost little by little every time a cell divides. If you have a clone, it comes from a cell which has already undergone some division, and so the telomeres are less to begin with (from my understanding).	Cloning
	Nature vs nurture	If the parents really want to raise their own children and this is the only way possible, there are other factors that relate to the development of a human child. Environmental factors play a huge role in the personality, experiences, and knowledge of an individual. Thus, even though the child may look identical to a parent, its personality could be quite different. And its experiences would be as well.	Cloning
		This scenario connects to evolutionary theory via the nature versus nurture argument. One side argues that it is solely the genes that result in an organism being what it is, while the other side argues that it is the environment that shapes an organism. In this scenario, the hypothesis is that changing a gene would make potential offspring smarter, but I believe it will not work unless changes are made to the environment as well.	Intelligence

Table 20 (Continued)

Topic	Subtopic	Example	Scenario
Genetics	Pleiotropy	If we took that particular gene away, would it affect something else?	Intelligence
	Genetic linkage	What if the ‘unintelligent genes’ were linked to some other important genes that we’re unaware of? Deletion of these genes may then be detrimental to the health of the individual or create unforeseen problems.	Intelligence
	Polygenic traits	It is one thing to be able to change eye color; we have isolated all the genes responsible for eye color; but intelligence is a multi-faceted abstract thing that arises not just from one gene, but from many	Intelligence
	Prokaryotic genetics	resistance of *Staph aureus* was obtained via lateral gene transfer from *Enterococcus faecalis*. Bacteria can pass genes even between species which means that these resistance genes could ultimately make antibiotics useless anyway	Antibiotics
Immunology		And while they <antibiotics> don't kill viruses, they can help with secondary infections.	Antibiotics
Biochemistry		unless the addition of antibiotics to your system changes the way enzymes grip onto different proteins and therefore causing mutations in the genes	Antibiotics

Table 20 (Continued)

Topic	Subtopic	Example	Scenario
Process of science		The argument should be supported with an experiment where a group of patients with compromised immune system are given antibiotic and another group is not given antibiotics. Other factors such as race, gender, age should be similar. Comparing the outcome and repeating the study successfully with the same results, someone could support his/her argument. But from a scientist's standpoint, just because it hasn't happened does not rule out the fact that it is theoretically possible	Antibiotics

These results describe the types of science content utilized during SSI negotiation. This next section describes how deeply the content was utilized.

RQ 1B: Depth of Evolutionary Science Content Reflected in SSI Negotiation

Research question 1B was, "What is the depth of the evolutionary science content reflected in college students' SSI negotiation?" Depth of evolution content use was assessed using the rubric described in Chapter Three for 59 participants. Scores ranged from -0.67 – 6.00 with a mean score of 2.22 (*SD* = 1.85). This distribution approached normal (skewness = 0.64; kurtosis = -0.63); however it did not meet the Shapiro-Wilk test for normalcy (W = .9222; p = .0012). Descriptive data are also presented in Table 21.

When looking for differences in depth of evolution content between the three scenarios, there was no significant difference between the means of each type of scenario, F (2, 104) = .86, p = .4244. A repeated measures analysis showed no significant difference between participants' scores from the first to second to third scenario addressed, regardless of the order of specific scenarios, F (2, 104) = 2.42, p = .0935.

RQ 2: Depth of Content Use, Understanding and Acceptance of Evolution

Research question 2 was, "What is the nature of the interaction between evolution understanding and evolution acceptance as they relate to depth of use of evolution content during SSI negotiation?" This question was answered by examining evolution understanding and acceptance and performing multiple regression analyses. In addition to reporting results from the multiple regression analyses, results for evolution understanding and evolution acceptance are reported, as well as correlations between those and depth of content.

Evolution Understanding

A total of 52 participants completed the Conceptual Inventory of Natural Selection (CINS: Anderson, Fisher, & Norman, 2002) assessment for evolution understanding. The mean score on a scale of 0 – 20 was a 13.61. Scores ranged from 4 – 20 with a standard deviation of 4.19. The distribution appeared normal with a skewness of -0.49 and a kurtosis of -0.21. A Shapiro-Wilk test for normalcy confirmed this (W = .9596, p = .0752). Descriptive data are also presented in Table 21.

Evolution Acceptance

A total of 52 participants completed the Measure of Acceptance of the Theory of Evolution (MATE: Rutledge & Warden, 1999) assessment of evolution acceptance. Scores ranged from 44 – 100 with a mean score of 85.21 (*SD* = 13.24). The distribution was skewed (skewness = -1.05) and platykurtotic or flat (kurtosis = 1.04) and did not meet the Shapiro-Wilk test for normalcy (W = .9007; p = .0004). Descriptive data are also presented in Table 21.

Table 21

Descriptive data for the variables Depth, Understanding, and Acceptance

	Depth of evolution content	Evolution understanding	Evolution acceptance
Number	59	53	52
Mean	2.22	13.38	85.21
Standard deviation	1.85	4.16	13.24
Skewness	0.64	-0.47	1.05
Kurtosis	-0.63	-0.18	1.04
W (p)	.9222 (.0012)	.9610 (.0816)	.9007 (.0004)

Note: W = Shapiro-Wilk test for Normalcy

Relationship Between the Variables

Scatterplots of each variable (depth, understanding, and acceptance) were examined for bivariate outliers or nonlinear relationships, and none was found. Consequently, all data were used in the analysis and their relationships summarized using correlations, which are presented in Table 22. All relationships were positive. The correlation coefficient, r, for depth of content and evolution understanding was .68 (p = .0163), which indicates a strong, significant correlation between the two variables. While statistically significant, the correlation coefficient between depth of content and acceptance of evolution is not quite as strong (*r* = .44; p <. 0001)

The data were also examined to determine the extent, if any, of the correlation between whether or not a participant used evolutionary content without prompting and evolution understanding and acceptance. A positive correlation was found for evolution use and evolution understanding (r = .4037, p = .0030); however there was no significant correlation between evolution use and evolution acceptance (r = .1404; p = .3208). This correlation alone does not imply a causal effect, though it seemed reasonable to surmise that understanding evolution would have been a prerequisite to using its content to negotiate an SSI. The lack of a correlation between evolution use and evolution acceptance is notable because it raised a couple of possibilities. The first possible explanation was that a lack of acceptance did not necessarily mean that one wouldn't use the evolution content, and the second possible explanation was that the individual was not aware that the concepts being utilized were related to evolution.

Table 22

Correlations between variables used in this study

	Depth	Understanding	Acceptance
Depth	1.0		
Understanding	0.6768 (p = .0163)	1.0	
Acceptance	0.4377 (p <.0001)	0.4774 (p = .0003)	1.0

Multiple Regression

A multiple regression analysis is only meaningful if certain assumptions are met. These include a linear relationship between variables, homoscedascity (homogeneity of variance), and normal distribution of the residuals (predicted minus observed values). An examination of scatterplots revealed linear relationships among the variables. In order to examine the homoscedasticity assumption, the residuals were plotted with the predicted values. This assumption did not appear to be violated, and the residuals were normally distributed (sk = 0.06, ku = -0.05). Outliers were screened for using studentized residuals and Cook's D. The maximum values found were 2.2 and 0.16, respectively, indicating that none of the data points were having an undue influence on the regression analysis. Based on the screening of the data, it appeared appropriate to proceed with the multiple regression analysis.

The multiple regression analysis predicting depth of use of evolution science content from the predictor variables, evolution understanding and evolution acceptance gave an R^2 value of .452. This suggests that about 45% of the variance in depth of use of evolution content is accounted for by the predictors, understanding and acceptance of evolution. Further studies are needed to determine what other types of variables might account for the remainder of the variance.

Cohen's (1992) effect size, $f^2 = R^2/(1-R^2)$, was computed to be .82, which can be interpreted as a large effect using Cohen's rough guidelines for multiple regression (.02 small, .15 medium, .35 large). This indicates that the R^2 value of .452 is of practical significance and explains how statistical significance was achieved even with the small sample used in this study.

The regression coefficient for understanding was statistically significant ($t = 5.13$, $p < .0001$), while the regression coefficient for acceptance was not ($t = 1.21$, $p = .2306$). The prediction equation was:

$$\text{Depth} = -2.815 + .2534(\text{understanding}) + .0188\ (\text{acceptance})$$

With this equation, if both evolution understanding and evolution acceptance were equal to zero, then we would expect depth of content use to equal -2.8. This negative number would only arise if a participant's responses consisted of multiple misconceptions about evolution and few, if any, accurate uses of evolution content. This equation also indicates that for every increased point in evolution understanding score, depth would be predicted to increase by .25, assuming acceptance was held constant.

