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# The Effects of Emotive Reasoning on Secondary School Students' Decision-Making in the Context of Socioscientific Issues

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The Effects of Emotive Reasoning on Secondary School Students' Decision-Making in  
the Context of Socioscientific Issues

by

Wardell A. Powell

A dissertation submitted in partial fulfillment  
of the requirements for the degree of  
Doctor of Philosophy  
in Curriculum and Instruction with an emphasis in  
Science Education  
Department of Secondary Education  
College of Education  
University of South Florida

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Keywords: ethical and moral issues, evidence-evaluation, science education.

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## **DEDICATION**

I dedicate my dissertation work to my family, friends, and mentors at the University of South Florida. First, I would like to thank my mother, Ellen Powell, for instilling in me the understanding that discipline and hard work are the keys to success. I also dedicate this work to my loving and supporting wife, Novene Powell, and our two children, Caresse and Anthony. Without your continuous support, encouragement, and understanding, this work would not have been possible.

I also thank the students, teachers, and administrators who helped make this paper possible. You have all contributed to making this research a reality. To the students who participated in this research, your thoughts and insights shed light on the potential impacts of emotions on learning. Your contribution to this study will help science educators better prepare more effective science education curriculum at the secondary school level.

## **ACKNOWLEDGMENTS**

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I came to the University of South Florida as a science teacher who wanted to accomplish more in contributing to K-12 students’ scientific literacy. Under your tutelage, I am now more equipped at contributing to the science education community in general and in particular to K-12 students’ functional scientific literacy. I plan to spend the rest of my teaching career contributing to these causes.

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## **ABSTRACT**

The discrepancy between what students are being taught within K-12 science classrooms and what they experience in the real world has been well documented. This study sought to explore the ways a high school biology curriculum, which integrates socioscientific issues, impacts students' emotive reasoning and their ability to evaluate evidence, make informed decisions on contemporary scientific dilemmas, and integrate scientific content knowledge in their reasoning on SSI. Both quantitative and qualitative methods were used to examine differences within and between an SSI treatment group and a comparison group as well as individual differences among students' responses over a semester of high school biology. Results indicated students used emotions largely to evaluate evidence and make decisions on contentious scientific dilemmas. In addition, the results showed students used newly gained scientific content knowledge to make logical predictions on contentious scientific issues. Statistical significance was found between groups of students in regard to their interest in the use of embryonic stem cell treatments to restore rats' vision, as well as students' abilities to evaluate evidence. Theoretical implications regarding the use of SSI in the classroom are presented.

## CHAPTER ONE: THE PROBLEM

### Introduction

The general public makes a plethora of non-trivial science-related decisions every day (Kolstø, 2001). Some of these decisions include, but are not limited to, making choices about preserving the environment (e.g., reducing carbon footprints, conserving drinking water sources, and landfill locations), determining whether our government should allow scientists to engage in embryonic stem cell research, and verifying when and if we should consume genetically modified foods.

Our public education system must produce graduates who are capable of making informed and responsible decisions on these issues. Many in the science education community have suggested that improving students' abilities to effectively deal with such issues represents the hallmark of democratic systems (Aikenhead, Orpwood, & Fensham, 2011; Kolstø, 2001; Miller, 1983; Miller, 1998; Sadler, 2004; Shamos, 1995). Others have argued that the ability to reason and make decisions about social dilemmas with conceptual, procedural, or technological associations with science (SSI) is regarded as important components of scientific literacy (Driver, Newton, & Osborne, 2000; Ohman & Ostman, 2008; Roberts, 2007; Zeidler & Sadler, 2011; Zeidler, Berkowitz, & Bennett, 2011; Zeidler, Walker, Ackett, & Simmons, 2002).

While the focus on students' abilities to make reasoned decisions on scientific dilemmas is not misplaced (Fleming, 1986; Kolstø, 2001a; Ratcliffe & Grace, 2003; Sadler, 2004; Zeidler & Keefer, 2003), it does appear that science education researchers have only recently recognized the important role that emotions play in students' reasoning and decision-making

regarding scientific dilemmas (Powell, Zeidler, & Huling, 2012; Sadler & Zeidler, 2005b). Earlier studies which investigated the relationship between emotions and reasoning asked participants to draw inferences from a set of premises or asked to determine whether an inference was valid or unsubstantiated based on particular premises. These studies generally suggested that emotion negatively impacts *correct reasoning* or logicity (Lefford, 1946, Melton, 1995; Oaksford, Morris, Grainger, & Williams, 1996; Palfai & Salovey, 1993). Recent studies focused on the integral emotion (i.e., the affect that is intrinsically linked to the semantic contents of the reasoning tasks where the emotion stems from the target stimuli) have shown participants reason more logically about emotional content rather than neutral contents (Blanchette & Richards, 2004; Blanchette, Richards, Melnyk, & Lavada, 2007b; Johnson-Laird, Mancini, & Gangemi, 2006).

However, the extent to which emotions influence secondary school students' scientific reasoning and decision-making abilities has recently been noted internationally in countries such as the United States, Jamaica, Sweden, Taiwan, Korea, and South Africa (Lee, Chang, Choi, Kim, & Zeidler, 2012; Zeidler, et al., 2011; Zeidler, et al., 2013). While these studies have reported that students use emotions when they are asked to make decisions on contentious issues, few studies have investigated the relationship between students' emotive reasoning and their ability to evaluate evidence and make decisions on SSI. In addition, very little research has been conducted to better understand students' abilities to integrate scientific content knowledge in their reasoning about SSI.

Therefore, the science education community must help students develop the competence to intelligibly navigate SSI by evaluating evidence and making informed decisions. Moreover, it is imperative for science educators to develop this competence within students with the

understanding that many of the choices students make on these issues are often influenced by their emotions. Since emotions appear to be large contributing factors in students' reasoning and decision-making processes (Lee, et al., 2012; Powell, et al., 2012; Sadler & Zeidler, 2005b; Zeidler, et al., 2011), science educators ought to give more consideration to students' emotive ways of reasoning. This consideration would allow science educators to better understand the influence of emotions on the ability of students to evaluate evidence and make decisions. Such understanding may then provide science educators with the evidence and arguments necessary to inform policymakers in our K-12 educational system, and teacher education programs of the need to give more consideration to students' emotive ways of learning, in our secondary school science curriculum.

With this in mind, the overall goal of this study was to design and implement a sixteen-week high school biology curriculum integrating SSI and evaluate students to determine:

1. The relation between students' emotive reasoning and their abilities to evaluate evidence and make informed decisions about contemporary scientific dilemmas.
2. The extent to which students completing this curriculum integrate scientific content knowledge during the process of reasoning about SSI.

The remainder of this chapter will provide an overview of what constitutes emotive informal reasoning. Conceptual distinctions between evidence evaluation and decision-making will also be identified. In addition, an overview of findings from previous studies on the relationship between scientific content knowledge and SSI will be delineated. Likewise, the influence of emotions on moral decisions, the lack of considerations for emotions in secondary education research, and the secondary education system in the United States lack of opportunities for students to engage in moral discourse in an effort to understand the impact of emotions on



learning will also be discussed. Finally, the relationships among SSI, character education, evidence evaluation, functional scientific literacy, and informal reasoning will be outlined.

## **Theoretical Background**

### **What is Emotive Informal Reasoning?**

For the purpose of this study, emotive informal reasoning is defined as reasoning in which individuals employ sympathy, empathy, or concern for the well-being of others to guide their decisions or course of action (Sadler & Zeidler, 2005b). In this investigation, sympathy is defined as an emotional reaction based on the apprehension of another's emotional state or condition that involves feelings of concern and sorrow for the other person (Eisenberg et al. 1994). Yet empathy is defined as a vicarious emotional response that is identical or very similar to that of the other person (Eisenberg et al. 1994). In this study, concern involves the interest or importance that one places on an event, thought, or thing.

The use of emotions to help in decision-making is not a new idea to the science education community. Empirical research has shown people routinely rely on emotions when making decisions during situations that involve controversies and risk (Finucane, Alhakami, Slovic, & Johnson, 2000; Slovic, 1999). However, students' use of emotions in general and emotive reasoning in particular, to make decisions about SSI in our secondary schools' science education curriculum has not received adequate attention by science education researchers. As a result, the main aim of this study is to advance the dialogue on the effects of emotive reasoning on students' abilities to evaluate evidence and make informed decisions on scientific dilemmas; as well as students' aptitudes to integrate scientific content knowledge in their reasoning about SSI.

To better understand the above constructs, students' informal reasoning, rather than formal reasoning, was explored. Although formal reasoning (i.e., reasoning about well-defined

problems that can be solved by information provided within the premises) has been historically known to contribute to scientific discovery, it has been suggested that such reasoning alone may not result in scientific progress (Kuhn, 1962). Furthermore, it has long been argued that most of the reasoning people do in their everyday or academic life is informal in nature (Perkins, 1985; Evans & Thompson, 2004). However, very little research has been done to investigate the relationship between students' emotions and their informal reasoning abilities.

Informal reasoning involves the generation and evaluation of positions in response to complex issues that lack clear-cut solutions (Sadler, 2004). Such reasoning has long been regarded as an important aspect of students' performance and learning (Kuhn, 1991; Perkins, 1985; Perkins, Allen, & Hatner, 1983; Sadler, 2004; Voss, Blais, Means, Green, & Ahwesh, 1986; Zeidler, Sadler, Simmons, & Howes, 2005). Recent research has shown that students often relied on emotive reasoning when they were put in a position requiring them to reason informally (Powell, Zeidler, & Huling, 2012; Sadler & Zeidler, 2005b). In examining the explicit forms of informal reasoning patterns in the context of SSI and the corresponding moral and ethical issues perceived by students, Sadler and Zeider (2005b) reviewed two decades of research, dating from the mid-1980s to the mid-2000s. From this extensive review of literature, these authors reported that students used personal experiences, emotive considerations, social considerations, morality, and their perceptions of complexity to drive their decision-making process on SSI. Since emotive reasoning appeared to have significant influence on the decision-making process of students, it is important that educators attend not only to the academic knowledge students need to succeed in the scientific fields, but also to students' emotive ways of reasoning, their moral and ethical development, as well as the moral and ethical aspects of the scientific issues with which they will be confronted. A science education curriculum that takes

into consideration students' use of personal experiences, emotive considerations, social considerations, morality, and their perceptions of complexity to drive their decision-making process on SSI may help our school systems produce graduates who are capable of making informed decisions regarding current scientific problems of this world.

According to Berkowitz and Simmons (2003), to accomplish the task of educating the entire person, it is imperative that science educators address both science education and character education simultaneously. These authors further suggest this type of education will provide students with opportunities to participate in informed reflections about ethics in science and technology, while at the same time providing students with the skills necessary to engage in social activism concerning scientific issues.

At present, the use of SSI as a key pedagogical strategy has been advocated by many in the science education community as a crucial component for preparing students to make informed decisions on scientific phenomena (Zeidler, 2003; Zeidler & Sadler, 2011; Sadler, 2011). Socioscientific issues include those issues that are complex and controversial in nature. These issues are open-ended problems that lack clear-cut solutions and are subject to multiple influences that are sometimes inconsistent or even conflicting (Zeidler & Sadler, 2011). Generally these issues have moral and ethical undertones that often allow students to use emotional ways of reasoning (Zeidler, et al. 2011). The infusion of SSI as a key pedagogical strategy in our science curriculum holds promise in helping students to enhance their abilities to evaluate evidence and make decisions. It may also help science educators to better understand the extent to which students integrate scientific content knowledge in the process of reasoning about SSI.

## **Evaluation of Evidence**

There are different interpretations of the term evaluation (Powell, Steele, & Douglass, 1996). However, the evaluation of evidence is considered to be a thoughtful process that takes into account consideration of the question(s) and topic(s) of concern and the collection of appropriate information (Powell et al., 1996). When students are asked to negotiate and arrive at conclusions on SSI, consideration of the question(s) and topic(s) are essential for informed decision making. As suggested by Sadler, Chambers, and Zeidler (2004), negotiating SSI should involve adept understanding of the content of the issue, processing information regarding the issue, attending to moral and ethical ramifications of the issue, and adopting a position on the issue. However, to engage in the above practices, the ability to analyze data should be paramount. The interpretation of data that supports or refutes the hypothesis under investigation is critical if one is to make an informed decision. Although analysis of data is important, Sadler et al. (2004) found that students may not necessarily know or understand what constitutes data and how it can be used. This should be cause for concern, especially in light of the increasing challenges that students will face in society that requires them to use scientific ways of thinking. Therefore, if students are to make appropriate decisions regarding scientific problems, then they must be presented with opportunities to help understand what constitutes data and how to analyze it.

## **Decision-Making**

There is no single definition for the term “decision-making” (Khishfe, 2012). Earlier researchers have defined decision-making as the making of reasoned choices from among alternatives (Cassidy & Kurfman, 1977). Other researchers have defined decision-making as the process of making reasoned choices among alternatives based upon judgments consistent with

the values of the decision maker (Heath, White, Berlin, & Park, 1987, p. 821). More recently, decision-making has been defined as the claim or stance that one has taken on an issue(s) that one considered (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Ratcliffe, 1996). Regardless of how the term is defined, the decision maker needs to examine the issue at hand in order to render an informed decision (Bingle & Gaskell, 1994; Kortland, 1996). For students to make informed decisions on scientific phenomena, examination of relevant scientific knowledge is important (Bingle & Gaskell, 1994). However, students must be given the opportunities to practice such skills in order to become competent at evaluating scientific evidence. This practice is paramount, since making informed decisions on SSI is regarded as an important component of scientific literacy (Driver, Newton, & Osborne, 2000; Ohman & Ostman, 2008; Roberts, 2007; Zeidler & Sadler, 2011; Zeidler, Berkowitz, & Bennett, 2011; Zeidler, Walker, Ackett, & Simmons, 2002).

To maintain our democratic way of life, students will be called upon to make informed decisions driven by the careful examination of data (Heath, White, Berlin, & Park, 1987). Opportunities in the classroom, which enhance students' understandings of what constitutes data with practice on how to analyze data, are necessary for the preparation of making informed decisions on real-world scientific problems.

### **Scientific Content Knowledge and Socioscientific Issues**

Socioscientific issues represent important social issues and problems that are conceptually related to science (Sadler, Barab, Scott, 2007). These issues have already been established as important factors in improving science content knowledge (Applebaum, Barker, & Pinzino, 2006; Sadler, 2009; Sadler, Barab, & Scott, 2007; Walker, 2003; Zeidler & Sadler, 2011; Zohar & Nemet, 2002). Previous studies already suggested that SSI, as a pedagogical

strategy, provided ideal opportunities for students to explore and apply ethical principles that are necessary for character development (Lee et al. 2012; Zeidler & Keefer, 2003). Exposure to SSI may also present opportunities to develop negotiation skills necessary for solving social problems arising from economic, ethical, and scientific tensions (Sadler, Barab & Scott, 2007). The use of SSI in the classroom encourages dialogue and debate to promote the art of developing claims, identifying and analyzing data, conducting testing and/or research to support or refute claims, and generating convincing arguments (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000). These are all practices of SSI, which improve students' knowledge in general, as well as specific content knowledge in particular.

Other studies that have examined the effects of SSI have found that carefully crafted interventions do in fact affect students' learning of science content (Sadler, 2009). These studies have been conducted in elementary, middle, and high schools throughout the United States and several other nations. For example, Barab, Sadler, Heiselt, Hickey and Zuiker (2007) directed an investigation on students' learning outcomes, including content knowledge, in the course of a learning intervention designed around a multi-user virtual environment situated in a SSI. In this investigation, 28 upper elementary school students used avatar software created to navigate a virtual park that was experiencing a steep decline in its riverine fish populations. The students were asked to collect data from the streams. Through interviews with characters within the virtual environment, they were asked to identify the cause of the problem and propose possible solutions. These researchers administered pre-/post-assessments of science content directly related to the intervention. In comparing the scores of these assessments, statistically significant changes in students' scores were discovered relating to the science content.

At the high school level, Klosterman and Sadler (2010) reported similar results in their

investigation of a three-week unit based on global warming. In this investigation, 83 students from five high school classes participated in a series of learning experiences designed to assess understandings of the science content underlying global warming, as well as understandings of the social dimensions of this SSI. These researchers developed and administered pre-/post-assessments of content directly related to the SSI curriculum. Reported results of these pre-/post-tests performances showed post-test results that were statistically and practically significant over the pre-test scores. These are examples of a few studies that show improvements in students' content knowledge, when SSI is embedded within the science curriculum.

### **Influence of Emotions on Rationalistic Informal Reasoning**

As students encounter real-world scientific dilemmas and are put in situations where they must make decisions, it is not uncommon for them to engage in rational thinking and reasoning. According to Stanovic, Toplak, and West (2008), to think rationally means adopting appropriate goals, take appropriate action given one's goals and beliefs, and holding beliefs commensurate with available evidence. While some (Kardash & Scholes, 1996; Toplak & Stanovich, 2003) argue that students should be equipped with skills which will allow them to engage in this type of thinking prior to making decisions, others recognize that such thinking is difficult; as a result, adults and children alike often avoid such thinking (Albert & Steinberg, 2011; Beyth-Morom, Fischhoff, Palmgren, & Jacobs-Quadrel, 1993; Kahneman, Slovic, & Tversky, 1982; Stanovic et al, 2008).

A number of studies have been done to simulate informal reasoning (Baron, 1991, 1995; Kuhn, 2000; Hofer & Pintrich). This type of informal reasoning has been advocated by some as important to secondary school students' educational growth, since such reasoning is so widely used both inside and outside of the classroom to help students in their decision-making on ill-

structured problems (Toplak & Stanovich, 2003; Evans & Thompson, 2004; Sadler, 2004; Sadler & Zeidler, 2005b). Informal reasoning is described as the cognitive and affective processes involved in the negotiation of complex issues and the formation, or adoption, of a position (Sadler & Zeidler, 2005b). Such reasoning plays a major role in the decision-making process of students on contentious issues.