To get a further sense of the contribution of each predictor variable, standardized regression coefficients were calculated. Values of .6072 and .1438 were obtained for understanding and acceptance, respectively. This indicated that one standard deviation change in understanding leads to .6072 standard deviation change in predicted depth of content use if holding acceptance constant. In other words, for two people who equally accept evolution, the one who understands evolution a standard deviation more than the other will also utilize evolution content .6072 of a standard deviation deeper. Likewise, one standard deviation change in acceptance leads to .1438 standard deviation change in predicted depth of content use if holding understanding constant. Thus, for two people who understand evolution equally, the one with a standard deviation greater acceptance will utilize evolution content .1438 of a standard deviation more deeply.

Interaction Between Understanding and Acceptance

As described in Chapter Three, interaction between the predictor variables was tested for by creating an interaction variable and adding that as a predictor variable in a multiple regression analysis. The adjusted R^2 value was .500, suggesting about 50% of the variance in depth of use of evolution content is accounted for by the predictors, understanding and acceptance of evolution and the interaction variable. This adjusted R^2 was significantly larger than that from the multiple regression analysis without an interaction variable, and the regression coefficient for the interaction variable was statistically significant ($\Delta R^2 = .048$; $t = 2.38$, $p = .0215$). This indicated a bilinear interaction between understanding and acceptance of evolution and supported the hypothesis that the extent of one's acceptance of evolution is a mitigating factor in how evolution content is evoked during SSI negotiation.

Cohen's (1992) effect size $f^2 = R^2/(1-R^2)$ was computed to be .98, which can be interpreted as an extremely large effect using Cohen's rough guidelines (.02 small, .15 medium, .35 large). This indicated that the results may be of great practical significance to science educators and that the interaction between one's evolution acceptance and evolution understanding may play a greater role in SSI negotiation than previously realized.

The regression coefficient for understanding remained statistically significant ($t = 5.76$, $p < .0001$), and the regression coefficient for acceptance remained not significant ($t = 1.72$, $p = .0918$). The prediction equation was:

$$\text{Depth} = -3.99 + .28(\text{understanding}) + .03\,(\text{acceptance}) + .01\,(U*A)$$

The strength of the interaction effect was calculated by taking the difference between the R^2 values for the regression analyses with and without the interaction variable. This yields .499 - .452 = .047, indicating that the interaction effect accounts for 4.7% of the variance in depth of evolution science content used during negotiation of the three SSI scenarios. To give a better sense of how the depth of content use changed depending on the value of evolution acceptance, the simple effect for predicting depth from understanding was calculated from three different values of acceptance: the lowest (44), the mean (85), and highest (100) obtained from the sample. The three intercepts obtained were -2.854, -1.398, and -1.788 respectively. Please also see Figure 3.

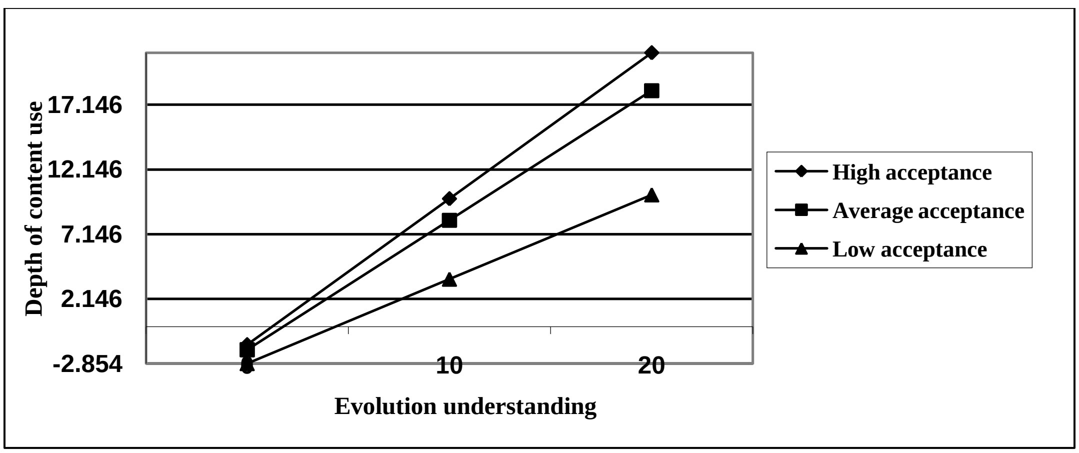

Figure 3. Slopes of how depth of content use changed depending on evolution acceptance.

Summary

Science content involved in SSI negotiation included four themes related to evolution: variation in a population, inheritance of traits, differential success, and change through time. A fifth theme included misconceptions about evolution, and a sixth included other science not explicitly tied to evolution. Content representing each of the six themes was found in each of the three scenarios. The majority of students used some evolutionary science content when negotiating the SSI scenarios; however, this was not often done to any great depth (range -0.67 – 6.0; mean = 2.22). Results from the multiple regression analysis testing for interaction effects indicate that acceptance of evolution is a mitigating factor in how deeply one utilizes evolution content when negotiating SSI. The interaction accounts for 4.7% of the variance in depth of evolution science content so that, the degree to which one who accepts evolution is likely to use evolution concepts to a greater extent depends on evolution understanding. The difference between those who are high and low on acceptance is small when understanding is low, but becomes more pronounced as evolution understanding increases.

Chapter 5

Introduction

The purpose of this study is to explore science content used during college students' negotiation of biology-based socioscientific issues (SSI) and to examine how evolution-based content relates to students' conceptual understanding and acceptance of biological evolution. This chapter first discusses the use of science content during SSI negotiation, specifically the prevalence of content related to evolution, how content varies by the context of the scenario, and the revelation of participants' misconceptions about biological evolution. Next, the depth of evolution content and its relation to evolution understanding and acceptance are discussed. The chapter closes with a discussion of implications for (1) the socioscientific issues questionnaire developed in this study and any further studies on scientific literacy, (2) science educators who use SSI as part of their research, and (3) SSI in teaching and learning.

Use of Science Content During SSI Negotiation

Prevalence of Evolution

Most of the participants in this study brought science content into their negotiation of each of the socioscientific issues, and much of the content fell into themes related to aspects of evolution: variation within a population, inheritance of traits from parent to offspring, differential success at survival and reproduction, and changes in populations over time. Though the data were analyzed in an inductive manner with no *a* *priori* assumptions regarding specific themes, the emergent themes are, nevertheless, consistent with Darwin's observations (Darwin, 1979/1859). Furthermore, while each of the scenarios used in this study was selected for its potential to utilize evolution science content, the fact that it was the dominant content used in all three scenarios is consistent with claims made by leading national organizations, such as the National Science Teachers Association (NSTA, 2003), National Academy of Sciences (NAS, 1998), National Association of Biology Teachers (NABT statement on teaching evolution located at http://nabt.org/sites/S1/index.php?p=65), and the National Research Council (NRC, 1996) that evolution is the central unifying principle of biology and that understanding it is essential to scientific literacy.

Variation by Context

While each of the themes occurred in all three SSI scenarios, there were variations in how each theme was utilized due to the situation-specific nature of each scenario. This is not surprising since other studies using multiple SSI scenarios have found variation of other factors between scenarios. Sadler (2005) made a similar observation while studying informal reasoning, as did Fowler and Amiri (2007) while studying moral sensitivity.

For example, the theme, "variation", was used in both the reproductive cloning and gene therapy for intelligence scenarios as a main argument against cloning and gene therapy because they could potentially decrease genetic variation in the human population. The preventative antibiotic scenario, on the other hand, did not use the concept of variation as a main argument. Instead, that concept was used more as support for an argument. The inheritance theme was used as an argument against cloning because of the potential for a parent to pass undesirable traits on to his or her offspring, thus perpetuating the existence of that trait. Others used inheritance to argue for cloning, claiming that it gives people an opportunity to contribute to the human gene pool. Meanwhile, the concept of inheritance was used as a supporting argument, either for or against gene therapy, with the claim that the manipulated gene would then be passed on to future generations and have a lasting effect on the human population. Content related to inheritance was used to enhance an argument rather than as a stand-alone argument in the preventative antibiotics scenario as well. Participants' use of the differential success theme was perhaps the most varied among the three scenarios. In the cloning scenario the predominant notion was that those who need this technology in order to reproduce have zero reproductive fitness and that cloning them would be contrary to natural selection. With the intelligence scenario, the argument was that gene therapy would raise overall fitness of the population. With the preventative antibiotics scenario, the major use of the differential success theme was to argue against antibiotics because they create selective pressures favorable for resistant bacteria. Change through time was used in the cloning scenario to argue against it based on the notion that widespread use would reduce the rate of human evolution. Meanwhile, the intelligence and preventative antibiotics scenarios utilized this theme to argue that gene therapy and antibiotics could cause a speciation event.

Driver, Newton, and Osborne (2000) promote the practice of argumentation in the science classroom with the claim that doing so will help students develop conceptual understanding of science content. It is not known whether or not participants in this study have had explicit exposure to argumentation techniques because that data was not collected for this study. However, that participants were able to argue using the same conceptual ideas in different contexts indicates some capability for argumentation, and this occurred with both biology and non-biology majors. It is possible that at least some of the participants practiced informal classroom argumentation while taking prior coursework. Further study is needed to determine whether or not some students acquire this capability from a deep exposure to science without explicit exposure to argumentation, such as that possibly experienced by biology majors.

Misconceptions Revealed

Misconceptions about evolution are often placed into one of two categories, those related to misunderstanding of nature of science and those related to misunderstanding the science content. Results from this study revealed several misconceptions regarding evolution, which included the following: asexually reproducing populations do not evolve; adaptations arise from a desire or need for change; there is a purpose or plan driving evolution; and individuals, rather than populations, evolve. The last three misconceptions are commonly reported in the literature (e.g. Anderson, Fischer, & Norman, 2002; Nehm & Schonfeld, 2008; Sadler, 2005); however the first, that asexually reproducing populations do not evolve, is not commonly reported. In fact, that misconception might have been entirely missed in this study had the reproductive cloning scenario not been used, because it was not revealed during the other scenarios.

The misconception that evolution is driven by some purpose or design occurred during both the cloning and intelligence scenarios, which is consistent with Sadler's (2005) findings using the same scenarios. The notion that adaptations can occur from a need or desire that an individual organism may have was noted in the intelligence and preventative antibiotics scenarios. Finally, the misconception that individuals, rather than populations, evolve was found in the preventative antibiotics scenario, but not the other two scenarios.

While these results are not surprising, they do show that the SSI-Q has the potential to significantly enhance our understanding of students' misconceptions about evolution in future studies. Since no two scenarios revealed the exact same set of misconceptions, future studies may benefit from creating a modification of the SSI-Q using a different set of SSI scenarios. Doing this may reveal other misconceptions as of yet not commonly found in the literature.

Use of Non-evolution Science Content

Other science content not explicitly related to evolution also varied by scenario. In virtually every instance, other science content was used as support or explanation for an argument rather than the main argument itself. The majority of the content in the reproductive cloning and gene therapy for intelligence scenarios was related to molecular genetics, while the preventative antibiotics scenario generated a richer variety of science content. This is not surprising given that the reproductive cloning and gene therapy for intelligence scenarios were related to biotechnology, while the preventative antibiotics scenario is related to medicine. The interesting part of this result is that while specific content may vary by scenario, content related to evolution remains fairly consistent. This is consistent with the claim that evolution is the central unifying principle of biology and that understanding it is essential to scientific literacy (NSTA, 2003; NAS, 1998; NRC, 1996).

Depth of Content Use, Evolution Understanding, and Acceptance

Relationship Between Evolution Understanding and Acceptance

Results from this study indicate a medium correlation between evolution understanding and acceptance. This is consistent with Dedniz, Donnelly, and Yilmaz (2008) who also found a correlation between evolution understanding and acceptance. The authors of that study also found that those who scored higher on an open-mindedness scale were more open to accepting evolution. Similar to that, Ingram and Nelson (2006) found that students who held no strong opinion about whether or not to accept evolution were decidedly more accepting of evolution after taking a course on evolution. In contrast, Sinatra, Southerland, McConaughy, and Demastes (2003) did not find a correlation between evolution understanding and acceptance. Their conclusion was that knowledge must reach a critical level before it can influence acceptance. This could account for the inconsistencies found in the literature because researchers sampling non-majors or first-year majors will not note a correlation to the extent of researchers sampling from students with upper level biology coursework.

In light of these prior studies, results from this current study are not surprising. They may be explained by the fact that all of the participants in this study were upper level students, and many were biology majors in their last semester of coursework. Those who could potentially come to accept evolution based on gains in understanding it would have already done so. In other words, results from this study open the possibility of a threshold of understanding evolution content that must be reached before people will accept it. Indeed, Sadler and Donnelly (2006) and Sadler and Fowler (2006) found a nonlinear relationship between content knowledge and argumentation quality, which can, but doesn't necessarily, include the use of science content. The results from this study raise the possibility that a similar relationship may exist between content understanding and depth of content use during SSI negotiation. However, this raises the question of how can evolution understanding reach a critical level without evolution acceptance? In other words, can those who adamantly do not accept evolution reach a high enough level of evolution understanding to effectively use the content during SSI negotiation? Further studies are needed to determine which pedagogical techniques may be effective in encouraging a deep evolution understanding among those who do not accept it.

Evolution Acceptance and SSI Negotiation

Results from this study support the hypothesis that the extent of one's acceptance of evolution is a mitigating factor in how evolution content is utilized during SSI negotiation. In other words, given equal understanding of evolution, one who also accepts it is more likely to use content related to evolution during SSI negotiation. This is more evident when evolution understanding is high then when it is low.

The literature suggests that informal reasoning involved with SSI negotiation contains affective patterns in addition to the rationalistic pattern (Sadler & Zeidler, 2004). Given the link between strong religious beliefs and acceptance of evolution, it is reasonable to consider acceptance an affective quality. The Sadler & Zeidler (2004) study used students' argumentation to study the informal reasoning involved in SSI negotiation.

Other studies of argumentation within a science classroom context typically examine the quality of arguments using Toulmin's (1958) argumentation pattern as a basis for analysis (Erduran, Simon, & Osborne, 2004). Rather than look at argumentation patterns, which can incorporate the use of evidence from many types of sources, this current study specifically examined whether or not and to what extent evolutionary science content was utilized to negotiate SSI.

The overall depth of use of evolutionary science content ranged from -.67 to 6.00. That the lowest score was a negative number suggests that the participant made little attempt to utilize content during SSI negotiation, and the small attempt that was made was done with inaccurate use of content. The distribution of the depth scores was slightly positively skewed. This indicates that most scores were on the low end of the scale, while the higher scores were made by fewer participants. Clearly, many students are not utilizing science content during SSI negotiation to the fullest extent possible. Possible reasons for this are discussed in the implications section beginning on page 121 of this chapter.

The tendency to utilize evolution content during SSI negotiation without being prompted to do so was correlated with evolution understanding but not with acceptance of evolution. At first blush this might seem contradictory to the finding that acceptance is a mitigating factor in depth of use of content during SSI negotiation. However, this, too, is understandable once one considers the possibility that some may readily accept concepts related to evolution as long as the word "evolution" is not mentioned. This possibility is highlighted in this study when at least one participant used the concept of differential success to argue vigorously against gene therapy then later claimed that the scenario had nothing to do with evolution. Further study on the effects of using the word "evolution" is warranted.

Implications

SSI-Q and Scientific Literacy

As described in Chapter One (page 2), one definition of a scientifically literate person is one who uses science content knowledge to make informed decisions, either personally or socially, about topics or issues that have a connection with science. The Socioscientific Issues Questionnaire (SSI-Q) developed as part of this study is a measure of the depth to which one utilizes evolution science content during SSI negotiation. While this does not directly measure scientific literacy, there exists the possibility of using a modified version to tap in to at least that part of scientific literacy defined by the use of science content to make an informed decision. This could be done by broadening the depth of science content from that only related to evolution to include all science content. Though the presence of other science content was minimal in the SSI scenarios used for this study, it is quite feasible that other SSI scenarios may tap in to a broader range of science content. A reformed version of the SSI-Q could also assess the way in which science content is used, such as whether or not it is used as a main argument or a counter-argument for or against an issue. Doing this could bring science educators closer to answering the question "to what extent do people use their content knowledge when making decisions?"