### **Influence of Emotions on Moral Decisions**

Making appropriate decisions regarding scientific problems often requires an individual to give moral considerations to the decision at hand, evaluate the evidence presented, and decide on a correct course of action. Human emotions are surely to be aroused when citizens are confronted with the task of making decisions about whether their local government should install septic systems in their communities that may pose potential health risks to residents, where to build landfills, if nuclear power plants should be allowed, or in which communities natural gas pipelines should be constructed. To prepare a generation that will possess the knowledge and understanding to effectively deal with these issues, science educators must be prepared to create and deliver instruction that will provide opportunities for students to practice the art of using morality to make fair and equitable decisions regarding the potential costs and benefits of these ethically imbued issues.

Therefore, it is extremely important for educators to teach students how to reason effectively and how to develop skills that will allow them to evaluate evidence and make evaluative-based decisions on issues which are complex, with no clear-cut solutions, and that require morality and ethics. If our secondary schools are to produce the next generation of graduates who can help solve many of our 21<sup>st</sup> century scientific problems, then policymakers and science educators cannot continue to overlook the importance of using SSI as a key



pedagogical strategy. Unfortunately, politicians and policymakers for our K-12 education system seem to place great emphasis on high stakes testing in their effort to reform the K-12 educational system. This emphasis has resulted in many teachers being unwilling to stop the practice of teaching to the test. Such method of instruction continues to ignore the role of emotions in students' learning for a method in which high stakes testing is the central focus (Lin, 2000; Lin, Graue, & Sanders, 1990).

Students often use emotions such as love, grief, anger, and joy to reason, to express their views, and to make decisions in SSI-based classroom discussions (Powell et al., 2012; Sadler and Zeidler 2005b; Zeidler et al., 2011). Other research on the role of emotions in decision-making has shown that both positive emotions (i.e., love and joy) and negative emotions (i.e., fear and anger) can have a significant impact on judgment and choices (Clore, 1992; Forgas, 1995; Lerner and Keltner, 2000; Schwarz, 1990). From their studies on anticipated emotions, Bell (1982, 1985), Loomes, and Sugden (1982, 1986) have proposed that individuals are motivated to avoid the experience of regret or disappointment and hence make decisions to minimize the likelihood of these emotions.

### **Long Standing Views of Emotions**

The role of emotions in decision-making and judgment is not a new phenomenon. There are research studies dating back to the early 1900s and early to mid-2000s that investigated the role of emotions in risky technological projects including, but not limited to, cloning, genetically modified foods, and nuclear energy (Finucane et al., 2000; Roeser, 2006; Slovic, 1999). Results from the above studies have shown that emotions play an integral role in peoples' abilities to make judgments concerning risks (Finucane et al., 2000; Roeser, 2006; Slovic, 1999; Sustain, 2005). However, it is important to point out that many of these studies compared the influence

of emotions of professionals, such as scientists, rather than that of layperson's decision-making, on risky technological projects (Slovic, 1999).

While the influence of emotion seems to play a pivotal role in students' thinking, judgment, reasoning, and decision-making on SSI (Sadler & Zeidler, 2005b), much of the research conducted on and related to emotion and reasoning is sketchy (Blanchette & Richards, 2004; de Souza, 1987; French & Wettstein, 1998). In most of these studies, participants were exposed to what are considered well-defined problems or formal syllogisms and then asked to make a decision on the correctness of the form of the argument presented.

### **Socioscientific Issues and Character Education**

As policymakers and science educators work toward designing and implementing educational programs for future generations, it is important they do not lose sight of the psychological, social, and emotive components in the educational development of students. These education reformers of our public education system need to understand that only focusing on scientific content is not sufficient to educate the entire child. To educate students in a holistic manner in science (or any) education, character education must be part of the same engine that drives such education (Aikenhead, 2006; Berkowitz & Simmons, 2003; Lee, et al. 2011; Östman & Almqvist, 2011; Zeidler & Sadler, 2008). Character education, broadly defined, encompasses all aspects of schooling that impacts the development of social and moral competencies of students, including the capacity to reason about moral and ethical issues (Berkowitz & Simmons, 2003). Educators in general and science educators in particular, must take into consideration students' moral values, moral reasonings, moral emotions, moral identities, and meta-moral characteristics. These are all characteristics that science education researchers have suggested are important for creating one's moral blueprint, which provides us with the ability to judge our

own conduct, think about right and wrong, experience moral emotions such as guilt, empathy, and compassion, and believe in moral good (Aikenhead, 2006; Berkowitz, 2002; Berkowitz & Simmons, 2003; Green, 1985; Lee, et al. 2011; Östman & Almqvist, 2011; Zeidler & Sadler, 2008; Zeidler, Berkowitz, & Bennett, 2011).

In helping students to become scientifically literate citizens with the ability to make informed decisions in a responsible manner, it is important students are given opportunities to engage in activities that promote their character education simultaneously with their science education. However, to accomplish this task, educators must be willing to pay close attention to all the voices of conscience, moral agency, moral reflection, and students' social-justice orientation (Green, 1985; Zeidler & Sadler, 2008; Zeidler, Berkowitz, & Bennett, 2011). For example, the conscience of craft, though not the only criterion to the formation of conscience or character, is paramount in our learning since it governs our ability to be competent. As Green (1985) put it, "the conscience of craft drives us to not fall into habits of repeated exclamation of Oops." (p. 6). Teaching students how to make responsible decisions requires educators to provide genuine real-world scientific dilemmas without clear-cut solutions in order to challenge their conscience and character. Such teachings are instrumental in helping students take personal responsibility for their actions.

Oftentimes, when confronted with the task of making decisions on SSI, we use our conscience, which governs our character to critically reflect on such issues prior to rendering judgment (Green, 1999; Zeidler, Berkowitz, & Bennett, 2011). In expanding on the importance of character in our ability to evaluate evidence and make appropriate decisions, Zeidler, Berkowitz and Bennett (2011) reminded us that conscience empowers one to do well. Thus, our conscience has the potential to guide us in fulfilling our capacity to be fully what we are capable

of being by allowing us to judge our conduct and be willing to stand in judgment of our actions (Green, 1985; Zeidler, et al., 2011).

Providing students with opportunities to use personal conscience during discourse and decision-making on ill-structured problems may provide the stimulus on which character education is allowed to take root and sprout. Such experiences may prove crucial whenever students are asked to think in a scientifically responsible manner (Zeidler et al., 2011). Therefore, we need to ask ourselves if we, as science educators, are providing the fertile ground where our students' character and conscience are allowed to develop and flourish.

In an extensive review of literature regarding scientific literacy that spans almost five decades, Roberts (2007) deduced two generalized views of scientific literacy, named Vision I and Vision II. According to Roberts (2007), Vision I allows students to focus on the products and processes of science. In contrast, Vision II allows students the opportunity to focus on understanding, decision-making, and the use of science in situations removed from the traditional boundaries of science (SSI). Extending on Roberts' Vision II, Zeidler and Sadler (2011; 2008a) reminded us of the importance of morality and character in solving SSI by suggesting that informed scientific decision-making is governed by the formation of conscience through the development of virtue and practice of reflexive judgment. Zeidler (in press) further stressed that students who possess autonomy and independence will assume shared responsibility for their decisions and actions. It is hoped that students will become part of the global community with the ability to function morally in the realm of worldly scientific matters (p. 72). Students will no doubt be called upon to make responsible decisions on matters involving, but not limited to, biotechnology, global warming, and locations to build nuclear power plants. If and when they are called upon to make decisions on these issues, we should feel secure that their conscience,

character, and morals will guide their decisions and actions.

Many science education researchers have argued that it will be extremely difficult for us to achieve scientific literacy without taking into consideration students' moral reasoning, ethical considerations, and character development (Sadler & Zeidler, 2009; Zeidler & Sadler, 2011; Zeidler, et al., 2005; Zeidler, 1984; Zeidler & Keefer, 2003; Zeidler & Sadler, 2008a). Others outside of the science education community have also emphasized the importance of moral education to the educational growth of students (Dewey, 1909; Kohlberg, 1966). For example, Kohlberg (1966), from his investigation, suggested that the development of character and moral education is largely influenced by tests of moral judgment, since such tests are more genuinely developmental and reflective of basic cognitive structuring of values. This suggestion is paramount in helping students to develop their moral autonomy, that is, their ability to make moral judgments and formulate moral principles independently, rather than to conform to moral judgments of others. Kohlberg believed exposing students to activities that foster social participation and role taking would ultimately stimulate moral development.

In emphasizing the moral purpose of school, Dewey (1909) suggested that the educator (i.e., parent or teacher) has a duty to ensure that the greatest possible number of ideas acquired by children and youth are acquired in such a vital way that they become *moving ideas*, motivating forces in the guidance of conduct (p. 11). In order for students to make decisions that are guided by genuine moral values, moral education and character development must take center stage in all instruction. Dewey (1909) stressed that “moral” does not designate a special region or portion of life. He believed that it is imperative that we translate the moral into the conditions and forces of our community life and into the impulses and habits of the individual (p. 36). This is important since each and every student will eventually be trusted with the

responsibility of maintaining the continuity of society. An education system that produces students who are unable to use their morals and character to guide their actions and decisions has surely provided such students with an education that can be considered wishy-washy and vague.

SSI can provide an epistemological context for students' conceptual understandings of important scientific and social matters, thereby serving as a venue for the development of character and reflective judgment (Zeidler & Sadler, 2011). However, in order for this to become a reality, students must be presented with opportunities in their classroom setting to use moral and character traits to solve contemporary scientific problems. Doing so has the potential of providing students with the education foundation that will allow them to make informed decisions on scientific issues that lack clear-cut solutions.

### **Socioscientific Issues and Evaluating Evidence**

It is expected that students will eventually be called upon to make many choices that require careful examination of data. In anticipation of this need, Korpan, Bisanz, Bisanz, and Henderson (1997) conducted a study focusing on the types of evidence essential for formulating a comprehensive account of the evaluation process of controversial issues. Results from the Korpan et al. (1997) study reported that participants made fewer requests about what was found, who conducted the research, and where the research was conducted. The results from this investigation should be cause for concern for educators since information on what was found in the research, who conducted the research, and where the study was conducted are all pertinent to allowing one to judge the credibility of research in ways that instruction focused on facts, methodology, and theory cannot (Korpan et al., 1997). This study does add to our understanding of the criteria students use to judge the trustworthiness of scientific knowledge claims. Results of this study suggest that preparing students to become competent in questioning the social

context in which they account for how scientific phenomena is developed is crucial to enhance their ability to evaluate evidence. This skill is paramount to their educational development. Other researchers have suggested that the ability to question context is important in helping students exhibit skepticism, when they must carefully evaluate information that is biased (Sadler, 2007; Sadler, et al., 2011).

Other research also highlighted some of the difficulties students experience when they are tasked with the responsibility of evaluating evidence. A study conducted by Ratcliffe (1999) showed students have a tendency to accept information without evaluation of evidence. At a time when we want students to think for themselves, evaluate evidence, and make appropriate and informed decisions, accepting claims without evaluation only adds to the difficulty of enhancing their educational growth.

In trying to understand how students evaluate evidence, Sadler, Chambers, and Zeidler (2004) conducted a study (part of a larger study) that investigated high school students' conceptualizations of the nature of science in response to the issue of global warming. Given the importance of empirical evidence in the sciences, which is often represented by data, these researchers were surprised to discover that just under one-half (47%) of the students sampled in their investigation were unable to accurately identify and describe what constituted data. While this problem may not be indicative of all the students in our secondary school systems, this is clearly a cause for concern. If students cannot accurately identify and describe what constitutes data, how can we expect them to evaluate evidence? Or expect them to use that evidence to make informed decisions on many of our scientific problems?

In order to better understand how individuals judge the trustworthiness of SSI, Kolstø (2001) conducted a study focused on how pupils judged the validity of information encountered,

in order to arrive at a personal opinion. Results of this investigation showed that individuals used a range of strategies in deciding whom to trust and what to believe. The participants used four different resolution strategies to arrive at their decision, namely: the acceptance of knowledge claims, the acceptance of authority, the evaluation of statements, and the ability to evaluate information with regards to interest, neutrality, or competence. While it was reported that some participants in this study used all four strategies and others used fewer in their evaluation of the issues encountered, the participants of this investigation clearly failed to look at the content of the knowledge claims. Instead, they merely evaluated the source of the claims. While considering the source of the claims is important, it cannot be sufficient when one is asked to evaluate evidence in order to make informed decisions.

### **Socioscientific Issues and Functional Scientific Literacy**

It is critical to develop students' morality and their moral reasoning skills, both of which are key ingredients in developing functional scientific literacy among our students.

Zeidler and Sadler (2011) have suggested that “in the realm of SSI, functional scientific literacy means that experience with social justice, tolerance for dissenting voices, mutual respect for cultural differences, and making evidence-based decisions with consideration for how those actions may impact one's community and the larger environment, must be provided to students” (p. 179). These researchers believed acquiring such skills might provide a foundation for becoming functioning members of an informed democracy. Students who possess skills that afford them opportunities to engage in practices of careful considerations of SSI and reflective decision-making regarding those issues are able to do so because they have acquired a degree of functional scientific literacy (Zeidler et al., 2005).

Today's mounting environmental challenges will eventually generate problems that students



will one day encounter in their lives (global warming, dead zones in the Gulf of Mexico, nuclear energy, alternative fuels, etc.). Many of these problems do not have clear-cut solutions. Making responsible decisions on these problems will require the use of morality and moral reasoning, two important elements in developing functional scientific literacy. Given the importance of this type of literacy, a secondary school science education curriculum that forces public school educators to teach to the test and compel students to recall factual information on those multiple-choice examinations (Aikenhead, Orpwood, & Fensham, 2011) is doing our students as well as our society a disservice. Clearly, a science education curriculum that advocates factual knowledge creates added pressure on teachers to complete the syllabus or curriculum maps at the expense of producing students who are functionally scientific literate. This takes away from the willingness of teachers to make the classroom a place where students are given the opportunities to engage in argumentation exercises (Erduran, Simon, & Osborne, 2004; Kuhn, 1993) that are so critical for developing a functional scientific populace. Argumentation exercises in the classroom are crucial to providing students with the competence needed to advance their reflective judgment, nature of science understanding, conscience, and moral decision-making (Sadler, 2004; Sadler & Zeidler, 2005; Zeidler & Sadler, 2008a; Zeidler, Sadler, Applebaum, & Callahan, 2009; Zeidler, Osborne, Erduran, Simon, & Monk, 2003). It becomes much more difficult to produce a new generation of students who are equipped with the skills to engage in the higher forms of reasoning (SSR). The skills necessary in helping to make responsible decisions regarding scientific problems will not be acquired unless students are given opportunities to practice required skills for such reasoning. Discourse opportunities in the classroom setting are a way for educators to empower students to develop their abilities to evaluate moral and ethical factors prior to rendering judgments about the validity and viability of

situated scientific data and information that are relevant to the quality of public and environmental health (Sadler, 2011; Zeidler et al., 2005; Zeidler (In press). This is necessary in building a functional scientific literate populace.

### **Socioscientific Issues and Informal Reasoning**

Informal reasoning is defined as the cognitive and affective processes involved in the negotiation of complex issues and the formation, or adoption, of a position (Sadler, 2004). In preparing secondary school students to develop competencies in generating and/or evaluating evidence pertaining to claims or conclusions and to make appropriate decisions, teachers, especially science teachers must provide opportunities for students to engage in informal reasoning as they ponder causes and consequences, pros and cons, and positions and alternatives (Means & Voss, 1996; Zohar & Nemet, 2002). In a study exploring students' reasoning skills, Means and Voss (1996) suggested that informal reasoning assumed importance when information was less accessible, or when the problems were more open-ended, debatable, complex, or ill-structured, or especially when the issue required that the individual build an argument to support a claim (p. 140). Numerous researchers have argued that informal reasoning is important to student performance and learning (Kuhn, 1991; Perkins, 1985; Perkins, Allen, & Hatner, 1983; Sadler, 2004; Voss, Blais, Means, Green, & Ahwesh, 1986; Zeidler, et al., 2005). The importance of informal reasoning on student learning should therefore encourage educators to recognize this feature as a central role in their classrooms.

### **Intuition and Its Influence on Decision-making**

There is no single definition associated with the term intuition (Dane & Pratt, 2007). An earlier definition of the term suggested it was the psychological function transmitting perceptions in an unconscious way (Jung, 1933). Other definitions include a preliminary perception of

coherence (pattern, meaning, structure) that is at first not consciously represented, but that nevertheless guides thought and inquiry toward a hunch or hypothesis about the nature of rational thinking (Bowers, Regehr, Balthazard, & Parker, 1990). More recently, intuition has been defined as the working of the experiential system (Epstein, 2004). Regardless of how the term is defined, intuition has been known to help guide people in making a wide range of critical decisions (Bowers, Regehr, Balthazard, & Parker, 1990). In the business world, research suggests that intuition may be integral to successfully completing tasks that involve high complexity and short time horizons, such as corporate planning, stock analysis, and performance appraisal (Hayashi, 2001; Isenberg, 1984; Shirley & Langan-Fox, 1996). Students will eventually encounter situations that will demand they use their intuition to make reasonable decisions on a host of issues. To do so effectively, opportunities to develop character and morals are imperative in helping students to develop the *hunch* or *gut feeling* to make high-quality decisions relatively quickly.

### **Problem Statement**

Studies have shown that moral and ethical factors, as well as character development, represent important influences on student decision-making relating to SSI (Sadler, 2004; Sadler & Zeidler, 2002; Zeidler & Keefer, 2003; Zeidler, et al., 2005). Results of other studies have also highlighted the significance affective factors, such as emotion and intuition, have on decision-making on SSI (Evagorou, Jimenez-Aleixandre, & Osborne, 2012; Zeidler & Schafer, 1984; Zeidler, et al., 2011). Psychology literature on morality has also emphasized the significance of emotion in moral decision-making (Eisenberg, 2000; Hoffman, 2000). While such studies entail aspects of emotive reasoning, the role of emotions in reasoning with respect to how it affects the evaluation of evidence and generation of responses and resolutions to SSI have

not been adequately explored. In addition, very little research has been done to understand the extent to which students integrate scientific content knowledge in the process of reasoning about SSI. The intent of this study is to provide a better understanding of the relationships between various affective factors on students' decision-making in the context of SSI. Specifically, this investigation examined details of students' emotive informal reasoning on their abilities to evaluate evidence and make informed decisions on SSI, in addition to understanding the degree to which they integrate scientific content knowledge in the process of reasoning about SSI.

### **Research Questions**

The guiding questions of this dissertation are:

1. What relationships exist between secondary school students' emotive reasoning and their abilities to evaluate evidence related to thoughts on socioscientific issues?

**Rationale.** Students sometimes have difficulties considering all the evidence at hand, before they make decisions on contentious issues on which they are asked to judge. In fact, this seems to be a common problem when students are asked to judge and make decisions on issues for which they have entrenched beliefs (Evagorou et al., 2012; Zeidler, 1997). In order for students to properly evaluate evidence and make informed decisions, they need to possess skills necessary to incorporate all available and relevant evidence and build strong arguments to support their claims prior to arriving at a decision.

Secondary school students regularly rely on emotions whenever they are put in a position of evaluating evidence positions on controversial scientific phenomena that challenge their moral and ethical values (Powell et al., 2012; Zeidler et al., 2011). Consequently, many students do not evaluate all the evidence before they arrive at a decision (Ratcliffe, 1997). Such practices sometimes cause students to give reasons for their claim that are less than convincing. Teachers

need to understand that, by providing opportunities for students to explore consequences, principles, emotions, and intuitions, they are in essence empowering students to resolve difficult issues on their own (Sadler & Zeidler, 2002).

2. What relationships exist between secondary school students' use of emotive reasoning and their decision-making regarding socioscientific issues?

**Rationale:** Exposing students to contentious issues often evoke emotive reasoning (Powell et al., 2012; Zeidler et al., 2011). Emotive reasoning entails the ability to use sympathy, empathy, compassion, and love when asked to engage in discourse and self-reflection to determine appropriate positions on issues. One generally uses his or her emotions in response to events that are important to him or her (Frijda, 1988). For example, observing or being aware of someone's loss of a loved one or personal property may elicit sympathy, which is a form of emotion. Many of the contentious scientific issues we experience in our society often raise ethical questions. As a result, members of our society often engage in heated debates or discussions on these issues, evoking a great deal of emotions. Our secondary school students are not immune to this discourse. Most students will rely on emotions whenever they are put in a position of making decisions on controversial scientific phenomena that challenge their entrenched beliefs. As a result, it is imperative that the science education community better understand the relationship between students' emotive reasoning and their decision-making on controversial scientific issues.

3. In what ways do students integrate scientific content knowledge in the process of reasoning about socioscientific issues?

**Rationale:** Today's society is impacted by many problems that are represented by SSI. Some science education researchers have suggested that the ability to reason and make decisions

about SSI is regarded as an important component of scientific literacy (Driver, Newton, & Osborne, 2000; Ohman & Ostman, 2008; Roberts, 2007; Zeidler & Sadler, 2011; Zeidler, Berkowitz, & Bennett, 2011; Zeidler, Walker, Ackett, & Simmons, 2002). SSI has already been established as important for improvement in students' science content knowledge (Applebaum, Barker, & Pinzino, 2006; Sadler, 2009; Sadler, Barab, & Scott, 2007; Walker, 2003; Zeidler & Sadler, 2011; Zohar & Nemet, 2002). Therefore, better understanding of the manner in which students integrate scientific content knowledge in the process of reasoning about SSI is important for teachers, curriculum planners, and science teacher educators concerned about developing conceptual understanding of science within students.

### **Significance of the Study**

This study has the potential for practical and theoretical significance. The main practical outcome involves the development of an integrated socioscientific issues based biology curriculum. This curriculum could be used by teachers, in the secondary school classroom setting, to specifically focus on students' abilities to evaluate evidence, make informed decisions, and use scientific content knowledge in their reasoning on scientific dilemmas that lack clear-cut solutions. The science education community is already aware of the fact that students' thought processes about controversial SSI are not always straightforward, as moral and affective factors often involve students' use of empathy and intuition (Sadler & Zeidler, 2002; Zeidler & Schafer, 1984). The above results seem to suggest that educators cannot separate students' emotional, ethical, and moral development from the development of their academic skills.

In order for our schools to become successful in producing the next generation of graduates, who will be the critical thinkers and problem solvers of the myriad of scientific problems we now face as a society, it is imperative for us to give more consideration to students'

emotive ways of thinking and reasoning on scientific issues that are controversial and those requiring students to use moral judgment. To become successful at solving many of today's scientific problems, students must be able to include emotive reasoning in their evaluation of socioscientific dilemmas requiring moral and ethical considerations.

Therefore, the focus of this research is to explore the relationships between students' emotive reasoning, their abilities to evaluate evidence, their abilities to make informed decisions on SSI, and their abilities to integrate scientific content knowledge in the process of reasoning about SSI. It has been suggested that most moral behaviors are determined largely by emotions and habits (Wilson, 1993). Morality does influence students' character and personalities. Since students' morality provides them with values they can use to differentiate between right and wrong, issues that push students to engage their moral thoughts are central to developing decision-making skills and ability to evaluate evidence. These are all key ingredients in helping our secondary school students achieve functional scientific literacy. This study will provide the opportunity for teachers, curriculum planners, and science educators concerned about developing conceptual understanding of science to become better prepared in developing future leaders of our society.

### **Summary**

In preparing students to solve the many scientific problems we now face, it is vital that educators attend to the moral and ethical aspects of those problems. To successfully produce a new generation of students who think critically about contemporary scientific problems, it is imperative that we take into consideration students' moral and ethical ways of thinking on socioscientific issues. Studies have shown that the majority of reasoning that is done in school is informal in nature (Perkins, 1985; Sadler & Zeidler, 2005; Shaw, 1996). Since such reasoning is

rampant in our schools, teachers should use it as a way to create and provide meaningful learning experiences for students to engage in tasks that will foster their abilities to evaluate evidence and make decisions on contentious issues.

As our secondary education system strives to produce the next generation of functionally scientific-literate citizens, embracing socioscientific issues as key pedagogical strategy should be given greater considerations by education policy makers and teachers. The use of socioscientific issues can provide teachers with viable opportunities to engage students in discourse practices that require the use of morality. Providing students with opportunities to engage in dialogue and debates requiring moral reasoning will allow them to evoke emotions, and thus emotive reasoning. This will in turn allow science education researchers to become better informed on the influence of emotions on the ability of students to evaluate evidence and make decisions on SSI.



## **CHAPTER TWO: LITERATURE REVIEW**

### **Introduction**

When they are put in a position to engage in negotiation and collaboration with their peers, families, and teachers on contentious scientific issues, many secondary school students often use emotive reasoning in their decision-making process (Powell, Zeidler, & Huling, 2012; Zeidler & Sadler, 2004; Zeidler et al. 2011). While this has been observed, not many studies have investigated this phenomenon. Therefore, the focus of this research is to explore the role of emotive reasoning on students' abilities to evaluate evidence and make informed decisions on SSI, as well as to understand the degree to which they integrate scientific content knowledge in the process of reasoning about SSI.

For the purpose of this study, emotive informal reasoning is defined as reasoning in which individuals employ the use of sympathy, empathy, or concern for the well-being of others to guide their decisions or course of action (Sadler & Zeidler, 2005b). In this investigation, sympathy is defined as an emotional reaction that is based on the apprehension of another's emotional state or condition and involves feelings of concern and sorrow for the other person (Eisenberg et al., 1994). In contrast, empathy is defined as a vicarious emotional response that is identical or very similar to that of the other person (Eisenberg et al. 1994).

Since emotions seem to play such a major role in students' reasoning and decision-making on contentious issues (Powell, Zeidler, & Huling, 2012; Zeidler & Sadler, 2004; Zeidler et al. 2011), more studies are warranted to better inform the scientific community of the impact of emotions on learning. Results from these investigations may then allow science education

researchers, as well as science teachers, to better understand the degree to which students' use of emotive reasoning enhances or hinders students' abilities to evaluate evidence and make decisions on SSI. This approach may also allow education officials to get a better understanding of the extent to which students use emotions to evaluate evidence and decision-making on SSI, as well as understanding the degree to which students integrate scientific knowledge in their reasoning on SSI. However, to accomplish such a task, secondary science education curriculum must provide for teaching practices that would encourage opportunities for the emotions to be utilized. Because SSI are open-ended, ill-structured, and contentious, these issues are prime for understanding more about students' use of emotive reasoning (Sadler & Zeidler, 2005a).

This chapter will begin with an overview of SSI as a key pedagogical strategy. Students' patterns of reasoning on SSI will then follow. Research findings on students' abilities to make informed decisions on SSI, as well as students' abilities to evaluate evidence will also be highlighted. Additionally, students' use of morality and judgment in decision-making will be discussed and students' abilities to use SSI to build content knowledge will also be evaluated.

### **What are Socioscientific Issues?**

Socioscientific issues (SSI), those issues that are typically contentious in nature, can be considered from a variety of perspectives, do not possess simple conclusions, and frequently involve morality and ethics (Sadler & Zeidler, 2002). Examples of SSI include a range of dilemmas such as biotechnology, environmental issues, health effects of diets, as well as genetic engineering (Kolstø, et al. 2006; Sadler & Zeidler, 2002; Sadler, Amirshokaohi, Kazampour, & Allspaw, 2006; Zeidler, Sadler, Applebaum, & Callahan, 2009). All these issues (SSI) call upon individuals to use moral and ethical considerations to help in their evaluation of evidence and decision-making entailing controversial scientific phenomena.

## **Emotions and the Evaluation of Evidence**

Korpan, Bisanz, Bisanz, and Henderson (1997) conducted a study focusing on the types of evidence that are essential for formulating a comprehensive account of the evaluation process of controversial issues. These investigators studied the external evaluation process in which university students were asked to read news briefs about a fictitious finding in each of four domains. These researchers looked at the following:

- a) The request for information students make when evaluating scientific briefs
- b) The influence of text characteristics on the evaluation process
- c) The extent to which requests vary systematically with personal characteristics

Korpan et al. (1997) reported the majority of students asked questions about how the research was conducted and why the results might have occurred. They reported students made fewer requests for information on what was found, who conducted the research, and where the research was conducted. While these researchers reported that requests for information about relevance, including requests for information about value or applicability of the research, were more frequent than what they were expecting, they also reported that it was disappointing, but not unexpected, to have the relatively low frequency and inconsistency of requests about social context.

If we want our students to be critical thinkers, who are skeptical (Sadler et al. 2007; Sadler et al. 2011) and who can harness the skill sets necessary to become scientifically literate citizens, then school science must do more to include social context that is scientifically related into the curriculum and classrooms. Such practices will allow students to understand that social context can influence judgments concerning quality of the research, data interpretation, data quality, along with other biases of those conducting the research (Korpan et al. 1997). In order for

students to critically evaluate the validity of conclusions drawn in scientific studies, students must become aware that research institutions, funding sources for research, and publication outlets of scientific studies can influence researchers to be biased in their research findings. When students fail to consider the power of these institutions, they may become gullible. If this becomes the norm, then inaccurate statements, which may be disguised as “findings” from scientific studies, will easily be accepted. Students who are able to recognize the inherent complexity of SSI (Hogan, 2002; Pedretti, 1999; Sadler et al. 2007; Sadler et al. 2011), able to examine issues from multiple perspectives (Sadler & Zeidler, 2005; Sadler et al. 2007; Sadler et al. 2011; Zohar & Nemet, 2002), willing to appreciate that SSI are subject to ongoing inquiry (Bingle & Gaskell, 1994; Sadler et al. 2007; Sadler et al. 2011; Yang & Anderson, 2003), and are skeptical about potentially biased information (Kolstø, 2001; Sadler et al. 2007; Sadler et al. 2011; Zeidler et al. 2002) will be able to uncover opinions masquerading as scientific findings. When students develop skills that enable them to easily uncover these farcical displays, they are well on their way to becoming scientifically literate citizens.

### **Students’ Reasoning and Their Abilities to Evaluate Claims**

Ratcliffe (1999) conducted a study that investigates the nature of students’ reasoning and evaluation of media reports on contemporary scientific issues. In this investigation, three different age groups of students were involved. Group number one ranged in age from 11-14 years old, the second group consisted of students who were 17 years of age, and the third group consisted of graduate students who ranged in age from 22-35 years old. In this investigation, the younger students were presented with an article to read as a class with assistance from their teacher. The group of 17-year-old students, along with the graduate students, all read their assigned article individually. All students provided written responses to the questions that

followed from the reading. Students' written responses were analyzed, transcribed, and coded into different categories (for further details on each category see study).

All students were asked to evaluate an unjustified claim made by one of the researchers. Students were asked to agree or disagree with the statement and to explain what they thought. It was reported that more graduate students than the other two groups of students disagreed with the unjustified claim that was given by the researcher. It was further reported that graduate students were able to provide logically valid reasons for their disagreement. While it was reported that 61% of the 11-14 years-old students and 51% of the 17 years-old students disagreed with the unjustified claim given by the researcher, Ratcliffe (1999) reported that only 40% of these students were able to reason logically about their disagreement. To rectify problems that may arise as a result of students' inability to recognize different types of statements, this researcher used certainties and uncertainties as a cue. It was discovered that most 11-14 years-old students along with the 17 years-old students could, when prompted, recognize that the reports contained both established facts and areas of uncertainties. These students were able to identify certainties much easier than uncertainties. However, it was also reported that the practice of quoting directly from the reports decreased with age. Reports indicated graduate students who were involved in this investigation-summarized answers rather than quoting directly from the article with which they were presented. It was also reported that most of the graduates reasoned consistently and correctly, identified areas of certainty, and uncertainty, and presented logical arguments for their rejection of the researcher's unjustified statement.

The results of this study seem to suggest that students with more educational experience are able to appropriately evaluate evidence and formulate logical reasoning more than students with less educational experience (Sadler, 2004). If this is indeed the case, it makes sense for

educators to do more to expose students to scientific issues that will provide them with opportunities to practice and develop skills to appropriately evaluate evidence. In evaluating findings from scientific studies, it is important for students to ask questions that include not only how the research was conducted, why the results are the way they are, who was involved in the study, what the outcomes are, where the study occurred, but also who financed the study.

### **Students' Informed Decision-Making**

In an attempt to understand how students develop informed decision-making skills, Lee (2007) employed the use of an issue-based approach with 160 secondary school students. These students ranged in age from 15 to 16 years old and were from two secondary schools in Hong Kong. This investigation was divided into four different parts.

- I. Part one was for students to develop a conceptual understanding of the effects of smoking and the possible effects of exposure to secondhand smoke.
- II. Part two required students to analyze and discuss scientific data and evidence concerning harmful effects of smoking.
- III. Part three challenged students to explore their own views about smoking and to provide reasons behind their decision whether they would or would not smoke.
- IV. Part four asked students to consider and decide on arguments for and against a complete ban on smoking in restaurants.

In part one of this investigation, students created a model that collected tobacco smoke. This was done to provide students with the opportunity to develop a conceptual understanding of the possible effects of smoking. The model that students created mimicked the respiratory tract and how it collected tobacco smoke. It was reported that students were able to use their model to collect yellowish tar deposits from tobacco smoke. The researcher reported that such deposits

startled students.

Students were then given scientific data to analyze regarding the number of cancer cases that were linked to cigarette smoking. Following exposing students to this scientific data they were interviewed. It was reported that nearly all those students who were interviewed suggested that they were less inclined to smoke or that they disliked smoking as a result of what they learned from the lesson. While this lesson seems to have impacted students' decisions on whether to smoke or not to smoke, it is important to point out that no pre-test was done prior to this portion of the investigation. Therefore, it was difficult to make any comparisons between pre- and post-test results.

Although students seem to have been impacted by what they learned from this lesson, how this impact translated into decisions they will make in their own lives concerning smoking is unclear. It was reported that when students were asked if they would definitely refrain from smoking in the future, students were unable to give a definitive response. Some students in the interview had reservations towards a complete ban on smoking in restaurants. To substantiate such views, it was reported that many of these students suggested that there was only limited evidence showing that passive smoking is dangerous to one's health. These students also made suggestions that most secondhand smoke gets dispersed into the environment and thus should not cause any serious harm. They also believed such smoke is less harmful than pollutants from cars, a major source of air pollution in Hong Kong.

In addition to the above reservations towards a complete ban on cigarette smoking in restaurants, it was reported that some students were cautious about the possible social and economic consequences of the ban, regardless of the evidence that indicated secondhand smoke can be detrimental to one's health. These findings prompted this researcher to conclude some

students seem willing to put higher value on social stability than on personal or public health. While it may be important for students to exhibit skepticism when presented with potentially biased information (Kolstø, 2001; Sadler et al. 2007; Sadler et al. 2011; Zeidler et al. 2002), it is equally important for students not to allow skepticism to blindfold them from scientific evidence whenever such evidence is presented to them. If students are able to collect scientific evidence of the dangers of smoking (model) and are presented with scientific evidence of the dangers of cigarette smoking, it becomes their responsibility to use that evidence to make appropriate decisions on the issue of banning cigarette smoking in restaurants.