Implication for Research

While the SSI-Q measures depth of content use during SSI negotiation, it is not intended to be used as an assessment of argumentation quality. This is because argumentation does not necessarily demand the use of science content during the argumentation process. Assessments of argumentation may include arguments and justifications that incorporate other factors, such as one's beliefs. Be that as it may, the finding from this study, that the extent to which one accepts evolution is a mitigating factor in the extent of content used during SSI negotiation, indicates that evolution acceptance could potentially mitigate measures of argumentation quality. For example, Sadler and Fowler (2006) developed a rubric for assessing argumentation quality within an SSI context that utilizes the justifications used to support a position. In this scoring scheme, possible scores range from zero (no justification) to four (justification with elaborate grounds and a counterposition). This rubric does not require one to use science content as justification for an argument, though it is feasible that one could do so either as a justification, grounds for the justification, or as a counter-position.

Using a rubric similar to Sadler and Fowler's (2006), Grace (2009) evaluated high school students' discussions while decision-making about SSI based on biological conservation. Reported results from this study exemplify how science content can be used to varying degrees during an assessment of argumentation. As a specific example, a Level 2 argument is one where there is an attempt to justify a decision, as in this example "Let evolution take its course because nature finds a way." (p. 558). A Level 5, on the other hand, utilizes a justification, explicit consideration of the SSI in question (biological conservation in this study), and consideration of alternatives, as in this example:

> I think that the answer is to kill some elephants humanely for their ivory which could be sold to make money for the local people. This way elephants won't be made extinct as some are saved and people's well being kept. Other things could also be tried like breeding elephants in an environment where tusks aren't needed. Then you can chop them off without killing the elephants. (p. 559)

Clearly the participant who gave Level 5 response has a deeper use of science content than the student who gave the Level 2 response.

If the degree to which a participant accepts evolution affects the extent to which science content is evoked when forming an argument, then it could potentially affect the overall rating of argumentation quality. This is particularly the case for those participants who do not accept evolution and may receive a lower rating for argumentation quality then they would have otherwise. In other words, studies that examine the complexity of an argument (e.g.: Grace, 2009; Sadler and Donnelly, 2006; Sadler & Fowler, 2006) may, in some cases, be underestimating the quality of science-based arguments in certain SSI situations.

Implications for Teaching and Learning

As discussed earlier in this chapter, the majority of the science content evoked for all three SSI scenarios was directly related to evolution concepts, and this strongly supports the claim that evolution is the central unifying principle of biology. The pedagogical uses of SSI has been convincingly argued for elsewhere (e.g., Zeidler, Applebaum, & Sadler, 2006; Zeidler & Sadler, 2008b); however, the findings of this study give even further support in favor of using an SSI-based pedagogy in the classroom for two reasons. First, it shows that the use of SSI throughout a biology curriculum can provide a cohesive way to promote overall understanding of biology. Second, the cohesiveness of the science content can provide a vehicle for using SSI to promote socioscientific reasoning and functional scientific literacy. Zeidler and Sadler (2008) assert that because an SSI framework involves students in decision-making within a science content that it provides an ideal context for, not only promoting conceptual understanding of science and social matters, but also for developing character and reflective judgment. With this comes the claim that functional scientific literacy transcends the contextual nature of individual SSI by utilizing socioscientific reasoning, which integrates the socio-moral implications of science with the content of science.

Catley and Novick (2009) claim that, “it is impossible to have a scientifically literate public without a widespread understanding of evolutionary principles that allow us to make sense of all facets of the natural world” (p. 311), and many science educators would undoubtedly agree with this. An SSI-based biological science curriculum that focuses on topics laden with evolution content would certainly meet this need. However, the problem is that it may not have the desired effect on students who don’t accept evolution. For example, if the desired effect is to have students who can negotiate the SSI using socioscientific reasoning involving science content, students who do not accept evolution may not negotiate the SSI using the science, and therefore, socioscientific reasoning, to the extent that the teacher had anticipated. Further studies on how a lack of evolution acceptance affects socioscientific reasoning are needed to explore this further.

Summary

Results from this study indicate that evolution is an important unifying concept in biology. This was seen in that each of the four themes directly related to evolution, Variation, Inheritance, Differential Success, and Change, made up the predominant science content used by participants for each of the three SSI scenarios used in this study and that, unlike other science content, were used consistently throughout the three SSI scenarios. Results from this study also indicate that students were able to argue within different SSI contexts using the same evolution concepts. Additional studies are needed to determine whether or not this phenomenon could be used as an indicator of capacity for argumentation. In addition to its potential to assess aspects of argumentation, a modification of the SSI-Q could be used for further study about students' misconceptions about evolution or scientific literacy, if it is defined as one's tendency to utilize science content during a decision-making process within an SSI context. Finally, the hypothesis that the extent of one's acceptance of evolution is a mitigating factor in how evolution content is utilized during SSI negotiation was supported, indicating that science educators ought to consider students' acceptance of evolution when using biology-based SSI as either a research or pedagogical tool. Future studies should explore a possible relationship between students' acceptance of evolution and socioscientific reasoning within a biology-cased SSI context.

References

Abd-El-Khalick, F. (2003). Socioscientific issues in pre-college science classrooms. In D. L. Zeidler (Ed.), *The role of moral reasoning and discourse on socioscientific issues in science education*. Netherlands: Kluwer Academic Press.

Aguillard, D. (1999). Evolution education in Louisiana public schools: A decade following Edwards v. Aguillard. *American Biology Teacher*, 61(3), 182 – 188.

American Association for the Advancement of Science. (1990). *Science for all Americans*. New York: Oxford University Press.

American Association for the Advancement of Science. (2008). Retrieved June 9, 2008 from: http://www.project2061.org/publications/bsl/online/index.php?home=true

Anderson, D.L., Fisher, K.M., & Norman, G.J. (2002). Development and evaluation of the conceptual inventory of natural selection. *Journal of Research in Science Teaching,* 952 – 978.

Asami, T., Gittenberger, E., & Falkner, G. (2008). Whole-body enantiomorphy and maternal inheritance of chiral reversal in the pond snail *Lymnaea stagnalis*. *Journal of Heredity*, 552 – 557.

Behe, M. J. (1996). *Darwin's black box*. New York: The Free Press.

Berkman M.B., Pacheco J.S., & Plutzer E. (2008). Evolution and creationism and American's classrooms: A national portrait. *PLoS Biology*, 6(5), Available online at http://biology.plosjournals.org/perlserv/?request=get-document&doi=10.1371%2Fjournal.pbio.0060124.

Bingle, W.H. & Gaskell, P.J. (1994). Scientific literacy for decision-making and the social construction of scientific knowledge. *Science Education*, 87, 185 – 201.

Boulter, C.J. & Gilbert, J.K. (1995). Argument and Science Education. In P.S.M. Costello & S. Mitchell (Eds.), *Competing and consensual voices: The theory and practice or argumentation*. Clevedon, UK: Multilingual Matters.

Bowen, B.W. & Karl, S.A. (2007). Population genetics and phylogeography of sea turtles. *Molecular Ecology*, 4886 – 4907.

Catley, K.M. & Novick, L.R. (2009) Digging deep: Exploring college students' nowledge of macroevolutionary time. Journal of Research in Science Teaching, 311 – 332.

Center for Curriculum Studies. (2006). Advancement of Instructional Materials in Science. Retrieved March 1, 2007 from http://block.sec.ntnu.edu.tw/3C/en%5Fv/

Chinn, C. and Samarapungavan, A. (2001). Distinguishing between understanding and belief. *Theory into Practice*, 40, 235-241.

Clarkeburn, H. (2002). A test for ethical sensitivity in science. *Journal of Moral Education*, 31, 439 – 453.

Cohen, J. (1992). A power primer. *Psychological Bulletin*, 155 – 159.

Colburn, A. & Henriques, L. (2006). Clergy views on evolution, creationism, science, and religion. *Journal of Research in Science Teaching*, 43, 419 – 442.

Cook, L.G., Morris, D.C., Edwards, R.D., Crisp, M.D. (2008). Reticulate evolution in the natural range of the invasive wetland tree species *Melaleuca quinquenervia*. *Molecular Phylogenetics and Evolution*, 506 – 522.

Darwin, C. (1979). *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. New Jersey: Random House. (Original published in 1859).

Dawson, V. & Venville, G.J. (2009). High school students' informal reasoning and argumentation about biotechnology: An indicator of scientific literacy? *International Journal of Science Education*, 1421 – 1445.

Deniz, H., Donnelly, L.A., & Yilmaz, I. (2008). Exploring the factors related to acceptance of evolutionary theory among Turkish preservice biology teachers: Toward a more informative conceptual ecology for biological evolution. *Journal of Research in Science Teaching*, 45, 420 – 443.