Based on students' views in regards to the effects of smoking, as well as secondhand smoke on one's health, these findings seem to suggest that some students in this investigation do not necessarily use scientific evidence to make decisions on matters with which they are confronted. It was reported that these students were able to collect tar from cigarettes in the respiratory tract apparatus, in addition to analyzing data that linked smoking to lung cancer deaths. Therefore, one would expect these students to use more scientific evidence in their decision-making on such issues. The use of such evidence should be critical in these students' reasoning; however, such use of evidence was non-existent. This does suggest that some students do have difficulties using scientific evidence in their reasoning on issues that are contentious (banning cigarette smoking in restaurants).

From the arguments generated by students for or against the banning of smoking in restaurants, it seems reasonable to suggest students do not always integrate scientific knowledge gained in reasoning and decision-making. As was reported earlier, students used economic and social factors to arrive at their decision, even if it meant a compromise to their health. This seems to suggest that getting students to make informed decisions can be a difficult process.



## **Influence of Context on Decision-Making**

A recent study by Molinatti, Girault, and Hammond (2010) that focused on how individuals make and justify claims and conclusions about SSI analyzed students' personal opinions on human embryonic stem cell research. It was reported students oftentimes have difficulties developing justifiable arguments. In this investigation, the authors wanted to engage students in a discourse that was personally meaningful and relevant to their lives. As a result, they formulated their study to assess the effects of contextualization on students' argumentation. In doing so, they allowed research participants to have direct interactions with scientists (neuroscientists) and a representative of an association for patients who suffer from neurodegenerative diseases.

In this investigation, there were a total of 196 high school students (107 girls and 89 boys) within seven science classes from Provence, France. The mean age of these students was 16.4 years old. All participants of this investigation were assigned the theme of the debate four to six weeks prior to engaging in actual debates. In the first part of this investigation, the participants were required to use this time to formulate their own definitions of stem cells, develop questions for future debates on stem cells, and build background information on stem cells. While participants were asked to engage in these tasks, it is important to point out that the researchers did not mention how participants were monitored throughout the four to six weeks period. A better understanding of what participants did and how they went about doing the tasks in the four to six weeks time frame would have been helpful for readers. These activities may have had an impact on the final outcome of this investigation. For example, if students procrastinated and waited until the last minute to complete what was assigned to them, this may (or may not) have had an impact on how well they argued the issue of stem cell research. Also, the fact that the

settings of this research were outside of the regular classroom settings (a cultural science center within a scientific institute), where participants may or may not have someone to motivate them and keep them on task, are all matters which could have potentially affected the outcome of this research.

In gathering students' information for this research, these researchers used three one-hour sessions on three different days to collect students' data. A description of the format employed in this investigation is listed below:

- Day one: Students were required to list the background questions they formulated during the four to six weeks period (again, no mention of what and how students formulated these questions). The participants were also required to identify one or two major issues (questions) that would serve as an outline for future debates.
- Day two: Students were asked to discuss their questions (study did not identify if it were their background questions or major issues questions) with experts. The students then took notes of the answers that were given by experts.
- Day three: Students debated the questions they identified on day one.

After the debate, students were assigned to one of two groups. One group served as the control, and students in this group met with a neuroscientist. The other group served as the contextualized group, and the students in this group met with the same neuroscientist and a representative of an association for patients suffering from neurodegenerative diseases such as Parkinson's disease, multiple sclerosis, and Huntington Chorea.

After meeting with the individuals described above, students were asked to give their definition of embryonic stem cells. They were also asked to provide oral arguments for or against the use of embryonic stem cells in scientific research as well as treatment for

neurodegenerative diseases. The researchers reported this phase of the investigation served as the post-test. In this phase, participants were videotaped.

The general analysis of the post-test activity revealed more than 75% of the students from the control and contextualized groups were in favor of human embryonic stem cell research. While this was the case, these researchers reported that some of the participants had difficulties giving justifications for their decisions. It was reported students rarely gave simple arguments; instead, their arguments often relied on many linked justifications. The common justification themes reported for students who were in favor of human embryonic stem cell were:

- The hope to cure, to save lives.
- This can make the world better.
- The embryo is a group of cells; thus, it does not think.

Interestingly, the above themes do reflect an element of emotive reasoning. However, since full excerpts from students were not presented in this study, it does make it difficult to examine in greater detail if such emotive reasoning enhanced or hindered students' rational thought processes, on the issues of human embryonic stem cell research.

These researchers reported that students who were against human embryonic stem cell research gave simple arguments with only one justification. The common themes identified among students' arguments included:

- The embryo is a future human being and its legal status is not clear.
- Human embryonic stem cell therapy is risky and further research is needed.
- This could lead to oocyte trading and the commercialization of life.
- Therapeutic cloning can lead to reproductive cloning.

Again, the participants' arguments above seem to hinge on emotive reasoning. However,

since these researchers did not include excerpts of students' arguments, it is difficult to assess how such reasoning hindered and/or enhanced their thought process and thus, their decision-making on the issue with which they were presented. Not being able to see common responses from students or excerpts of their responses made it difficult to formulate an opinion on the degree to which students may or may not have used emotions to evaluate evidence, when reasoning about embryonic stem cell research. Such issues are generally considered complex, so it would have been interesting to see the many views students took on such issues to justify their claims.

These researchers reported they conducted further analysis of argumentation in control and contextualized sessions as well as arguments during debates. They reported students had difficulties developing argumentation. While this was the case, again no excerpts were provided. Remarkably, it was reported some students used scientific arguments in their reasoning in support of embryonic stem cell research when presenting their arguments. However, the degree to which students engaged in using scientific arguments was not detailed. For example, it was reported some of the participants consider the embryo to lack human character because it lacks a nervous system.

After analyzing the results of this investigation, a reiteration of some important tenets of what educators can do to help students develop skills of using justification in their decision-making process is warranted. In order for students to gain skills that will allow them to debate issues and provide justification for their decisions, it is necessary that science education researchers provide the opportunity for students to gain the necessary background knowledge on the issues about which they are asked to argue. After equipping students with the background knowledge, students must be given opportunities to practice formulating arguments for or against

issues that relate to the background knowledge that was achieved. While the above may not necessarily be done in the order expressed above, students must be given these opportunities. If this process is not completed, then we should not be surprised with students' weak argumentation skills.

While the contextualized approach these researchers employed for this study seemed valuable in getting students to hear from experts on both sides of the issues, the four to six weeks time period participants were given to formulate definitions of stem cells, develop questions for future debates on stem cells, and build background information on stem cells should have been monitored more closely. It is highly likely that since monitoring was not done, it may have affected the outcome of this study. Students in general, and high school students in particular, need close monitoring and guidance whenever they are asked to engage in inquiry activities on their own (Zeidler, Applebaum, & Sadler, 2011). They need guidance, but most of all they need their questions answered whenever they are asked to engage in activities that may challenge their core beliefs. If researchers do not provide guidance to students assigned tasks reflecting matters of which they have little knowledge as well as those that challenge their core beliefs, then adverse effects may occur on the final products students provide.

### **Scientific Content Knowledge and Its Influence on Reasoning**

The science education community must appreciate that scientific knowledge is both symbolic in nature as well as socially negotiated (Driver, Asoko, Leach, Mortimer, & Scott, 1994). The objects of science are not the phenomena of nature, but constructs that are advanced by the scientific community to interpret nature (Driver et al. 1994, p 5). To interpret and explain nature at times does pose challenges for scientists and lay people alike (Driver et al, 1994; Miller, 2001). Students have difficulties when they are asked to interpret scientific phenomena

and then asked to use scientific knowledge to explain those phenomena (Dawson & Venille, 2009; Sadler & Zeidler, 2004). To help students develop and use scientific knowledge in their reasoning on socioscientific issues, science educators must create opportunities for students to make personal sense of the ways in which knowledge claims are generated and validated, rather than to organize individual sense making about the natural world (Driver et al. 1994). Students must be given opportunities to practice negotiation with their peers and teachers regarding scientific issues that are contentious and personally relevant to their lives. Such practices may provide students with the opportunities to learn the content, while gaining the knowledge needed to use when reasoning on socioscientific issues.

There are studies that show students lack the necessary skills to argue and negotiate on contentious scientific issues. For example, Zeidler, (1997) reported flaws in students' argumentation quality that included problems with validity, naïve conceptions, as well as the tendency of students to use core beliefs to influence their argumentation. Another study also found that students had difficulties valuing evidence as well as being able to distinguish data from opinion (Sadler, Chambers, & Zeidler, 2004).

### **Socioscientific Issues and Its Effects on Scientific Content Knowledge**

Socioscientific issues as key pedagogical strategies have been advocated by many in the science education community as an important element in the development of knowledge and processes contributing to scientific literacy. These strategies include evidence-based argumentation, consensus building, moral reasoning, and understanding and application of science content knowledge (Sadler, 2009; Zeidler & Sadler, 2011). A recent study by Eastwood, Sadler, Zeidler, Lewis, Amiri, and Applebaum (2012) investigated the effects of two learning contexts for explicit-reflexive nature of science (NOS) instruction. The two learning contexts

were SSI driven and context driven on students' NOS conception. In this project, four 11<sup>th</sup> and 12<sup>th</sup> grade Anatomy and Physiology classes (27-31 students per class) taught by an experienced high school science teacher who was also a graduate student in science education participated in a yearlong research on SSI-learning environments. At the time little had been published regarding student development of reflective judgment, moral sensitivity, and NOS understanding. In this investigation, two curricular sequences that featured explicit-reflective NOS were used. One curricular sequence (the SSI-driven curriculum) was organized around a series of SSI with conceptual links to Anatomy and Physiology. The content-driven curriculum was organized around anatomy and physiology content. Data results from the pre-instruction VNOS questionnaire showed no statistical significant difference in the level of NOS understanding between the SSI and Content groups prior to instruction. However, after instruction, both SSI and Content groups showed significant gains in each aspect of NOS with the exception of the social/cultural NOS for the group. The scientific models category for the SSI group also was an exception.

Differences in the ways in which students used specific examples to support their discussion on VNOS questions were discovered. Fine-grained analysis paid particular attention to the use of contextualized examples. The analysis subsumed NOS tenets showed that a greater proportion of students in the SSI group used examples to strengthen their presentations of their perspectives related to how science is socially and culturally influenced. However, post hoc chi square analysis revealed that the group differences were not statistically significant. It is sufficient to say that this research had a relatively small sample size. However, the results from this investigation show that similar research using larger sample sizes may be warranted.

Klosterman and Sadler (2010) conducted a three-week unit of seven learning exercises across 15 contact hours. Their investigation employed the use of a multi-level assessment framework that explored the effects of using SSI-based instruction on student learning of content knowledge. In this research, 151 (data collected for only 108) students from two different schools who were enrolled in two different courses (environmental science and chemistry) participated in this project. Students enrolled in the environmental science course ( $n = 75$ ) were from three different classes at the same school and were taught by the same teacher. Students enrolled in the chemistry course ( $n = 76$ ) were from two classes at the same school and were also taught by the same teacher.

In this investigation, two measures of science content knowledge served as the primary data sources. These measures were obtained from standard-aligned tests that were developed by creating a pool of publicly released items from standardized tests such as: TIMSS (Third International Mathematics & Science Study), NAEP (National Assessment of Education Progress), and state assessments (from Oklahoma, California, and New York). The first measure of content knowledge was administered before and after the intervention was provided to students using the standards-aligned test. The second measure of content knowledge was conducted through a curriculum-aligned test consisting of five open-ended items (see study for details). Results from this investigation showed overall gains in students' content knowledge from pre- and post-test scores on the standards-aligned test. The average gains for the environmental science class was 1.88 and for the chemistry class it was 1.294. It was reported that the results of the analysis indicated that students' post-test scores were statistically significantly different than their pre-test scores.



It was reported that qualitative analysis of students' responses to items on the curriculum-aligned test showed that student understandings of global warming was diverse. It also included a range of responses that illustrated commonly held misconceptions as well as clear understanding of the factors contributing to global warming. Students' responses addressing the greenhouse effect also varied from unrelated responses to more accurate descriptions of the relationship between the greenhouse effect and global warming (see study for more detail). Results from this investigation highlighted the potential impact of SSI instruction on students' content knowledge.

### **Scientific Literacy and Socioscientific Issues**

While there are several definitions to the term scientific literacy, the *National Science Education Standards* (National Research Council, 1996) included the following points in defining the term scientific literacy:

- A person can ask, find, or determine answers to questions derived from curiosity about everyday experiences
- A person has the ability to describe, explain, and predict natural phenomena
- Entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions
- Implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed
- Citizens should be able to evaluate the quality of scientific information on the basis of its resource and methods used to generate it
- Implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately

While the science education community awaits a consensus on a proper definition as well as what constitutes the term scientific literacy, some countries around the world still regard scientific literacy as the “Be All and End All” to that which represents science education for all students (DeBoer, 2000). As we await a consensus on what constitutes scientific literacy (DeBoer, 2000), there are those in other countries who have used other terminologies to represent the term scientific literacy. For example, the term *Scientific Culture* and *La Culture* are used in some parts of Europe and Canada (Solomon, 1998). In England and other places, the term *Public Understanding of Science* is widely used (Durant, 1994; Hunt & Miller, 2000).

In sifting through the different definitions of scientific literacy, Roberts (2007) identified two visions of scientific literacy he believed to best capture the way the term was represented in the literature; namely, Vision I and Vision II. According to Roberts, Vision I gave meaning to scientific literacy by looking inward at what he suggested was the canon of orthodox natural science, which are the products and processes of science itself (Roberts, 2007). Vision II, he believe derived its meaning from the character of situations with a scientific component. These situations reflecting possible scenarios students are likely to encounter as citizens (Roberts, 2007).

While the science education community continues to struggle with the notion of what is meant by the term scientific literacy, as well as what constitutes scientific literacy, the problem of where we start in helping students to develop proper understanding and competence of science still exists. In making the case for providing students with an education critical for developing scientific literacy skills, Choi, Lee, Shin, Kim and Krajcik (2011) developed a framework for scientific literacy that included five dimensions: character and values, science as a human endeavor, metacognition and self direction, habits of mind, and content knowledge. Choi et al.

(2011) argued current views of scientific literacy have limitations with respect to global perspectives and competencies that citizens need for the 21<sup>st</sup> century. These researchers further suggested that today's view of scientific literacy most often lies within a personal and societal framework, while ignoring issues that are related to a global society. This conclusion was reached after these researchers reviewed the notion of scientific literacy from four major documents, which are described below:

1. The Organization for Economic Co-operation and Development (OECD, 2004).  
Scientific literacy as described by this organization refers to the capacity to use scientific knowledge, to identify questions, and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity (p. 40).
2. The *Science for All Americans* (AAAS, 1989, p. XIII) described scientific literacy as the understanding and habits of mind students need to become compassionate human beings who are able to think for themselves and to face life head on. This description further stated that scientific literacy should equip students to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital.
3. The *National Science Education Standards* (NSES) (NRC, 1996) described scientific literacy as knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity (NRC, 1996, p. IX).
4. Millar and Osborne's (1998) *Beyond 2000* is a document that described scientifically literate individuals as "those who are comfortable, competent, and confident with scientific and technical matters and artifacts."

While there are values to the suggestion of Choi et al. (2011) that the context of scientific literacy most often lies within a personal and societal framework and does not consider issues related to a global society, it is necessary to point out that many in the science education community have been advocating for a science education curriculum which will foster the enhancement of sound decision-making on the part of students (Zeidler & Lewis, 2003). When students develop the proper skills that will afford them the opportunity to make sound decisions on scientific phenomena, not only do they and their communities stand to gain from these decisions, but the global society also stands to make gains. For example, the current debates regarding ozone depletion, the need for alternative energy sources, genetic engineering, and pollution of the environment cannot be seen as strictly problems for North America or problems with which only the western world must contend. Rather, these are global problems that affect the global society. To enable students to make informed decisions on these issues would require learning opportunities to enhance students' content knowledge development and their abilities to carefully evaluate scientific claims by discerning connections among evidence, inferences, and conclusions (Zeidler & Lewis, 2003). In addition, moral development, character development, and ethical reasoning play important roles as students consider what is best for the common good of society (Zeidler & Lewis, 2003; Zeidler, Berkowitz, & Bennett, 2011).

A recent article by Zeidler, Berkowitz and Bennett (2011) advanced the scientific literacy discussion a bit further with suggesting that the existence of conscience is a precursor to scientific literacy. Making informed decisions on many of today's contemporary scientific issues requires value judgment as well as ethical principles, both of which may be influenced by, but are not limited to, cultural, personal, and religious beliefs (Abd-El-Khalick; Zeidler, & Keefer, 2007). Therefore, making informed decisions on scientific issues that are ill-structured

and contentious requires the use of conscience. Without the use of conscience when one is asked to decide on these issues, the risk of being disingenuous with one's decisions only gets wider. When conscience is used at the forefront of any decision, it becomes much easier for one to measure up to that interior bar of integrity to which one so inclined strives to measure up to (Zeidler et al. 2011). These researchers argued that one needs to possess the capacity to seek evidence in confirming and disconfirming ways to be challenged and challenge their own understandings of scientific evidence, including the probable short and long-term outcomes associated with decisions related to that evidence (p. 7). Other publications by Zeidler et al. have pushed this discussion even more by pointing out how important it is for science educators to encourage students to develop formation of conscience through the exercise of reflective judgment (Zeidler & Sadler, 2008; Zeidler, Berkowitz, & Bennett, 2011; Zeidler, Sadler, Applebaum, & Callahan, 2009). The central argument here is that conscience is considered a major ingredient of scientific literacy. The statement below signifies the importance of conscience as a precursor to scientific literacy:

Prior to our students engaging in scientific reasoning, becoming scientifically literate, or engaging in moral reasoning, we need to first provide them with the opportunity to exercise the reflexive nature of conscience—after which moral reasoning can have its day. Moral education and its related forms of character education, therefore, presupposes the formation of conscience (Zeidler & Sadler, 2008, p. 204).

Having a conscience is an important gateway through which students evaluate the morality of issues that are contentious. If we are to give students opportunities to become scientifically literate citizens, then opportunities to practice and engage in discourse on SSI is

imperative. Such issues do provide students with opportunities to exercise conscience when evaluating evidence and making decisions on contentious issues.

### **Emotions and Socioscientific Issues**

As we work to educate our students, we must do so with the understanding that students form ways of thinking through natural inclination as well as social experiences, which include substantive understanding of moral concepts like justice, rights, equality, and welfare (Turiel, 1998). Students generate judgments, which are built on emotions such as sympathy, empathy, respect, love, and attachment, to which they have a commitment and are not in conflict with their natural or biological disposition (Eisenberg, 1998, p. 867). Since this is the case, it seems as if more consideration must be given to include character education as a key element in our science education curriculum (Berkowitz & Simmons, 2003; Kolstø, 2001, Zeidler & Sadler, 2008).

### **Influence of Feelings on Moral Reasoning in Decision-Making on Contentious Issues**

Feelings like sympathy, empathy, compassion, and love are important components of moral judgments that are rendered by individuals whenever they are placed in positions to make informed decisions on controversial topics (Hoffman, 2000; Powell et al. 2012; Turiel, 2006; Walker, 2004; Zeidler & Sadler, 2005b; Zeidler et al. 2011). As students grow and become tomorrow's decision makers, it is expected they will be called upon to make decisions and/or vote on matters deemed controversial to many. Although many of our secondary school students are not of the age where they are called upon to vote or enter into contract on issues that are controversial in nature, studies have shown students' empathetic-related emotions may have influence on their moral thoughts (Skoe, 1998, 2008, 2010).

Investigations conducted by other researchers have found convincing evidence suggesting people generally express sympathy for others when they have concerns for others in

need (Eisenberg, 2000, 2005; Eisenberg et al. 2001; Juujarvi, 2003). These studies reported that sympathy generally has positive correlations with moral reasoning (Eisenberg, 2000, 2005; Eisenberg et al. 2001; Juujarvi, 2003). If we as educators expect our students to make informed decisions on contentious issues, then it is reasonable for us to investigate students' emotive reasoning habits on issues that are controversial in nature, since students' morals are called into question on these issues, as well as the fact that the self is inseparable from the emotion (Kristjansson, 2009). Taking this approach may provide science education researchers and practitioners with valuable knowledge of how to enhance their students' scientific literacy development. However, one way of doing so may be to expose students to SSI and employ heuristics as an approach to understanding the meaning and experience of students and teachers as they ponder these ill-structured issues and arrive at their decisions.

### **Empathy-Related Constructs to Care-Oriented Moral Development**

Research on the relationships between the care aspects of moral thoughts has been relatively sparse. However, a recent study conducted by Skoe (2010) investigated the relationship of empathy-related constructs (perspective taking, sympathy, and personal distress) to care-oriented moral development among men and women. In this investigation, a total of 58 students (30 women, 28 men) from a university on the Canadian eastern coast who ranged in age from 20-42 were selected to participate in this study. Skoe conducted empirical tests of these constructs because of the claim that empathy and care-based moral reasoning might entail interdependent developmental processes (Skoe, 2010, p. 192).

Data for this investigation was collected using the Interpersonal Reactivity Index (Davis, 1980) and the Ethic of Care Interview (Skoe, 1998). In testing for relationships of empathy with an ethic of care perspective, a multiple regression analysis was computed to examine the unique

contributions of perspective taking, sympathy, and personal distress to care-based moral reasoning. In looking at correlations among variables such as parent education, ethic of care interview total score, perspective taking, empathic concern or sympathy, and personal distress, results indicated that sympathy was positively related to age and to both perspective taking and personal distress in the zero-order correlations, but only to an extent in the partial correlation. The results also showed perspective taking and personal distress were not significantly related to each other or to age.

Results from prior research have suggested women generally score higher than men on emotional empathy measurements (Gilligan, 1982; Davis, 1996; Eisenberg et al. 2002; Eisenberg et al. 2006). In Skoe's investigation, having 30 women and 28 men as participants was indeed a wise move to reduce any skewness in the data generated from this study. However, because the participants of this investigation were predominantly single with no children (90%) and the majority were Caucasian (97%) with 3% were Asian, the results obtained from this investigation may not be representative of other racial or ethnic groups.

### **Influence of Affect on Higher Level Cognition**

Researchers have historically been known to study higher levels of cognitive process separately from the affective system (Blachette & Richards, 2010). However, new studies are now beginning to investigate the interaction between cognitive and affective processes (Blachette & Richards, 2010). To determine whether there is an effect of emotion on higher levels of cognitive processes, specifically interpretation, judgment, decision-making and reasoning, in addition to the mechanisms that underlie the effects of emotion on these processes, Blanchette and Richards reviewed over two decades of behavioral research that empirically examined the impacts of affective variables on higher level of cognitive processes. From this



extensive review, their main conclusion was affective variables can have a large influence on higher-level cognitive processes.

### **Effects of Emotion on Interpretation**

Interpretation is important for one to resolve any ambiguity inherent in an argument or a situation that confronts such individuals. In their study, Blachette and Richards (2010) reminded us of the fact that our ability to correctly interpret ambiguous signs, which could predict harm, is critical for our safety and survival. It was reported by these researchers when looking at the effects of emotion and interpretation, context should be an integral aspect to examine (Blachette & Richards, 2010). From their extensive review of studies that examine the effects of emotion on interpretation, Blanchette and Richards noted studies that presented participants with ambiguous words embedded within a sentence. In these studies, they reported that the task could not be performed without reference to the contextual sentence.

In finding solutions for many of today's problems, students need to be able to consider the context of the situation in which they are confronted, in addition to the evidence presented in those situations. For example, when some people think of our government providing funding for projects such as stem cell research, they may become angry toward the government as well as the researchers who are involved in such research. Some of these individuals may reach conclusions without evaluating the potential benefits that may arise from such research. As educators, we want our students to be able to be effective at interpreting evidence, considering alternative solutions, and assessing the viability of scientific claims for any situation and in any context with which they are confronted. SSI as key pedagogical strategies in the classroom will provide students with the necessary opportunities to practice evaluation of scientific claims in different contexts.

## **Effects of Emotion on Judgment**

The Merriam-Webster's School Dictionary (2006) defined judgment as the process of forming an opinion by discerning and comparing. As such, it should be of no surprise that judgment research examines how people estimate the likelihood of future events. Blachette and Richards (2010) reviewed two decades worth of empirical studies that documented the influence of affect on judgment. They concluded that the effects of affect on judgment influences a wide range of emotions, including anger, sadness, anxiety, and positive moods. From their review of literature, they found that emotional events are generally memorable, without necessarily being more frequent. Thus, they concluded that judgment is more heavily based on individuals' memory processes (Blachette & Richards, 2010).

Since judgment is based on memory processes, the thought of using SSI as a key pedagogical strategy in our secondary school science education curriculum to enhance decision-making skills among our students is even more important. SSI with its focus on teaching topics that are relevant, controversial, emotional, devoid of clear-cut answers, and require moral and ethical reasoning may remain in the memory pathways of individual students. In the long run, this may impact students' ability to make judgments on these issues. Such practices may be pertinent in developing students who will be able to think critically and logically in order to evaluate scientific problems. These practices are necessary in order to produce students who are considered scientifically literate citizens. Science educators need to engage students in activities that are more relevant and meaningful to their lives and activities that impact their memory and thus their judgment about SSI.

## **Effects of Emotion on Decision-Making**

Making decisions has to do with how people choose among different options. In their

investigation, Blachette and Richards (2010) examined how the emotional arousal induced in a decision-making task influenced cognitive processes. From their review of literature, they concluded that different emotions produced specific affects on decision-making (Blachette & Richards, 2010). These researchers further concluded that anxious states as well as positive states increased risk aversion, while sadness increased risk tolerance or even risk seeking (Blachette & Richards, 2010, p. 575). In general, Blanchette and Richards concluded from their review of research on decision-making that positive and anxious mood states do have influences on decisions.

In looking at the specific question as to whether decision-making is hindered or improved by affective reactions, Blachette and Richards (2010) suggest that the issue of rationality is at the center of cognitive decision-making literature and emotion and decision-making literature. From review of the literature as to whether the experience of emotional arousal hindered or promoted normally correct behavior in decision-making tasks, these researchers discovered that the Iowa gambling task and the measures of skin conductance responses (SCRs) were the instruments that frequently had been used in these decision-making studies.

Results from the Iowa gambling task showed that participants quickly learned to avoid the decks that lead to the bigger losses. On the measure of skin conductance response, it was discovered that participants not only produce SCRs when the outcome is revealed to be a loss, but that most, though not all, participants also developed anticipatory SCRs.

Blanchette and Richards (2010) concluded these findings have led to the hypothesis that peripheral physiological reactions are used in the decision-making process and help individuals to avoid risky options by evoking a negative feeling at the time these options are considered. The general conclusion is that affect is beneficial for normatively correct decision-making.

## **Effects of Emotion on Reasoning**

The majority of the work on reasoning and emotion that has been done in the past used deductive reasoning paradigms. In these studies, participants were asked to draw inferences from a set of premises or to determine whether an inference was valid or not based on some premises. These studies generally suggested that emotion negatively impacted *correct reasoning* or logicity (Lefford, 1946, Melton, 1995; Oaksford, Morris, Grainger, & Williams, 1996; Palfai & Salovey, 1993).

In recent studies focused on the integral emotion affect that is intrinsically linked to the semantic contents of the reasoning tasks, where the emotion stems from the target stimuli, has shown that participants reason more logically about emotional than neutral contents (Blanchette & Richards, 2005; Blanchette, Richards, Melnyk, & Lavada, 2007b; Johnson-Laird, Mancini, & Gangemi, 2006).

As a result of these findings, it seems reasonable to suggest that emotion can both enhance as well as hinder reasoning. Blanchette and Richards (2010) echoed a similar sentiment by concluding that the differences of the impact of emotion and reasoning seemed to suggest emotion can both enhance and impair normatively correct responses. These responses depend on the type of emotion examined, the features of the task, or the interaction between the reasoning style and the requirement of the task (Blachette & Richards, 2010).

## **Effects of Emotions on Moral Judgment**

Psychologists, philosophers, and neurobiologists over the last four decades have shared widespread opinion on the importance of understanding emotion and the effects that emotion plays in moral judgment (Green, Nystrom, Engell, Darley, & Cohen, 2004; Green, Sommerville, Nystrom, Darley, & Cohen, 2001; Haidt, 2001; Hume, 1978; Prinz, 2006; Schnall, Haidt, &

Jordan, 2008). There appears to be a link between moral judgment and emotion (Blass, 2004; Prinz, 2006). While debates over whether we can make moral judgment without being motivated to act are ongoing (Huebner et al. 2008), several studies have suggested that moral judgments are emotional in nature (Berthoz, Armony, Blair, & Dolan, 2002; Moll, de Oliveir-Souza, & Eslinger, 2003; Prinz, 2006; Sanfey, Rilling, Aronson, & Nystrom, 2003).

In looking at the role of reasoning and emotion on moral judgment, Green et al. (2001) conducted a study using two ethical dilemmas. One of the dilemmas of this study was the runaway trolley dilemma, while the other was the footbridge dilemma. While both scenarios were similar and should require similar moral judgment, these researchers found contrasting moral reasoning as well as contrasting decisions. The runaway trolley dilemma suggested that a runaway trolley was headed for five people who would be killed if it proceeded on its present course. In this dilemma, it was suggested the only way to save the five people was to hit a switch that would then turn the trolley onto an alternate set of tracks with one person who would be killed instead of the five. When the participants of this investigation were presented with this scenario, the overwhelming majority suggested that the switch should be hit to save the lives of five people at the expense of one life.

The second scenario suggested that the only way to save the lives of the five people on the track was to push a stranger off the footbridge. The stranger would fall onto the tracks below killing him instead of the five people who were on the track. When these same participants were asked, "Ought you to save the lives of five by pushing this stranger to his death?" the majority of the participants said no. When people make such decisions, it is important to know the rationale used for making such decisions.

In searching for the understanding of what makes it morally acceptable to sacrifice one

life to save the lives of five in the trolley dilemma, but not in the footbridge dilemma, these researchers reported they were exposed to many answers. These researchers reported the crucial difference between the trolley dilemma and the footbridge dilemma involved people's tendency to use emotions. The suggestions were that the thought of pushing someone to his/her death was more salient than the thought of hitting a switch that would produce similar consequences. The suggestions from these researchers concluded that some moral dilemmas engaged emotional processing to a greater extent than others; these differences in emotional engagement affected people's judgments.

The facts are that students will be confronted with moral dilemmas that will trigger emotions, and they will no doubt be expected to make sound decisions on these dilemmas. To get students prepared for such eventualities, more credence must be given to science education curriculum that fosters students' abilities to evaluate evidence, make decisions on SSI, and integrate scientific content knowledge in their reasoning about SSI.

Opportunities to practice these skills are best guided by a science education curriculum that uses ill-structured problems that are controversial in nature; those opportunities requiring students to engage in discourse and negotiation with their peers and teachers are of paramount importance. By exposing students to such pedagogical strategies, educators will be able to expose students to many moral dilemmas that will foster emotive reasoning, moral reasoning, and moral growth of students. In order to do this, socioscientific issues as a pedagogical strategy is paramount as such issues expose students to ill-structured problems that are controversial in nature.

## **Effects of Education on Informal Reasoning Skills**

Since it has long been argued that most of the reasoning that people do in their everyday or academic life is informal in nature (Perkins, 1985), a considerable amount of research has been done in an attempt to determine if age variations (Sadler, 2004b; Yang & Anderson, 2003) or variations in educational experience affected individuals' informal reasoning abilities (Hofer & Pintrich, 2002; Klaczynski, 2000; Klaczynski & Gordon, 1996; Klaczynski et al. 1997; Kuhn, 1991, 1993, 2000; Perkins, 1985, 1989; Sadler, 2004; Sadler & Zeidler, 2005; Stanovich & West, 1997; Zeidler & Sadler, 2008; Zeidler, Sadler, Applebaum, & Callahan, 2009). In an attempt to examine the association between educational experience and performance on measures of informal reasoning, Toplak and Stanovich (2003) conducted a study with 112 students (39 males, 73 females) from a large Canadian university. In this investigation, the authors examined the reasoning performances of those participants on issues such as increasing cost of tuition, permitting the sale of human organs, and doubling the cost of gasoline to discourage people from driving (Toplak & Stanovich, 2003). One might wonder how the views of people with strong religious beliefs differ on these said issues. While these researchers conceded their approach may generate new insight into how individuals reasoned on an informal basis, the fact is these researchers should have taken issues such as religion into consideration. Studies have shown that people's religious beliefs do impact their reasoning and decision-making on issues that may arouse moral emotions, for example, issues involving organ transplantations (Zeidler et al. 2011). The use of such an issue may have affected these participants, since it might have an effect on their responses to the questions that were posed by the researchers. An example of one of the questions from the Toplak and Stanovich (2003) study is highlighted below:

Think through the following issue carefully and feel free to take your time. The real cost

of a university education is \$12,000/year. Students are currently paying approximately \$3,500 in tuition while the taxpayers pay the difference. University students should pay for the full cost of their university education. Please write down arguments both for and against this position. Try to write as much as you can. Remember to try and give reasons both for and reasons against your position (Toplak & Stanovich, 2003, p. 853).

The authors of this study went to great lengths to place emphasis on the cognitive abilities of the participants of this study, without stopping to consider the connectedness of moral emotions to moral knowledge and moral actions (Blasi, 1999; Kristjansson, 2009; Montada, 1993). Results from this investigation also showed that years in university affected individuals' my-side bias. In this study, there was a tendency for my-side bias to decrease across years one to four among the students who were involved in this study. This comes as no surprise because universities are (hopefully) preparing students to reason based on facts and evidence and not merely on intuition. While we may acknowledge that entrenched beliefs are generally difficult to change, we must not lose sight of the fact that emotions play a significant role in those entrenched beliefs. Educators should never lose sight of the influence that emotions have on the informal reasoning of our students.

### **Informal Reasoning and Its Effects on Science Curriculum**

Informal reasoning has long been regarded as an important aspect of students' performances and learnings (Baron, 1998; Kuhn, 1991; Perkins, 1985; Perkins, Allen, & Hatner, 1983; Sadler, 2004; Voss, Blais, Means, Green, & Ahwesh, 1986; Zeidler, Sadler, Simmons, & Howes, 2005). It is imperative that educators foster students' informal reasoning and develop curricula that will transform their informal reasoning to the extent that they can use those reasoning skills to evaluate evidence, make decisions on SSI, and integrate scientific content



knowledge in their reasoning about SSI.

Means and Voss (1996) investigated the effects of students' levels of abilities and how the impact of such abilities related to informal reasoning and found that informal reasoning performance of gifted students was distinctly superior to that of average and low-ability students. Means and Voss divided this investigation into two separate experimental studies. In the first study, a total of 60 students (35 boys, 25 girls) from grades 5, 7, 9, and 11 from a public school system in the Pittsburg suburbs were selected. These students were divided into three groups, gifted, average, and low-ability students. It is interesting to note two different tests were used to determine group placement. However, no explanation was given for this approach. After placing students into groups, they were assigned three tasks; ill-structured problems that consisted of four open-ended problems, a problem solution task designed to assess participants' skills in evaluating solution acceptability, and a problem difficulty assessment task that was designed to judge when informal reasoning may or may not be useful.