Department of Children, Schools, and Families. (2008). *Organisms, behaviour, and health*. Retrieved Oct 10, 2008 from http://www.standards.dfes.gov.uk/secondary/framework/science/fwg/obh

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

Donnelly, L.A., & Boone, W.J. (2007). Biology teachers' attitudes toward and use of Indiana's evolution standards. *Journal of Research in Science Teaching*, 236 – 257.

dosSantos, W.L.P. & Mortimer, E.F. (2003). Socioscientific issues and classroom interaction: A case study. In: Fourth International Conference of the European Science Research Association - E.S.E.R.A., 2003, Noordwijkerhout-Holanda. Programme & Abstracts, CD-ROM, 2003. p. 202-203.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*. 287 -312.

Duit, R. (2007). Science education research internationally: Conceptions, research methods, domains of research. *Eurasia Journal of Mathematics, Science, & Technology Education*. 3 – 15.

Duschl, R.A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education*. 677 – 687.

Erduran, S., Simon, S., & Osbourne, J. (2004). TAPping into argumentation: developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education*, 88, 915 – 932.

European Commission. (2006). Science Teaching in Schools in Europe. Belgium: Eurydice European Unit. Available at www.eurydice.org.

Florida Department of Education (2008). *Florida Sunshine State Standards*. Available online at: http://www.fldoestem.org/Uploads/1/docs/Science%20Standards%20Both-FINAL%203-20-08.pdf.

Fowler, S.R. & Amiri, L. (2004). *The influence of content and gender on moral sensitivity about socioscientific issues*. Presented at the 2004 meeting of the Southeastern Association for Science Teacher Education, October, Gainesville, Fl.

Fowler, S.R. & Amiri, L. (2007, April). *Consistency of moral sensitivity across varying socioscientific issues*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, La.

Fowler, S.R., and Meisels, G.G. (in press). Florida Teachers' attitudes about teaching evolution. *The American Biology Teacher.*

Fowler, S.R., Zeidler, D.L., and Sadler, T.D. (2009). Moral sensitivity in the context of socioscientific issues in high school science students. *International Journal of Science Education*, 279-296.

Galindo-Sanchez, C.E., Gaffney, P.M., Perez-Rostro, C.I. (2008). Assessment of genetic diversity of the eastern oyster *Crassostrea virginica* in Veracruz, Mexico using microsatellite markers. *Journal of shellfish research*, 721-727.

Garey, J.R., McInnes, S.J., & Nichols, P.B. (2008). Global diversity of tardigrades (Tardigrada) in freshwater. *Hydrobiologia*, 101 – 106.

Gordon, C.P. (1996). Adolescent decision making: A broadly based theory and its application to the prevention of early pregnancy. *Adolescence*, 31, 561-584.

Griffith J. & Brem S. (2004). Teaching evolutionary biology: Pressures, stress, and coping. Journal of Research in Science Teaching, 41(8), 791 – 809.

Gronlund, N.E. (1993). *How to make achievement tests and assessments* (5th ed). Boston: Allyn & Bacon.

Hogan, K. (2002). Small groups' ecological reasoning while making an environmental management decision. *Journal of Research in Science Teaching*, 39, 341-368.

Hughes, G. (2000). Marginalization of socioscientific material in science-technology-society science curricula: Some implications for gender inclusivity and curriculum reform. *Journal of Research in Science Teaching*, 37, 426 – 440.

Hume, D. (1740). *A treatise of human nature: being an attempt to introduce the experimental method of reasoning into moral subjects, Volume III*. London. Based on information from English Short Title Catalogue. Eithteenth Century Collections Online. Gale Group.

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

Jaccard, J. & Turrisi, R. (2003). Interaction Effects in Multiple Regression (2nd ed), Sage University Papers Series on Quantitative Applications in the Social Sciences. Thousand Oaks, Ca.:Sage.

Jensen, M., Moore, R., Hatch, J., & Hsu, L. (2007). A scoring rubric for student responses to simple evolution questions: Darwinian components. *American Biology Teacher*, 69, 394 – 399.

Johnson, P.E. (1991). *Darwin on Trial*. Washington D.C.: Regnery Gateway.

Kittler, R., Kayser, M., & Stoneking, M. (2003). Molecular evolution of *Pedicularis humanus* and the origin of clothing. *Current Biology*, 1414 – 1417.

Kolbe, J.J., Glor, R.E., Schettino, L.R. Lara, A.C., Larson, A., & Losos, J.B. (2007). Multiple sources, admizture, and genetic variation in introduced Anolis lizard populations. *Conservation Biology*, 1612 – 1625.

Kolstø, S.D. (2006). Patterns in student's argumentation confronted with a risk-focused socio-scientific issue. *International Journal of Science Education*. 1689-1716.

Kolstø, S.D., Bungum, B., Arnesen, E., Isnes, A., Kristensen, T., Mathiassen, T.K., Mestad, I., Quale, A., Tonning, A.S.V., & Ulvik, M. (2006). Science students' critical examination of scientific information related to socioscientific issues. *Science Education*, 632 – 655.

Kuhn, D. (1991). *The skills of argument*. Melbourne, Australia: Cambridge University Press.

Kuhn, D. (1992). Thinking as argument. *Harvard Educational Review*, 155 – 178.

Lincoln, Y.S. & Guba, E.G. (1985). *Naturalistic Inquiry*. Newbury Park, Ca.: Sage Publications.

Linder, D. (2002). The Scopes trial: An introduction. Retrieved online on October 6, 2005 at http://www.law.umkc.edu/faculty/projects/ftrials/scopes/scopes.htm.

Means, M.L., & Voss, J.F. (1996), Who reasons well? Two studies of informal reasoning among children of different grade, ability, and knowledge levels. *Cognition and Instruction*, 14, 139 – 178.

Mehrens, W.A. and Lehmann, I.J. (1991). *Measurement and Evaluation in Education and Psychology. (4th ed ed.),* Chicago: Holt, Rinehart and Winston.

Melville, W., Yaxley, B. & Wallace, J. (2007). Virtues, teacher professional expertise, and socioscientific issues. *Canadian Journal of Environmental Education*, 95 – 109.

Moore, R. (2001). Educational malpractice: Why do so many biology teachers endorse creationism? *Skeptical Inquirer*, 38 – 43.

Moore R. (2008). Creationism in the biology classroom: What do teachers teach and how do they teach it?. *American Biology Teacher*, 70(2), 79 - 84.

National Association of Biology Teachers. (2008). NABT statement on teaching evolution, retrieved 9/26/08 from http://nabt.org/sites/S1/index.php?p=65.

National Center for Science Education. (2000). Evolution, creation, and science education. Retrieved June 9, 2008 from http://www.ncseweb.org/resources/articles/3117_evolution_creation_and_scien_12_7_2000.asp.

National Research Council. (1996). *National science education standards*. Washington: National Academy Press.

National Science Teacher Association. (2003). NSTA position statement: The teaching of evolution. Retrieved June 9, 2008 at http://www.nsta.org/pdfs/PositionStatement_Evolution.pdf.

Nehm, R.H. & Schonfeld, I.S. (2007). Does increasing biology teacher knowledge of evolution and the nature of science lead to greater preference for the teaching of evolution in schools?. *Journal of Science Teacher Education*, 18. 699 – 723.

Norris, S.P., (1995). Learning to live with scientific expertise: Toward a theory of intellectual communalism for guiding science teaching. Science Education (201-217.

Norris, S.P. & Phillips, L.M. (1994). Interpreting pragmatic meaning when reading popular reports of science. *Journal of Research in Science Teaching*. 947 – 967.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, 41, 994-1020.

Pedretti, E. (1999). Decision making and STS education: Exploring scientific knowledge and social responsibility in schools and science centers through an issues-based approach. *School Science and Mathematics*, 99, 174-181.

Perkins, D. N., Farady, M., & Bushey, B. (1991). Everyday reasoning and the roots of intelligence. In J. F. Voss, D. N. Perkins & J. W. Segal (Eds.), *Informal reasoning and education* (pp. 83-105). Hillsdale, NJ: Lawrence Erlbaum Associates.

Pew Forum on Religion and Public Life. (2005). Public divided on origins of life. Retrieved May 30, 2008 at: http://pewforum.org/surveys/origins/.

Reis, P. & Galvao, C. (2004). Socio-scientific controversies and students' conceptions about scientists. *International Journal of Science Education*, 26, 1621 – 1633.