While we do expect students with more experience and knowledge to out-perform those with less, it is fair to expect factors related to an individual's morality that is their determination of what is right, good, and virtuous, to play a major role in their abilities to evaluate evidence and make informed decisions on these issues. Several science educators in the last decade have documented the role as well as the impact of individuals' moral consideration in their decision-making on ill-structured problems (Bell & Lederman, 2003; Hogan, 2002; Sadler, 2004c; Zeidler, Walker, Ackett, & Simmons, 2002). Moral reasoning needs to be given greater consideration in analyzing students' argumentation quality on ill-structured problems, since these problems appear to be open to several plausible solutions (Sadler & Donnelly, 2006).

## Summary

Helping to solve many of the scientific problems of the 21<sup>st</sup> century world and beyond will require citizens to have a general scientific education. This education is important in order for citizens to be able to evaluate scientific evidence, make informed decisions, and integrate scientific content knowledge in the process of reasoning about these problems. To produce such citizenry, school science needs to provide students with experiences that tap the different perspectives of many of the world's scientific problems. This approach is important in order to produce scientifically literate citizenry.

Since the main reason for producing scientifically literate citizens is that people make informed decisions on scientific problems, it is evident that school science needs to provide opportunities for students to develop Robert's Vision II of scientific literacy. To develop these traits, students' ways of reasoning on controversial issues in general and their emotive informal ways of reasoning in particular must be given greater considerations in schools' science curriculum.

We have seen from the literature review discussed earlier in this investigation how important students' emotive considerations are in their reasoning on contentious scientific issues. Students' use of emotions was also critical to their abilities to interpret, judge, make decisions, and reason on various issues. The above observations should be a testament to the science education community that emotions do in fact play a major role in students' educational development. With emotions playing such key roles in students' educational growth, the timing is now perfect for science educators to better understand the influence of emotive reasoning and its effects on students' abilities to evaluate evidence and make decisions. A good starting point is for science educators to adopt curriculum that will provide students with opportunities to

actively engage in investigations of contemporary issues, while facilitating dialogue and negotiation of such issues in classroom settings. Doing so will indeed help students get closer to achieving the scientific literacy skills that Roberts and others suggested.

## CHAPTER THREE: METHODOLOGY

### Introduction

The use of emotions to help in decision-making is not a new concept to the science education community. Empirical research has shown individuals often rely on emotions when asked to make decisions on issues involving controversies and risks (Finucane et al. 2000; Slovic, 1999). However, it appears that science educators have only recently recognized the influence of emotions on students' reasoning and decision-making processes on contemporary scientific issues (Lee, Chang, Choi, Kim, & Zeidler, 2012; Powell, Zeidler, & Huling, 2012; Sadler & Zeidler, 2005b; Zeidler, Ruzek, Powell, Orasky, Applebaum, Chin, Lin, Linder, Linder, & Herbert, 2011; Zeidler, Herman, Ruzek, Linder, & Lin, 2013). Nevertheless, students' general use of emotions and specifically emotive reasoning to make decisions about SSI in our secondary schools' science education curriculum has not received adequate attention by the science education community. Therefore, the primary purpose of this dissertation study was to design, implement, and evaluate a semester long integrated SSI high school biology curriculum. The curriculum aimed at understanding the relationships between students' emotive reasoning and their abilities to evaluate evidence, make decisions on SSI, and integrate scientific content knowledge in the process of reasoning about SSI.

This study employed the use of a quasi-experimental design using students from two intact high school biology honors classes that were selected into treatment (SSI curriculum) and comparison (traditional curriculum) groups. In order to better understand how content knowledge was utilized in the process of reasoning about SSI, this study utilized mixed methods.

The use of mixed methods allowed for thorough checking of the consistency of findings that were generated by the different data collection methods of this study (Patton, 2002). This approach was preferable for the present study due to no single method ever adequately being able to solve the problem of rival causal factors (Denzin, 1978b).

The majority of this study was qualitative in nature with the use of open-ended surveys and semi-structured interviews. To better uncover themes and trends in students' responses on open-ended questionnaires and semi-structured interview questions, a constant comparative analysis of the data was conducted (Glaser & Struss, 1967). This technique allowed for the repeated study of students' artifacts (Glaser & Struss, 1967; Lincoln & Guba, 1985; Thomas, 2003), thereby facilitating a more thorough exploration of students' emotive reasoning on contemporary scientific problems. Information from students' rich and extended narrative discourse and written artifacts that could not easily be accessed with the use of quantitative approaches were captured by the use of this method (constant comparative method of data analysis).

### **Research Questions**

The guiding questions of this dissertation were:

1. What relationships exist between secondary school students' emotive reasoning and their abilities to evaluate evidence related to thoughts on socioscientific issues?
2. What relationships exist between secondary school students' use of emotive reasoning and their decision-making regarding socioscientific issues?
3. In what ways do secondary school students integrate scientific content knowledge in the process of reasoning about socioscientific issues?

## **Population and Sample**

The populations of students in this study were primarily 9<sup>th</sup> grade high school students who were enrolled in two Biology Honors classes. I chose ninth grade biology students because I wanted students who had not yet been exposed to SSI instruction at the high school level. I have been a teacher at this school for over nine years and have been using SSI instructions in my courses for over five years. Many of my former students were enrolled in other science classes throughout the school, so I chose 9<sup>th</sup> graders to ensure I was investigating students who were not already exposed to SSI instruction at the high school level. These students were from the same suburban Tampa Bay area high school. One teacher volunteered to use two of her classes for this study. This teacher had one class randomly assigned as the treatment group and the other as a comparison group.

This school is situated in the northeastern area of Tampa Bay, Florida. Based on the demographic data for the 2010-2011 school year (the latest data available by Florida Department of Education), the school population consisted of 1,312 students. Out of this total, 60.8% of the population was Caucasian, 9.4% African American, 25.3% Hispanic/Latino, while 4.5% was made of Asians and those classified as others. Students who were classified with intellectual disabilities made up 18.1% of the population, while those who were classified as economically disadvantaged made up 55.3% of the population.

For the 2009-2010 school year (the latest available data on the Florida Department of Education and School's websites), the graduation rate of the school was 86.6 percent. The graduation percentage represented students who graduated within four years of initial entry into 9<sup>th</sup> grade. Graduates included students who received a standard high school diploma or a State of Florida diploma earned through a GED Exit Option program. These results are used in the

calculation of schools' Adequate Yearly Progress (AYP). This school did not make AYP for the 2009-2010 school year.

### **Instructional Context**

In addition to selecting classes that had not been exposed to SSI instructions, ninth grade biology was also chosen because teachers were willing to participate in this study. Ninth grade biology classes were also the most abundant science classes offered at the school, where the study was conducted. Below is a brief description of the teacher who volunteered for this study:

#### **Teacher**

The teacher had four years of teaching experience with three of those years being at the school where this study was conducted. She taught science courses ranging from Anatomy and Physiology Honors, Biology Honors, Biology 1, and Integrated Science. The teacher was asked if she would be willing to participate in this study because she was always looking for new ways to enhance her pedagogical strategies with her students.

At the school where this study was conducted, Biology Honors was reserved for incoming 9<sup>th</sup> graders who had taken and passed the State of Florida's End-of-Course Algebra 1 Examination as 8<sup>th</sup> graders. For students in the State of Florida who entered 9<sup>th</sup> grade, during the 2011-2012 school year, the State's Biology End-of-Course Examination accounted for 30% of their final grade in this course. All incoming 9<sup>th</sup> graders for the 2012 school year and beyond must pass the State's Biology End-of-Course Examination in order to graduate from high school with a standard high school diploma. Regardless of whether students are enrolled in a Biology Honors or regular Biology course, all are required to take and pass the same end-of-course examination in the State of Florida.

Before the teacher and the students participated in this study, permission from the teacher

and students, parents of these students, Pasco County Schools Research and Evaluation Services, and the University of South Florida's Division of Research Integrity and Compliance Office were obtained. The teacher collected all permission forms from the students and delivered them to the researcher prior to the start of this study.

### **Teacher Training**

This particular teacher had no experience using SSI as a pedagogical strategy; therefore, the principal investigator provided initial as well as ongoing training on socioscientific issues throughout the study (*See Appendix A for introduction training on SSI*). If the SSI movement is to help students succeed, then the curriculum must be palatable to the vast majority of teachers who are not experts in the history, sociology, and philosophy of science education (Callahan, 2009). The initial training, plus the ongoing meetings and trainings I offered to the teacher, allowed her to gain a better understanding of SSI as a key pedagogical strategy. As part of the training, I modeled SSI instructions for the teacher prior to and during the investigation. I also invited the teacher to visit my classroom to observe SSI being taught. I also video recorded some of my SSI instructions and shared these instructions with the teacher at our weekly meetings.

For the initial training, I discussed with the teacher the goals of science education and ways of achieving those goals. I also shared with the teacher the findings from different articles that highlighted many of the problems associated with scientific literacy (DeBoer, 2000; Durant, 1994; Hunt & Miller, 2000; Roberts, 2007; Solomon, 1998). I introduced Roberts' Vision I and II (Roberts, 2007) and explained the differences between these two visions. Socioscientific issues were then introduced and the close association between Roberts' Vision II and SSI was pointed out to her.



I conducted a follow-up training two days after the initial training. In this training, I introduced a theoretical article that suggested SSI has considerable potential to improve science education at the elementary school level (Zeidler & Nichols, 2009). I used the article to highlight what socioscientific issues were. The teacher and I then read and discussed the contents of this article. Opportunities were given to the teacher to ask questions about the article. I then modeled an SSI lesson in the teacher's class the following day. I met with the teacher the evening after modeling the SSI lesson to talk about the lesson. Again, the teacher was given opportunities to ask for clarification on my presentation to her students. Two days after this meeting, I met with the teacher to discuss the companion article to the Zeidler and Nichols (2009) article. This companion article, titled "*Using Socioscientific Issues in Primary Classrooms*," was used to expose the teacher to SSI in a 5<sup>th</sup> grade class. This article provided information regarding the impact of SSI on elementary school students' scientific literacy skills. At this meeting, I showed a recorded SSI lesson I conducted with my students. The teacher was encouraged to ask questions about my presentation.

To help the teacher better understand how to enact SSI in a typical high school science classroom, I again met with her three days after sharing my recorded SSI lesson. At this meeting, I discussed the Zeidler, Applebaum, and Sadler (2011) article that provided information on how to enact a SSI lesson. The template of this article outlining common elements of a SSI unit was used to provide the teacher with added background knowledge of SSI. Although this template provided the teacher with a better understanding of the various elements of a common SSI unit, I verbally expressed to the teacher that these elements are not to be seen as fixed prescriptions (See Appendix B for development of an SSI unit). I then used the template and worked with the teacher to develop an SSI lesson. I invited her to visit my classroom to observe

me presenting the SSI lesson we collaboratively planned with my students. At this point, the teacher was allowed to make any changes to the SSI lesson we created to fit her curriculum. The teacher then began implementation of the SSI units into her treatment class. Subsequently, I visited her classrooms at least twice per week throughout the duration of this study to observe her SSI instructions. During my visits, I took written notes of my observations and shared those observations with her during our debriefing. The observations were also used as my field notes. I had weekly meetings to debrief on the developments of each SSI lesson she presented to her students.

In addition to regular biology classes for the 2012-2013 school year, the teacher also taught Biology Honors level classes. However, this study was only conducted with two of the three biology honors classes the teacher was assigned to teach, since I was interested in having one Biology Honors class serve as the treatment group and the other as the comparison group. In terms of this teacher’s education, she obtains a Bachelor’s Degree in Animal Science and is certified to teach Biology/Grades 6-12, in the State of Florida. The teaching schedule for the teacher who volunteered to be part of this study and the researcher schedule are listed in Table 1.

Table 1

*Teacher’s and Researcher’s Teaching Assignments for 2012-2013 School Year*

Teacher	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Teacher	Bio Hon Treatment	----	----	Bio Hon Comparison	----	----
PI	Plan	A&P	A&P	A&P	Env. Sc.	Env. Sc.

The training exercises for the teacher started in late November. At that point, I visited each of her classes twice per week for fifty minutes each visit. The visit was to observe and allow students to become comfortable with the presence of another teacher in their classroom.

Such visits lasted for two weeks and were done prior to exposing students to any interventions of this study. At the end of the two weeks of visitations, I explained to the students I was interested in how students their age thought about controversial issues in science. I also informed the students that for the spring semester their teacher and I would provide opportunities for them to think about, discuss, and respond to scientific questions that are controversial.

I met regularly with the teacher throughout the implementation of the study to discuss the design of the SSI curriculum. At our meetings, I read through and discussed all relevant and available course materials that were used in the SSI curriculum. This was done to ensure that the teacher clearly understood my perspectives on SSI as well as the goal of the study. During these meetings, opportunities were given for the teacher to say what went well versus what did not go well during the SSI lessons. I acted upon the teacher's suggestions to ensure that the educational objectives of her students were met.

### **Integrated Curriculum Development**

The integrated biology curriculum in this study consisted of three SSI units. This curriculum addressed all the sub-units with the exception of the evolution and classification sub-units that are outlined on the school's science department biology timeline (See Appendix C for biology timeline). The development of the integrated SSI Biology Honors curriculum was done prior to its implementation in the spring semester. All units were selected by the researcher with the teacher's input to make certain of the students' interest in the topics. The units used in this study came from several sources, including previous SSI units developed by the researcher, new SSI units developed specifically for this study, and SSI case units from the National Center for Case Study Teaching in Science Website:

<http://ublib.buffalo.edu/libraries/projects/cases/ubcase.htm>. The National Center for Case Study

Teaching is located at the State University of New York in Buffalo NY, and grants permission to educators to use the cases in their classrooms. I requested and received permission from the National Center for Case Study Teaching in Science to use their cases in my investigation.

Each unit in this study satisfied the requirements of the district's curriculum map, the school's science department biology timeline, and was aligned to the Sunshine State Standards for biology. The district's curriculum map was also aligned to the Next Generation Sunshine State Standards. However, because of the complex nature of SSI, some of these units satisfied multiple requirements of the district's curriculum map as well as multiple Next Generation Sunshine State Standards. Each unit provided students with opportunities to learn biological concepts from the various activities presented to them throughout the study. A month prior to the start of this study the teacher received copies of all units in a binder. This was done so she could further familiarize herself with the content of each unit.

The use of pedagogical strategies incorporating political, economic, and ethical factors to learn scientific content can create a learning environment where students feel they can easily relate because of the relevance of the factors that will be discussed in such environment. Such an environment may provide opportunities for students to engage in discourse with their peers and teachers, negotiate different points of view, and even conduct research to further enhance their understanding of different issues. The units presented in this study created such an environment and provided students with the necessary opportunities to engage in discourse activities with their peers and teachers. The students were able to negotiate with their peers and engage in research to find solutions to problems. The teacher involved in this study served as mentor to the students as they worked through the different units. An outline of the correlations between the SSI units and the Sunshine State Standards for Biology Honors is shown below.

Table 2

*Correlation of SSI Units and Sunshine State Standards for Biology Honors*

Sunshine State Standards	Evaluating Evidence	Decision Making	Content Knowledge
Practice of Science	X	X	X
1. Scientific inquiry is a multifaceted activity.			
2. Scientific argumentation is necessary for scientific inquiry.			
3. Scientific knowledge is based on observation and inferences.			
Characteristic of Scientific Knowledge	X	X	X
1. Scientific knowledge is based on empirical evidence			
2. Science strives for objectivity			
Science and Society	X	X	X
1. Engage in scientific processes to find solutions to real world problems.			
Organization and Development of Living Organisms			X
1. Cells have characteristics structures and functions.			
2. Different classification of cell processes			
Heredity and Reproduction			X
1. DNA stores and transmit Genetic information.			
2. Genetic information is inherited.			
3. Manipulation of DNA can create new organisms and products			
4. Reproduction is characteristic to living things.			
Interdependence	X		X
1. Human activities and natural events can cause problems			
Matter and Energy Transformation			X
1. Living things are composed of our basic macromolecules			

The units in this study required students to work independently and collaboratively to find solutions for many of the problems they were asked to confront. Students were required to make individual and group presentations. Students also engaged in debates as they worked through the various issues of the curriculum. Although the focus of the study was on the implementation of the integrated SSI curriculum, the teacher was able to use lectures and laboratory activities to reinforce students' learning of different concepts. While this was the case, approximately seventy-five percent of the course time was devoted to the SSI curriculum. The SSI curriculum provided the teacher with opportunities to use many strategies to present the curriculum to the students. These opportunities included an introduction of the topics and assignments, assigning students to individual and group assignments, assigning students to use computers and iPads, using clicker activities to engage students in tasks, and arranging debates and discussions. I visited the teacher's classes to observe and provide help in leading some of the class discussions. For example, before the students debated "Stem Cells: Promise to Keep," I assisted the teacher in the formation of the supporting and opposing teams. I also acted as timekeeper to ensure teams received equal amounts of time to present their arguments. I also acted as scorekeeper for the entire activity.

### **Description of the Curriculum for the SSI Group (Treatment Group)**

A brief description of each of the three units used for the treatment classes are outlined below. A more detailed description of the assessment instruments for each unit can be found in appendices D-J.

**Unit One: Evaluation of Evidence.** This unit was comprised of five SSI lessons. The main goal of this unit was to provide students with opportunities to learn about factors that are paramount to the evaluation of evidence. Students were given pre/post- quantitative and

qualitative questionnaires. The instrument used in this unit to assess students' abilities to evaluate evidence was adopted and modified (different news brief and additional questions) from Korpan et al. (1994). See Appendix D for a detailed description of the instrument.

Below are the titles and objectives of each lesson:

1. Extrasensory Perception: Pseudoscience?

The objectives of this activity were to teach students to be skeptical of sensational scientific claims. Another objective of this activity was to provide students with opportunities to evaluate information and data to determine scientific evidence.

2. Thinking Inside the Box

The objectives of this black box experiment were to allow students to make indirect observations, report on those observations, and conduct peer review of research proposal. Students also were able to learn about atomic structure and how experimental evidence can be used to infer structure.

3. Cell Phone Use and Cancer

The objectives of this lesson were to provide students with the opportunity to identify the basic elements of a scientific research study. Students were given the opportunity to evaluate a scientific study and offer suggestions for improvement. Students analyzed the appropriateness of the headlines of news articles in relation to their content and compared the accuracy of information offered to the public in a news article with the information presented in a scientific paper.

4. Killing Coyote

The objectives of this lesson were to allow students to state an ethical perspective regarding wildlife and wildlife management verbally and in writing. Students had

opportunities to write a cohesive statement in a group, even though the position may be contrary to one's personal feelings. Students were then asked to critically evaluate the sources. Another objective of this activity was to allow students to have increased awareness of current controversial issues and practices in wildlife management and to be able to evaluate the cultural and scientific validity of those practices.

5. The Deforestation of the Amazon

The objectives were to allow students to understand the political, cultural, and economic history leading to tropical deforestation in the Amazon. Students were given opportunities to critically evaluate economic versus ethical evaluation of the ecosystem. Students learned to appreciate the difficulties of making decisions with limited or nonexistent data.

**Unit Two: Decisions about Socioscientific Issues.** This unit was comprised of five SSI lessons. The main goal of this unit was to provide students with opportunities to learn scientific concepts and make informed decisions. Students were given pre/post- quantitative and qualitative questionnaires to collect data concerning their decisions about SSI. The instrument used to assess students' abilities to make decisions was adopted and modified (modified by combining two questionnaires into one, additions of context to questionnaire, and inclusion of additional questions) from Zeidler et al. (2011). See Appendix E for a detailed description of the instrument.

Below are the titles and objectives of each lesson:

1. Stem Cells: Promise to Keep

The objectives of this lesson were to provide students with opportunities to discuss the concept of stem cells. Students learned the differences between embryonic stem cells and



adult stem cells. Students learned to debate ethical dilemmas posed by stem cell use and learned to make decisions on issues pertaining to those dilemmas.

## 2. Saving Superman

The objectives of this lesson were to allow students to identify pros and cons of adult stem cell usage and embryonic stem cell usage. Students learned how public and private funding could affect research. Students gained an understanding of the ethical concerns surrounding stem cell isolation and research, and an understanding of how the issue of abortion arises with embryonic stem cell isolation. Students learned the potential of conducting stem cell therapy, took a position on the issue of stem cell isolation, and researched to be able to defend their position of the issue.

## 3. Sometimes It Is All in the Genes

The objectives of this lesson were to allow students to discuss symptoms and treatments of genetic disorders such as cystic fibrosis. Students also had to decide if parents should test for genetic disorders for which there are no cures.

## 4. Cloning Animals for their Body Parts to Replace Worn Out Human Organs

The objectives of this lesson were to allow students to explore issues surrounding the present organ transplant system. Students examined the implications of using cloned pig organs for human transplantation. Students demonstrated knowledge of the issue through participation in a panel discussion. Students learned to synthesize personal perspectives on the issue and learned to express their views on the issue by writing a letter to an editor.

## 5. Sex and Vaccination

The objectives of this lesson were to give students opportunities to probe the boundaries between elected officials' duties to protect the public health and the right of individuals to

make decisions affecting their health and well-being. Students learned to discern potential bias and partiality in scientific issues. Students learned to fashion a compromise solution that makes allowances for dissenting or minority viewpoints in addressing a major public health issue.

**Unit Three: Use of Scientific Content Knowledge to Reason about SSI.** There were six SSI lessons in this unit. The main goal of this unit was to provide students with opportunities to learn how to use scientific content knowledge to reason about SSI. Students were given pre/post- qualitative questionnaires. These instruments were adopted from Zohar & Nemet (2002). See Appendix F and G for a detailed description of the instruments.

Below are the titles and objectives of each lesson:

1. Torn at the Genes

The objectives of this lesson were to allow students the opportunities to consider the benefits as well as the cost of genetic engineering and to examine the potential ecological consequences of genetic engineering of crops. Students were given opportunities to discuss the ethical arguments involved in the manipulation of DNA in organisms and the issue of labeling genetically modified food.

2. Golden Rice

The objectives of this lesson were to allow students to describe concepts associated with genetically modified foods and examine arguments supporting or opposing the use of genetically modified food. Students were also given the opportunities to consider the socio-political causes and implications of malnutrition in developing countries and were allowed to propose the best strategies to remedy malnutrition in real life.

### 3. Genetic Testing and Breast Cancer

The objectives of this lesson were to allow students to formulate and defend a decision for or against genetic testing, while taking into consideration various kinds of information. Students received the opportunity to critique the effects of obtaining genetic information for employment, health insurance, and personal decisions.

### 4. Two Peas in a Pod

The objectives of this lesson were to give students opportunities to learn concepts of fertilization, twinning, fraternal versus identical twins, *in vivo* and *in vitro* fertilization, and DNA profiling. Students also learned to interpret evidence from several single locus DNA gel electrophoresis tests. They learned about the benefits and limitations of reproductive technology. Students also explored legal and ethical issues implied by the use of reproductive technology.

### 5. Bringing Back Baby Jason

The objectives of this lesson were to introduce students to the concept of human cloning. Students developed an understanding of the basic genetic concepts underlying the cloning process, including imprinting, mitosis, meiosis, asexual reproduction, and sexual reproduction. Students were encouraged to consider the scientific and social aspect of human cloning.

### 6. Life: Is It, or Is It Not? A Closer Look at the Abortion Issue

The objectives of this lesson were to allow students to use terminologies associated with the reproductive system. Students learned about the organization of the male and female reproductive systems. Students learned to identify structures and functions of the male and female reproductive systems. Human copulation, pregnancy, development, and birth

were concepts taught as well. They also learned to evaluate core beliefs and use scientific evidence to evaluate and decide on issues that were in conflict with their core beliefs.

### **Description of Curriculum for the Traditional Group (Comparison Group)**

The teacher was instructed not to use SSI lessons with students in the comparison class. I visited the comparison class while the research was in progress to ensure that the teacher was complying with this request. The topics covered with students in the comparison group included properties of life, cell structure and function, ecology, cellular reproduction, and genetics. However, since these students were given the opportunity to engage in discourse activities with their peers, the extrasensory perception activity was done with these students so they could learn how to be skeptical of certain scientific claims. The black box experiment was also conducted in order for the students to develop competence in making indirect observations, reporting on those observations, conducting peer review of research proposals, and learning how experimental evidence can be used to infer structure. These students also learned basic concepts of these topics prior to the beginning of each intervention in this study. However, the contents for the comparison class were taught using a traditional approach that utilized the course topics as they are organized in the students' textbook. Classroom activities included lectures, laboratory activities, whole class debates, and worksheets. Students from the traditional group were also given pre- and post-test questionnaires to complete.

### **Research Design and Methodology**

This study employed the use of a quasi-experimental design by using students from two intact high school Biology Honors classes. This design was used to obtain both quantitative and qualitative data in order to get a better understanding of the effects of emotive reasoning on the

above constructs.

The teacher in this study had one class randomly assigned as a treatment group and the other as a comparison group. Both the treatment and the comparison classes were given pre/post-test questionnaires to complete. Individual students were also randomly selected for follow-up interviews. The students in this study had various background experiences, although many were from the same communities that surrounded the school. The academic abilities of these students in the different groups (treatment and comparison) also varied. The school generally placed students in honors classes, such as Biology Honors, who met certain academic criteria (e.g., passing scores on the End-of-Course State Algebra examination). After the identification of the students from the different classes, their 8<sup>th</sup> grade Science and Reading FCAT scores along with their End-of-Course Algebra Examinations scores (latest FCAT data) were analyzed to determine academic similarities between treatment and comparison groups. This was done in order to uphold the internal validity of this study (Campbell & Stanley, 1966).

### **Study Timeframe**

The teacher who volunteered to use her classes for this study was a colleague of the principal investigator. The teacher was also given a brief overview of SSI (See Appendix A). I also shared an SSI unit with the teacher and gave her the opportunity to ask questions to clarify any misunderstanding of what SSI was or was not. At this time, the teacher was given a copy of this SSI overview to use as a template to develop her own SSI units in the future.

Before the Winter break, the teacher shared with her students our intent to conduct this study in their class. Permission slips were given to the students and their parents. Upon receiving all signed permission slips from the students and their parents, the steps outlined in the instrumentation section were implemented. The total time span of this research was

approximately 16 weeks. In total, each student completed six qualitative questionnaires and four quantitative questionnaires. Semi-structured interviews were also conducted with six students who were selected randomly from the two classes. An outline of the events in regards to the data collection is shown in Figure 1.

Students were given the pre-test evidence evaluation instrument a day prior to the start of the treatments. Treatments for evidence evaluation were then conducted over the course of 12 class periods lasting 55 minutes each. At the end of this timeframe, students were given the post-test evidence evaluation instruments (See Table 3 for details).

Pre-test qualitative and quantitative questionnaires to assess students' decision-making abilities were administered to students a day prior to the treatments. Treatments for decision-making were conducted over the course of 15 class periods lasting, 55 minutes each. At the end of this timeframe, students were given the post-test decision-making instruments (See Table 3 for dates).

It was necessary to sequence the administration of the instruments in the manner described above because two weeks into the study, the administration informed the science department to revise the timeline for the annual reviews of the State of Florida End-of-Course Biology Examination. Therefore, I became concerned that I would not have enough time to administer all my posttest instruments at the end of the interventions. This led to the decision to sequence the data collection in the manner described.

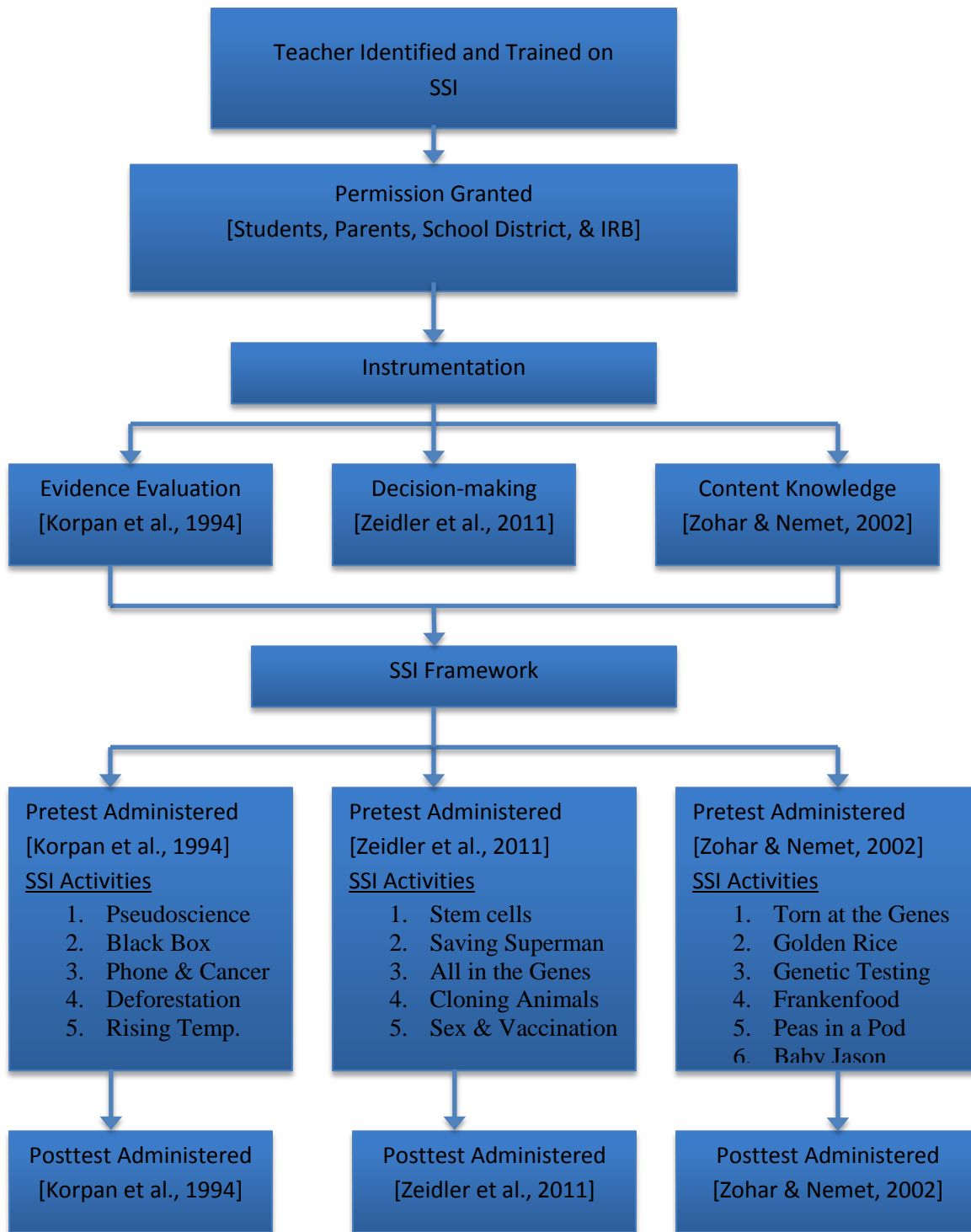


Figure 1. Study Overview

Pre-test qualitative questionnaires to assess students' abilities to integrate scientific content knowledge in their reasoning were administered to students a day prior to treatment. Treatments to enhance students' abilities to integrate content knowledge in their reasoning of ill-structured problems were then conducted over the course of 15 class periods that were each 55 minutes long. At the end of this timeframe, students were given the post-test instrument to assess their abilities to use content knowledge when reasoning about SSI (See Table 3 for dates).

Table 3

*Timeline for treatment*

Date	Tasks
Week 1	Pre-test quantitative and qualitative questionnaires to assess students' abilities to evaluate evidence administered.
Week 1	SSI instructional unit started with experimental groups. Traditional methods of instruction also started with comparison groups.
Week 5	Post-test quantitative and qualitative questionnaires to assess students' abilities to evaluate evidence administered.
Week 5	Pre-test quantitative and qualitative questionnaires to assess students' abilities to make decisions on SSI administered.
Week 6	SSI instructional unit that provided students with opportunities to make decisions and support those decisions started with experimental groups. Traditional methods of instruction started with comparison groups.
Week 10	Post-test quantitative and qualitative questionnaires to assess students' abilities to make decisions on SSI administered.
Week 11	Pre-test qualitative questionnaires to assess students' abilities to use scientific content knowledge in their decisions on SSI administered.
Week 11	SSI instructional unit that provided students with opportunities to use content knowledge in their decisions started with experimental groups. Traditional methods of instruction started with comparison groups.
Week 15	Post-test qualitative questionnaires to assess students' abilities to use scientific content knowledge in their decisions on SSI administered.
Week 16	Semi-structured interviews were conducted. Interview ended.



Table 4

*Timeline for conducting study*

	Aug.	Nov.	Dec	Jan.	Feb	March	Apr.
Teacher Identified	X						
Teacher Trained/students informed and permission slips given/secured		X	X	X			
Pre-test Data for Evidence Evaluation				X			
Evidence Evaluation				X			
Intervention for Treatment Classes							
Post-test Data for Evidence Evaluation					X		
Pre-test Data for decision-making					X		
Decision-making intervention in treatment classes					X		
Post-test data for decision-making					X		
Pre-test data for scientific content knowledge					X		
Content knowledge intervention in treatment classes						X	
Post-test data for scientific content knowledge							X
Semi-structured Interviews							X

An outline of the timeframe for conducting this study is shown in Table 4.

**Procedures for Maintaining Confidentiality**

Maintaining confidentiality is always a top priority in any scientific investigation dealing with students; therefore, a random number and lettering identifier was used for each student involved in the study. The student’s name and their school district supplied identification number were needed to gather raw data; however, the researcher removed these potential

identifiers prior to presenting the data to the analysts for review. The audio recordings from the interviews were transcribed by the researcher and assigned random number and lettering identifiers. Again, the analysts were presented with the interview data that had these randomly assigned numbers and letters. For the quantitative measures, the classes' data was reported for each outcome variable. For the qualitative measures, the random number and lettering identifiers were used to report all data. The researcher was the only person who could match the number identifiers with a student name. At no time during the reporting of the data would an observer be able to determine which student was responsible for a particular piece of data.

**Research Question and Data Analysis Summary**

The table below gives an overview of the data sources and analysis that were conducted for each research question.

Table 5

*Summary of each research question, data source(s), and the analysis*

Research Questions	Data Source(s)	Analysis
What relationships exist between secondary school students' emotive reasoning and their abilities to evaluate evidence related to thoughts on socioscientific issues	Quantitative Questionnaires-requiring students to read a fictitious News Brief and then collect data on students' experience, interest, extent of scientific content knowledge and emotions to evaluate evidence etc.). Qualitative Questionnaires (Questions students want to have answered before they can decide whether the conclusion made in a news brief is true). Semi-structured Interviews	Kruskal-Wallis Non-Parametric Analysis of Variance (ANOVA) statistical technique to analyze difference of pre and post median scores between treatment and comparison groups.  Constant Comparative Method (Glaser & Strauss, 1967) Inductive Analysis (Lincoln & Guba, 1985).  Transcribe students' responses Inductive analysis (Lincoln & Guba, 1985). Constant Comparative Method of

Table 5 (Continued)		
		Analysis (Glaser & Strauss, 1967).
What relationships exist between secondary school students use of emotive reasoning and their decision-making regarding socioscientific issues?	Quantitative Questionnaires (Students rank ordering among patients who should receive an organ transplant).  Qualitative Questionnaires (Students provide justification for their rank ordering).	Kruskal-Wallis Non Parametric Analysis of Variance (ANOVA) statistical techniques on difference scores were conducted. Constant Comparative Method of Analysis (Glaser & Strauss, 1967). Inductive analysis (Lincoln & Guba, 1985).
In what ways do secondary school students integrate scientific content knowledge in the process of reasoning about socioscientific issues?	Qualitative Questionnaires (Students argument on the course of action for a family who is a carrier of the defective gene for Huntington Disease).	Inductive Analysis (Lincoln & Guba, 1985). Constant Comparative Method of Analysis (Glaser & Strauss, 1967).