Roberts, D. A. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.) *Handbook of research on science education,* 729–780. Mahwah, NJ: Lawrence Erlbaum Associates.

Rutledge, M.L. (1996*). Indiana high school biology teachers and evolutionary theory: Acceptance and understanding*. Doctoral dissertation, Ball State University.

Rutledge, M.L. & Sadler, K.C. (2007). Reliability of the measure of acceptance of the theory of evolution (MATE) instrument with university students. *The American Biology Teacher*, 332 – 335.

Rutledge, M.L. & Warden, M.A. (1999) Development and validation of the measure of acceptance of evolutionary theory of evolution instrument. *School Science and Mathematics*, 99, 13 – 18.

Sá, W.C., West, R.F., & Stanovich, K.E. (1999). The domain specificity and generality of belief bias: Searching for a generalizable critical thinking skill. *Journal of Educational Psychology*, 91, 497 – 510.

Sadler, T.D. (2003). *Informal reasoning regarding socioscientific issues: The influence of morality and content knowledge*. Doctoral dissertation, University of South Florida.

Sadler, T.D. (2004). Moral sensitivity and its contribution to the resolution of socio-scientific issues. *Journal of Moral Education*, 33, 339 – 358.

Sadler, T.D. (2005). Evolution theory as a guide to socioscientific decision-making. *Journal of Biological Education*, 39, 68 – 72.

Sadler, T.D. (2007). The aims of science education: Unifying the functional and derived senses of scientific literacy. *Proceedings of the Linnaeus Tercentenary Symposium*, 85 – 89.

Sadler, T.D., Amirshokoohi, A., Kazempour, M., & Allspaw, K.M. (2006). Socioscience and ethics in science classrooms: Teacher perspectives and strategies. *Journal of Research in Science Teaching*, 43, 353 – 376.

Sadler, T.D., Chambers, F.W., & Zeidler, D.L. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. *International Journal of Science Education*, 19, 387 – 409.

Sadler, T. D., & Donnelly, L. A. (2006). Socioscientific argumentation: The effects of content knowledge and morality. *International Journal of Science Education*, 28, 1463 - 1488.

Sadler, T.D. & Fowler, S.R. (2006) A Threshold Model of content knowledge transfer for socioscientific argumentation, *Science Education*, 90, 986 - 1004.

Sadler, T.D. and Zeidler, D.L. (2004). The morality of socioscientific issues: construal and resolution of genetic engineering dilemmas. *Science Education*, 88, 4 – 27.

Sadler, T.D. and Zeidler, D.L. (2005). Patterns of Informal Reasoning in the Context of Socioscientific Decision-Making. *Journal of Research in Science Education*, 42, 112 - 138.

Samarapungavan, A., Vosniadou, S., & Brewer, W.F. (1996). Mental models of the earth, sun, and moon: Indian children's cosmologies. Cognitive Development, 11, 491-521.

Sandoval, W. A., & Millwood, K. A. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and Instruction, 23*, 23-55.

Santos, J.R.A. (1999). Cronbach's alpha: A tool for accessing the reliability of scales. *Journal of Extension*, 37, retrieved Nov. 25, 2008 from http://www.joe.org/joe/1999april/tt3.html.

Sinatra, G.M., Southerland, S.A., McConaughty, F., Demastes, J.W. (2003). Intentions and beliefs in students' understanding and acceptance of biological evolution. *Journal of Research in Science Teaching*, 510 – 528.

Toulmin, S. (1958). *The uses of argument*. Cambridge: Cambridge University Press.

Turner, T.F., Trexler, J.C., Harris, J.L., & Haynes, J.L. (2000). Nested cladistic analysis indicates population fragmentation shapes genetic diversity on a freshwater mussel. *Genetics*, 777-786.

Walker, L.L., (1998). *Genetic variation in Chrysopsis floridana Small, the endangered Florida golden aster, as revealed by random amplification for polymorphism detection (RAPD)*. Masters thesis, University of South Florida.

Weld J., and McNew J.C. (1999). Attitudes towards evolution. *The Science Teacher*. 66(9), 27–31.

Wood, P.K. & Kardash, C. (2002). Critical elements in the design of critical thinking studies. In B.K. Hofer & P.R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing*. Mahwah, NJ: Erlbaum.

Zeidler, D.L. (2007). An inclusive view of scientific literacy: Core issues and future directions. *Proceedings of the Linnaeus Tercentenary Symposium*, 72 – 84.

Zeidler, D.L., Applebaum, S. & Sadler, T.D. (2006). *Using socioscientific issues as context for teaching content and concepts*. Paper presented at the Annual Meeting of the Association for Science Teacher Education, Portland, OR.

Zeidler, D.L., Osborne, J., Erduran, S. Simon, S., & Monk, M. (2003). The role of argument and fallacies during discourse about socioscientific issues. In D.L. Zeidler (Ed.), *The role of moral reasoning on socioscientific issues and discourse in science education*. The Netherlands: Kluwer Academic Press. (pp. 97-116).

Zeidler, D.L. & Sadler, T.D. (2008a). Social and ethical issues in science education: A prelude to action. Science and Education, 799 – 803.

Zeidler, D.L. & Sadler, T.D. (2008b). The role of moral reasoning in argumentation: Conscience, character and care. In S. Erduran & M. Pilar Jimenez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 201-216). The Netherlands: Springer Press.

Zeidler, D. L., Sadler, T. D., Callahan, B. E., & Applebaum, S. (2009). Advancing reflective judgment through socioscientific issues. *Journal of Research in Science Teaching*. 74 – 101.

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, 357 – 377.

Zeidler, D.L., Walker, K.A., Ackett, W.A., & Simmons, M.L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas, *Science Education*, 86(3), 343-367.

Zimmerman, M. (1987). The evolution-creation controversy: Opinions of Ohio high school biology teachers, *Ohio Journal of Science*, 115 – 125.

Zohar, A. and Nemet, F. (2002). Fostering student's knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching*, 39, 35-62.

Appendices

Appendix A: SSI Questionnaire

For each of the 3 topics, participants were asked to read a passage about topic and a related SSI scenario. They were then asked the following set of questions.

1. Should <gene therapy be used to increase the intelligence of potential offspring>? Why or why not? ***The purpose of this question was to determine the participants' position on the issue.***

2. Using as much scientific evidence as possible, how would you convince a friend or acquaintance of your position? ***The purpose of the above question was to give the participant an opportunity to offer a rationale to his or her position and allow an additional opportunity for participants to use science content in his or her reasoning.***

3. Can you think of an argument that could be made against the position that you have just described?

4. How could someone support that argument?

The purpose of these 2 questions was to give the participant an opportunity to pose a counter position and allow an additional opportunity to prompt the participants to use science content in his or her argument.

5. If someone confronted you with that argument, what could you say in response? How would you defend your position against his/her argument? For example, if someone said __________, how would you use science content to defend your position against his/her argument?

6. Is there anything else you might say to prove you are right?

7. In what ways does the above scenario connect to evolutionary theory?

The purpose of this last question was to encourage the participant to include evolution content in his/her SSI negotiation.

Issue: Gene Therapy

Gene Therapy Reading

Germ-line gene therapy is a potential genetic technology. It has not yet been used in humans. This type of gene therapy would involve altering a gene in an individual's sex cells (egg or sperm cells) or in a newly conceived embryo (just after fertilization). The intent of gene therapy would be to remove an undesirable gene and replace it with a preferred gene. The sex cell or embryo resulting from gene therapy would possess the "new" gene and would be missing the "old" gene.

Scenario: Intelligence

We know that a person's intelligence is controlled by a variety of factors including both environmental and genetic influences. It is likely that several genes contribute to a person's intelligence. No single factor, whether genetic or environmental, could completely determine a person's intelligence; however, it is conceivable that scientists could find a single gene that at least contributed to an individual's intelligence. If science were able to isolate a gene that significantly contributed to a person's intelligence, should that gene be used for gene therapy to increase the intelligence of potential offspring?

Issue: Cloning

Cloning Reading

The process of cloning is designed to produce an organism genetically identical to another organism. In the normal process of mammalian reproduction, genetic material from an egg cell and a sperm cell combine during fertilization to produce a new genetic combination. The new genetic makeup of the offspring is distinct from both parents. The fertilized egg cell will eventually develop into a new offspring.

In cloning, the genetic material of an unfertilized egg cell is removed, and a complete set of genetic material (from a donor) is inserted into the egg cell. The donor genetic material can be relatively obtained from most body cells (for example, skin cells). The egg cell which carries the donor's genetic material can be stimulated to grow as if it were a fertilized egg. The cloned offspring would be genetically identical to the donor organism.

Scenario: *reproductive cloning*

Many otherwise healthy couples are unable to bear children. Modern reproductive technologies like fertility drugs and in-vitro fertilization have enabled some of these individuals to have their own children. However, some couples remain infertile and unable to have a baby. For these individuals, cloning could be used as another reproductive technology. In this case, one of the parents would serve as the genetic donor. The donor's genetic material would be inserted into an egg cell, and then the embryo (the egg carrying a complete set of the donor's genetic material) would be implanted into the woman. The embryo would develop into a fetus and eventually be born a baby. Should individuals who want to carry and have their own children be able to choose cloning as a reproductive option?

Issue: Antibiotics

Antibiotics reading

Antibiotics is the general class of medications, including penicillin, that are used against bacteria and also some parasites. Antibiotics do not work against any viruses. The first ever discovered antibiotic was penicillin. Antibiotics are probably the largest ever breakthrough in health. They are responsible for the end of the scourge of humanity from a variety of plagues and diseases. Almost all bacterial conditions can be treated by antibiotics. A major area of controversy with antibiotics is over-use of them in everyday treatment. Because antibiotics are helpful and rarely cause major side effects, they are easy for doctors to prescribe. Patients ask for them because people are coming to know how effective they can be, and request them from their doctor. Antibiotics are widely used as both a treatment and as prevention against various bacterial conditions. The problem that over-use of antibiotics creates is the emergency of antibiotic-resistant strains of certain diseases. There are several types of disease that are becoming resistant to various antibiotic drugs, making them more difficult to treat successfully.

Scenario: Preventative antibiotics

Antibiotics do not kill viruses. Thus, the use of antibiotics against a virus such as flu or the common cold will not treat the condition. However, many doctors prescribe antibiotics for people with cold or flu in order to prevent bacterial diseases, particularly in patients whose immune systems are compromised, such as those with AIDS, chemotherapy, or organ transplants. This preventive use of antibiotics applies especially to the prevention of secondary infections or opportunistic infections. Should antibiotics continue to be used as a preventative measure?

Appendix B: Conceptual Inventory of Natural Selection (CINS: Anderson, Fisher & Norman, 2002)

Your answers to these questions will assess your understanding of the Theory of Natural Selection. Please choose the answer that best reflects how a biologist would think about each question.

Galapagos finches

Scientists have long believed that the 14 species of finches on the Galapagos Islands evolved from a single species of finch that migrated to the islands one to five million years ago (Lack, 1940). Recent DNA analyses support the conclusion that all of the Galapagos finches evolved from the warbler finch (Grant, Grant & Petren, 2001; Petren, Grant & Grant, 1999). Different species live on different islands. For example, the medium ground finch and the cactus finch live on one island. The large cactus finch occupies another island. One of the major changes in the finches is in their beak sizes and shapes as shown in this figure.

Choose the one answer that best reflects how an evolutionary biologist would answer.

1. What would happen if a breeding pair of finches was placed on an island under ideal conditions with no predators and unlimited food so that all individuals survived? Given enough time,

A. the finch population would stay small because birds only have enough babies to replace themselves.

B. the finch population would double and then stay relatively stable.

C. the finch population would increase dramatically.

D. the finch population would grow slowly and then level off.

2. Finches on the Galapagos Islands require food to eat and water to drink.

A. When food and water are scarce, some birds may be unable to obtain what they need to survive.

B. When food and water are limited, the finches will find other food sources, so there is always enough.

C. When food and water are scarce, the finches all eat and drink less so that all birds survive.

D. There is always plenty of food and water on the Galapagos Islands to meet the finches' needs.

3. Once a population of finches has lived on a particular island with an unvarying environment for many years,

A. the population continues to grow rapidly.

B. the population remains relatively stable, with some fluctuations.

C. the population dramatically increases and decreases each year.

D. the population will decrease steadily.

4. In the finch population, what are the primary changes that occur gradually over time?

A. The traits of each finch within a population gradually change.

B. The proportions of finches having different traits within a population change.

C. Successful behaviors learned by finches are passed on to offspring.

D. Mutations occur to meet the needs of the finches as the environment changes.

5. Depending on their beak size and shape, some finches get nectar from flowers, some eat grubs from bark, some eat small seeds, and some eat large nuts. Which statement best describes the interactions among the finches and the food supply?

A. Most of the finches on an island cooperate to find food and share what they find.

B. Many of the finches on an island fight with one another and the physically strongest ones win.

C. There is more than enough food to meet all the finches' needs so they don't need to compete for food.

D. Finches compete primarily with closely related finches that eat the same kinds of food, and some may die from lack of food.

6. How did the different beak types first arise in the Galapagos finches?

A. The changes in the finches' beak size and shape occurred because of their need to be able to eat different kinds of food to survive.

B. Changes in the finches' beaks occurred by chance, and when there was a good match between beak structure and available food, those birds had more offspring.

C. The changes in the finches' beaks occurred because the environment induced the desired genetic changes.

D. The finches' beaks changed a little bit in size and shape with each successive generation, some getting larger and some getting smaller.

7. What type of variation in finches is passed to the offspring?

A. Any behaviors that were learned during a finch's lifetime.

B. Only characteristics that were beneficial during a finch's lifetime.

C. All characteristics that were genetically determined.

D. Any characteristics that were positively influenced by the environment during a finch's lifetime.

8. What caused populations of birds having different beak shapes and sizes to become distinct species distributed on the various islands?

A. The finches were quite variable, and those whose features were best suited to the available food supply on each island reproduced most successfully.

B. All finches are essentially alike and there are not really fourteen different species.

C. Different foods are available on different islands and for that reason, individual finches on each island gradually developed the beaks they needed.

D. Different lines of finches developed different beak types because they needed them in order to obtain the available food.

Venezuelan guppies

Guppies are small fish found in streams in Venezuela. Male guppies are brightly colored, with black, red, blue and iridescent (reflective) spots. Males cannot be too brightly colored or they will be seen and consumed by predators, but if they are too plain, females will choose other males. Natural selection and sexual selection push in opposite directions. When a guppy population lives in a stream in the absence of predators, the proportion of males that are bright and flashy increases in the population. If a few aggressive predators are added to the same stream, the proportion of bright-colored males decreases within about five months (3-4 generations). The effects of predators on guppy coloration have been studied in artificial ponds with mild, aggressive, and no predators, and by similar manipulations of natural stream environments (Endler, 1980).

Choose the one answer that best reflects how an evolutionary biologist would answer.

9. A typical natural population of guppies consists of hundreds of guppies.

Which statement best describes the guppies of a single species in an isolated population?

A. The guppies share all of the same characteristics and are identical to each other.

B. The guppies share all of the essential characteristics of the species; the minor variations they display don't affect survival.

C. The guppies are all identical on the inside, but have many differences in appearance.

D. The guppies share many essential characteristics, but also vary in many features.

10. Fitness is a term often used by biologists to explain the evolutionary success of certain organisms. Which feature would a biologist consider to be most important in determining which guppies were the "most fit"?

A. large body size and ability to swim quickly away from predators

B. excellent ability to compete for food

C. high number of offspring that survived to reproductive age

D. high number of matings with many different females.

11. Assuming ideal conditions with abundant food and space and no predators, what would happen if a mating pair of guppies was placed in a large pond?

A. The guppy population would grow slowly, as guppies would have only the number of babies that are needed to replenish the population.

B. The guppy population would grow slowly at first, then would grow rapidly, and thousands of guppies would fill the pond.

C. The guppy population would never become very large, because only organisms such as insects and bacteria reproduce in that manner.

D. The guppy population would continue to grow slowly over time.

12. Once a population of guppies has been established for a number of years in a real (not ideal) pond with other organisms including predators, what will likely happen to the population?

A. The guppy population will stay about the same size.

B. The guppy population will continue to rapidly grow in size.

C. The guppy population will gradually decrease until no more guppies are left.

D. It is impossible to tell because populations do not follow patterns.

13. In guppy populations, what are the primary changes that occur gradually over time?

A. The traits of each individual guppy within a population gradually change.

B. The proportions of guppies having different traits within a population change.

C. Successful behaviors learned by certain guppies are passed on to offspring.

D. Mutations occur to meet the needs of the guppies as the environment changes.

Canary Island Lizards

The Canary Islands are seven islands just west of the African continent. The islands gradually became colonized with life: plants, lizards, birds, etc. Three different species of lizards found on the islands are similar to one species found on the African continent (Thorpe & Brown, 1989). Because of this, scientists assume that the lizards traveled from Africa to the Canary Islands by floating on tree trunks washed out to sea.

Choose the one answer that best reflects how an evolutionary biologist would answer.

14. Lizards eat a variety of insects and plants.

Which statement describes the availability of food for lizards on the Canary Islands?

A. Finding food is not a problem since food is always in abundant supply.

B. Since lizards can eat a variety of foods, there is likely to be enough food for all of the lizards at all times.

C. Lizards can get by on very little food, so the food supply does not matter.

D. It is likely that sometimes there is enough food, but at other times there is not enough food for all of the lizards.

15. What do you think happens among the lizards of a certain species when the food supply is limited?

A. The lizards cooperate to find food and share what they find.

B. The lizards fight for the available food and the strongest lizards kill the weaker ones.

C. Genetic changes that would allow lizards to eat new food sources are likely to be induced.

D. The lizards least successful in the competition for food are likely to die of starvation and malnutrition.

16. A well-established population of lizards is made up of hundreds of individual lizards.

On an island, all lizards in a lizard population are likely to . . .

A. be indistinguishable, since there is a lot of interbreeding in isolated populations.

B. be the same on the inside but display differences in their external features.

C. be similar, yet have some significant differences in their internal and external features.

D. be the same on the outside but display differences in their internal features.

17. Which statement best describes how traits in lizards will be inherited by offspring?

A. When parent lizards learn to catch particular insects, their offspring can inherit their specific insect-catching-skills.

B. When parent lizards develop stronger claws through repeated use in catching prey, their offspring can inherit their stronger-claw trait.

C. When parent lizards' claws are underdeveloped because easy food sources are available, their offspring can inherit their weakened claws.

D. When a parent lizard is born with an extra finger on its claws, its offspring can inherit six-fingered claws.

18. Fitness is a term often used by biologists to explain the evolutionary success of certain organisms. Below are descriptions of four fictional female lizards. Which lizard might a biologist consider to be the "most fit"?

	Lizard A	Lizard B	Lizard C	Lizard D
Body length	20 cm	12 cm	10 cm	15 cm
Offspring surviving to adulthood	19	28	22	26
Age at death	4 years	5 years	4 years	6 years
Comments	Lizard A is very healthy, strong, and clever	Lizard B has mated with many lizards	Lizard C is dark colored and very quick	Lizard D has the largest territory of all the lizards

A. Lizard A

B. Lizard B

C. Lizard C

D. Lizard D

19. According to the theory of natural selection, where did the variations in body size in the three species of lizards most likely come from?

A. The lizards needed to change in order to survive, so beneficial new traits developed.

B. The lizards wanted to become different in size, so beneficial new traits gradually appeared in the population.

C. Random genetic changes and sexual recombination both created new variations.

D. The island environment caused genetic changes in the lizards.

20. What could cause one species to change into three species over time?

A. Groups of lizards encountered different island environments so the lizards needed to become new species with different traits in order to survive.

B. Groups of lizards must have been geographically isolated from other groups and random genetic changes must have accumulated in these lizard populations over time.

C. There may be minor variations, but all lizards are essentially alike and all are members of a single species.

D. In order to survive, different groups of lizards needed to adapt to the different islands, and so all organisms in each group gradually evolved to become a new lizard species.

Appendix C: Measure of Acceptance of the Theory of Evolution (MATE: Rutledge & Warden, 1999)

For the following items, please indicate your agreement or disagreement

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

_____ 1. Organisms existing today are the result of evolutionary processes that have occurred over millions of years.

_____ 2. The theory of evolution is incapable of being scientifically tested.

_____ 3. Modern humans are the product of evolutionary processes that have occurred over millions of years.

_____ 4. The theory of evolution is based on speculation and not valid scientific observation and testing.

_____ 5. Most scientists accept evolutionary theory to be a scientifically valid theory.

_____ 6. The available data are ambiguous (unclear) as to whether evolution actually occurs.

_____ 7. The age of earth is less than 20,000 years.

_____ 8. There is a significant body of data that supports evolutionary theory.

_____ 9. Organisms exist today in essentially the same form in which they always have.

_____ 10. Evolution is not a scientifically valid theory.

_____ 11. The age of earth is at least 4 billion years.

_____ 12. Current evolutionary theory is the result of sound scientific research and methodology.

Appendix C (continued)

_____ 13. Evolutionary theory generates testable predictions with respect to the characteristics of life.

_____ 14. The theory of evolution cannot be correct since it disagrees with the Biblical account of creation.

_____ 15. Humans exist today in essentially the same form in which they always have.

_____ 16. Evolutionary theory is supported by factual historical and laboratory data.

_____ 17. Much of the scientific community doubts if evolution occurs.

_____ 18. The theory of evolution brings meaning to the diverse characteristics and behaviors observed in living forms.

_____ 19. With few exceptions, organisms on earth came into existence at about the same time.

_____ 20. Evolution is a scientifically valid theory.

Appendix D: Sample participation information sheet

Name: ____

Major: ____

Age? _______

Gender? ________

With which ethnicity do you most identify? ________________________________

____

With which religion(s) do you most identify? If you do not identify with any, please write none. ____

Please list any prior college level coursework you have taken in the biological sciences, including any advanced placement (AP) or dual enrollment courses you may have had in high school. Examples of college level coursework in the biological sciences are Biology I & II, Ecology, Genetics, Microbiology, Cell Biology, Anatomy, Physiology, Comparative Anatomy, Organic Evolution, Histology, etc.

____

Appendix E: Semi-structured interview protocol

Semi-structured interviews took place in the primary investigator's office approximately 2-5 weeks after participants completed the CINS, MATE, and SSI Questionnaire.

Part I.

Participants were asked the following series of questions for each SSI scenario given in the SSI Questionnaire. The purpose of these questions was to determine that participants' responses are consistent with responses from the SSI Questionnaire. Responses were transcribed and scored according to the rubric designed from the SSI questionnaire so that consistency between scores could be determined.

1. How do you feel about reproductive cloning? Why?
2. Some people might disagree with this. Why do you think that is?
3. What else would you say to those people who disagree?
4. So far you have mentioned <science content mentioned>. Is there any other science content that applies to how you feel about reproductive cloning?

Part II.

The following questions are the oral interview on evolution developed by Nehm & Schonfeld, 2008. Questions 1, 2, and 4 were scored according to the rubric designed by Jensen, Moore, Hatchm and Hsu (2007) and correlated with participants' scores from the

CINS. Question 3 was derived from the CINS and correlated with participants' answers when they originally completed the CINS.

1. A number of mosquito populations no longer die when pesticides are sprayed on them, but many years ago pesticides killed most mosquitoes. Could you explain why many mosquitoes don't die anymore when pesticides are sprayed on them?

2. Seals can remain underwater without breathing for nearly 45 minutes as they hunt for fish. How would a biologist explain how the ability to not breathe for long periods of time has evolved, assuming their ancestors could stay underwater for just a few minutes?

3. In a population of guppies (fish), what are the primary changes that occur gradually over time?

A. The traits of each individual guppy within a population gradually change.

B. The proportions of guppies having different traits within a population change.

C. Successful behaviors learned by certain guppies are passed on to offspring.

D. Mutations occur to meet the needs of the guppies as the environment changes.

4. Cave salamanders (amphibian animals) are blind (they have eyes that are not functional). How would a biologist explain how blind cave salamanders evolved from ancestors that could see?

Part III.

The purpose of these questions was to determine whether participants' answers are consistent with their responses to the questions on the MATE.

1. Do you accept the theory of evolution? Please explain why or why not?

2. Are there some parts of the theory that you agree with and other parts that you do not? Please explain. (if necessary, prompt with "such as human evolution, age of the earth, scientific evidence", etc.)

About the Author

Samantha R. Fowler received her BS in Biology from the University of Central Florida in 1997 and immediately began working on her MS degree in Biology at the University of South Florida during which she discovered a love for teaching and changed her major to Science Education. She received her MA in Science Education with a concentration in Biology in 2000. Since then she has taught several high school biology courses. She entered the doctoral program in 2003 and has made numerous presentations at regional and national meetings and teacher workshops and authored publications related to socioscientific issues, moral sensitivity, argumentation, and evolution. In 2005 she began working for the Coalition for Science Literacy where she became Senior Social and Behavioral Sciences Researcher. In the fall of 2009, she joined the faculty of Clayton State University as Assistant Professor of Biology.