## Research Questions, Instrumentation, and Analysis

**Research Question 1.** What relationships exist between secondary school students' emotive reasoning and their abilities to evaluate evidence related to thoughts on socioscientific issues?

### Instrument

An instrument that was adopted and modified from Korpan et al. (1994) was employed to assess both quantitative and qualitative data (See Appendix D). Korpan et al. (1994) developed the evidence evaluation instrument in response to the growing public recognition that adequate levels of scientific literacy were not being achieved by many children and adults (American Association for the Advancement of Science, 1989; Science Council of Canada, 1984). The instrument was designed for use in research projects focused on how individuals assessed the credibility of brief reports. This instrument was divided into three sections. Section 1 required

students to provide responses to seven questions. This section (section 1) was further subdivided into Parts 1a and 1b.

In Part 1a, students were given a fictitious news brief to read. Using a scale that ranged from 1—100, the students were then required to determine:

- How likely they thought a given claim from the article was true.
- Identify how much experience with or knowledge of the general topic of the claim they had.
- Identify how interested they were in the general topic of the claim.
- Outline what amount of scientific knowledge they used to evaluate the claim.
- Identify the type(s) of emotions they experienced as they judged the claim.
- Indicate how they rated their ability to evaluate evidence.

The seventh question in section 1 required students to explain why they rated their ability to evaluate evidence the way they did on question 6. Part 1 b represented the results of students' responses to the seventh question (See Appendix D).

In Section 2, students were asked to formulate questions they would want to have answered before they could decide whether the conclusion made in a news brief was true. For each question they generated, students were required to indicate how they thought the answer to that question would help them to evaluate the conclusion in the news brief. Students were asked to identify the types of emotions they experienced in regards to their questions and to explain how those emotions might influence the way they evaluated the claim. Students were also asked to explain if the answers they provided satisfied their emotions.

Section 3 reported results of the semi-structured interviews. These interviews were conducted to generate a better understanding of what motivated students to ask the questions

they asked in section 2.

## **Analysis**

### **Quantitative Analysis-Section 1**

In Part 1a, students' pre/post-test responses to an individual item (i.e., how likely they thought a given claim was true, how much experience with or knowledge of the general topic of the claim did they have, etc.) from both the treatment and the comparison groups were analyzed using Kruskal-Wallis Non-Parametric Analysis of Variance (ANOVA) statistical technique. This technique was employed because it is ideal for determining if there are any differences between the pre/post median scores compared between the treatment and the comparison groups. It is also ideal for recognizing if those differences in the treatment group fall under the null hypothesis. In instances where there were differences between the treatment and the comparison groups, the Test Statistic—K was used to determine how large the reported differences in scores were between these groups. The overall alpha was set at 0.05.

### **Qualitative Analysis-Section 1**

In Part 1b, students were required to provide a brief explanation as to why they rated their abilities to evaluate evidence the way they did in question six. Two analysts, who were also doctoral candidates with extensive experience using SSI as a key pedagogical strategy, along with the researcher were involved with the analysis of the students' data. The researcher and the two analysts independently read and re-read students' explanations to identify common themes and trends. The researcher then met with the two analysts to discuss the themes and trends that were identified. At this meeting, we all laid out our themes, we reviewed and collapsed everyone's themes and separated them into three groups: 1) similarities; 2) close similarities; and 3) different. We then further analyzed the themes to arrive at the results discussed.

## **Qualitative Analysis-Section 2**

Section 2 of the evidence evaluation instrument required students to formulate questions they would want to have answered before they could decide whether the conclusion made in a news brief was true. Students provided feedback on the types of emotions they experienced in regards to their questions (See Appendix D for further detail). Again, the two analysts along with the researcher were involved with the analysis of the students' data. The analysts and the researcher independently read and re-read students' questions to identify the different categories of requests from the questions they asked (See Appendix J). The researcher then met with the two analysts to discuss categories of questions that were identified. There were some disagreements on the interpretation of the wording of students' questions, but through discussion, both analysts and the researcher were able to come to a common understanding and agreement. A coding scheme for evaluations of evidence adopted from Korpan et al. (1994) was used to assign scores to students' categories of questions. To accomplish this task, an a-priori rubric for the questions students generated (Evidence Evaluation Section 2) was developed based on Korpan et al. (1994) taxonomy for classifying questions and knowledge about scientific research. Korpan et al. (1994) identified: Social Context; Agent; Methods; Data/Statistics; Relevance; and Related Research as topic descriptions that were pertinent to helping individuals evaluate conclusions of a News brief. In order to provide scores to the questions students generated as they attempted to evaluate the claim that embryonic stem cells were successfully used to repair rats' vision, criterion, pre-test and post-test scores, with a description of each criteria was added to the rubric (See Appendix H). The researcher and the two research analysts next utilized inductive analysis (Lincoln & Guba, 1985) for refinement of the rubric criteria. The analysts and the researcher crosschecked the scores that were assigned. There were some disagreements on

the scores assigned, but through discussion both analysts and the researcher were able to come to a common consensus.

The use of the Kruskal-Willis non-parametric ANOVA was employed to analyze students' scores for individual categories. Again, this technique was chosen because it was ideal for determining if there were any differences in scores between the treatment and the comparison groups given the level of data. The Test Statistic—K was used to determine how large the reported difference in scores was between these groups.

Students' responses about how they thought the answer(s) to the question(s) they formulated would help them to evaluate the conclusion in the news brief were evaluated qualitatively for evidence of emotions. Two analysts and the researcher (principal investigator) were involved in this process. Both analysts and the researcher independently read and re-read students' generated questions to identify trends and themes. All disagreements were discussed and potential conflicts eliminated resulting in above 90% inter-coder agreement for all the themes and trends identified.

### **Semi-Structured Interviews-Section 3**

As it was difficult to arrange for an analyst to be at the school on multiple days to conduct interviews with the students, coupled with the fact that the science department was informed by the school's administration to revise the timeline of their annual reviews for the State of Florida End-of-Course Biology Examination two weeks after the study begins, I made the decision to conduct semi-structured interviews at the end of the study. I conducted semi-structured interviews with six randomly selected students (three from each group) to gain better clarity of their responses to the items in section 2. Results of students' interviews were then transcribed and made available for the analysts. The analysts were aware which interviews were

from the pre-test and which interviews were from the post-test, but the analysts were kept blinded to the comparison and the treatment group. The analysts and researcher read through students' transcribed interviews and identified commonalities and themes (see Chapter Four for details) among students' responses.

**Research Question 2.** What relationships exist between secondary school students' use of emotive reasoning and their decision-making regarding socioscientific issues?

### **Instrument**

An instrument that was adapted from Zeidler et al. (2011; 2013) was employed to assess both quantitative and qualitative data (See Appendix E). In Part I, students' justifications for their decisions to award the organ transplant to their first and second choice patients were analyzed using Kruskal-Wallis Non-Parametric Analysis of Variance (ANOVA) statistical technique. A coding scheme that awards scores for students' justification adopted from Zeidler et al., 2013 was used (See Appendix, K). An inductive analysis to identify emergent themes and trends from students' emotive and scientific considerations that influenced their decisions to award the organ transplant were reported under Part II. The decision-making instrument was developed as an open-response questionnaire that required students to imagine they served on a public review committee to help create guidelines and policy for how a transplant program should operate. The task that students were asked to complete from this instrument did not require them to select a particular patient over another; rather, it entailed the development of a protocol in order to implement policy. Therefore, the instrument tapped aspects of distributive justice by requiring the evaluation of criteria typically weighted against one another in situations that required the distribution of scarce medical resources (Armstrong & Whitlock, 1998, Zeidler et al., 2011).



In order for students to rank the order for who should receive an organ transplant, they had to consider the patient's attributes such as, but not limited to, the degree of illness, ability to pay for transplant, and the patient's survival chance after receiving the organ transplant. Students provided justifications as to why they ranked the order of the patients in the manner they provided. This instrument was used intact with the only modification being two additional questions aimed at revealing the possible use of emotive reasoning in their justification. These additional questions required students to explain their use of scientific and emotional considerations in their decisions on how they ranked the order of the different patients (See Appendix E for further detail).

## **Assessment**

### **Quantitative Analysis**

Students' responses to Part 1 of the decision-making instrument required them to rank the order among seven patients, who should receive an organ transplant, was analyzed using Kruskal-Wallis Non-Parametric Analysis of Variance (ANOVA) statistical technique. Other researchers have suggested that students invested the most cognitive energy deciding between first and second place positions and generally prioritized these choices over the remaining choices (Zeidler et al., 2011; 2013). Therefore, only students' first and second choices were examined with the use of Kruskal-Wallis test of mean ranks to identify statistical significant differences between the treatment and the comparison groups' mean scores.

### **Qualitative Analysis**

To identify emergent themes in the data, we used a constant comparative method of analysis of students' responses for their ranking of scientific and emotional considerations influencing their decisions regarding which patient should receive an organ transplant (Glaser &

Strauss, 1967). The researcher (principal investigator) and two doctoral candidates, with extensive experience in analyzing qualitative data were involved in this process. The transcripts were provided to all the analysts for reading and re-reading (15 transcripts for each analysts and researcher). Both analysts and the researcher independently coded sentences, sections, and paragraphs. The analysts and the researcher then independently used the codes identified to form themes. The researcher and two analysts then met to discuss the results. All disagreements were discussed until the researcher and the two analysts reached a consensus. The steps above continued until an inter rater reliability of 90% was reached between the researcher and analysts.

**Research Question 3.** In what ways do secondary school students integrate scientific content knowledge in the process of reasoning about socioscientific issues?

### **Instrument**

Students' abilities to integrate and use scientific content knowledge in their reasoning about SSI were assessed using writing assessment tasks. Students were required to write persuasive essays regarding scientific issues. The students were given basic information about the topics from multiple perspectives to discuss and then wrote persuasive essays. The writing assessment tasks were adopted from Zohar and Nemet (2002). Students were given two cases to read and asked to respond to questions about each case (See Appendices F and G).

The first case (Appendix F) required students to work in groups of three to discuss a small excerpt outlining the effects of Huntington disease on a family. After discussing the excerpt, individual students were required to determine a course of action that the family should take if they found that a family member, who was pregnant, was a carrier of the gene for Huntington disease. Students provided justifications for their course of action. This case was used to collect pre-test qualitative data.

The second case (See Appendix G) required students to read and discuss the issue of aborting a fetus that was a carrier of the allele for Huntington disease. Individual students made their decision regarding if the fetus should be aborted. Students then provided justifications for their decision.

### **Analysis**

Students' responses were analyzed inductively (Lincoln & Guba, 1985) to promote understanding of the types and/or quality of scientific content knowledge students' used in their reasoning on what course of action the family should take. A constant comparative method of analysis (Glaser & Strauss, 1967) on students' suggested course of actions and justifications were conducted to identify emergent themes. The principal investigator and the two doctoral candidate analysts were involved in this process. All three independently scored five data sets per round and conducted two iterations of the students' data. This was done until an inter-rater agreement of above 90% was achieved. All disagreements were discussed, and all potential conflicts were eliminated.

### **Interview Protocol**

**Use of Emotions to Evaluate SSI.** Semi-structured interviews were used to better understand students' responses to items in section 2 of the evaluation of evidence instrument (See Appendix D). These interviews were conducted at the end of all interventions. Interviews were tape recorded, transcribed, and analyzed. During these semi-structured interviews, students were given copies of their written responses from the questionnaires. Students were instructed to read through the questions and their responses to refresh their memory. Students were then asked to respond to the following open-ended questions (Appendix K).

1. Why did you ask such questions first? Second? Third?

2. Can you tell me about any emotions that influence such question(s)?
3. What is the significance of these emotions?
4. Can you see any potential benefits from you using these emotions to evaluate the claim?
5. Can you see any potential problems from you using these emotions to evaluate the claim?

After transcribing students' responses to the items for each question, both analysts and the researcher read and re-read each student's response and attributed codes to sentences and/or paragraphs. Several emergent themes (detailed in Chapter Four) were identified. All disagreements were discussed, until a consensus was reached.

### **Qualitative Safeguards**

In order to produce research that was persuasive and deemed credible by an informed audience, it was important that the researcher considered safeguards against factors that may have derailed the trustworthiness of their research. In building trustworthiness for one's research, the researcher must satisfy criteria such as credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). This research satisfied these requirements (See below).

#### a) Credibility:

Achieving credibility required prolonged engagement, persistent observation, and triangulation. The duration of this study was over 16 weeks. I visited the classes of the teacher who was involved in this study at least twice per week during implementation of the units. I took notes on what was observed during each visit. I had regular meetings with the teacher, at least once per week throughout the duration of the study, to ensure that she shared my views as the researcher. This research employed the use of data

collection modes such as interviews, questionnaires, and observations. These are safeguards that were implemented to ensure the credibility of this study.

b) Transferability:

Detailed descriptions of the data were completed in order to provide clarity and enable other researchers to apply the results from this investigation to their own context. Such detailed descriptions of the data were provided to create the possibility of transferability judgments (Lincoln & Guba, 1985).

c) Dependability:

Another doctoral student with experience in analyzing qualitative research served as my auditor and conducted checks on the data to ensure dependability (Lincoln & Guba; Patton, 1990). After I completed my analysis of the data, this doctoral student thoroughly examined students' original transcripts, data analysis documents, my field notes journal, and the text of the dissertation itself.

d) Confirmability:

The use of quantitative analysis to confirm what had been observed from the qualitative analysis of the data was done as a means to help establish confirmability.

## **Summary**

A mixed-method approach was employed in this study with the purpose of exploring relationships between students' emotive reasoning and their abilities to evaluate evidence. In an attempt to understand the effects of emotive reasoning on students' abilities to make decisions on SSI, students were required to rank the order factors and determine who should receive an organ. Students were asked to provide justifications for their ranking order of who should be awarded an organ transplant. Students' justifications were analyzed for the use of emotive reasoning.

Students' abilities to use scientific knowledge in their reasoning on SSI were evaluated by qualitative approaches. One teacher used two of her Biology Honors classes in this study. This teacher had one class that served as the treatment group and one that served as the comparison group. The duration of this investigation was over 16 weeks. During this study, pre-test instruments were given to students before they were exposed to basic knowledge of the topics under consideration. Advance SSI instructions were given to the treatment group, and advance traditional instructions were given to the comparison group. All instructions were aligned to the district and school's science department mandates for Biology Honors. Analyses of students' responses to the different questionnaires and interview questions were conducted.

## **CHAPTER FOUR: RESULTS**

### **Introduction**

The purpose of this study was to explore the effects of emotive reasoning on secondary school students' decision-making in the context of socioscientific issues. Specifically, this study sought to investigate three main questions:

1. What relationships exist between secondary school students' emotive reasoning and their abilities to evaluate evidence related to thoughts on socioscientific issues?
2. What relationships exist between secondary school students' use of emotive reasoning and their decision-making regarding socioscientific issues?
3. In what ways do students integrate scientific content knowledge in the process of reasoning about socioscientific issues?

The first research question was answered through a combination of quantitative and qualitative analyses of students' responses to items from a fictitious news brief (See Appendix D). The analysis of the responses is reported in three main sections. Section 1 contains two sub-sections (Part 1a and Part 1b). Part 1a illustrates the quantitative findings (See Appendix D, questions 1-6), and Part 1b illustrates the results of the themes and trends that emerged (See Appendix D, question 7).

Before beginning their research, the students generated a list of questions they wanted answered. In Section 2 of research question one, the themes and trends that emerged from these questions will be reported. In addition, the explanations the students gave for those questions and types of emotions that influenced the questions will be identified

(See Appendix D). Finally, Section 3 will outline the themes and trends that emerged during the semi-structured interviews.

Part 1a of the first section of research question one required students to use scales that ranged from 0—100 to determine the following:

1. How likely they think embryonic stem cells are used to restore rats' vision?
2. Identify how much experience with or knowledge of stem cells they have.
3. Identify how interested they were in the topic of stem cells.
4. Identify the scientific knowledge they used to evaluate the claim that embryonic stem cells were used to repair impaired vision in rats.
5. Identify the type of emotions they experienced as they judged the claim that embryonic stem cells can repair impaired vision in rats.
6. How do they rate their ability to evaluate evidence?

Part 1b required students to explain why they rated their abilities to evaluate evidence the way they did in their responses to question 6 above.

Section 2 of the first research question asked students to formulate questions they would want to have answered prior to deciding if the statement that embryonic stem cells can be used to repair impaired vision is true. Students then indicated how they thought the answer to their questions would help them evaluate the conclusion, identify the types of emotions that influenced their question, and explain if their emotions may have influenced how they evaluated the claim. Students' responses were analyzed through qualitative methods to identify common trends and themes. Presentations of the common trends and themes will be discussed in section 2.



To better capture what empowered students to ask the questions from section 2 of the evidence evaluation questionnaire, semi-structured interviews were conducted and analyzed through qualitative methods. The common trends and themes that emerged from students' interviews are reported under the section titled semi-structured interviews.

The second research question was answered in two parts using both quantitative and qualitative analyses. Students' responses to the second research question are addressed and discussed under two main parts. Part 1 contains the quantitative results of students' rankings regarding who should be awarded the organ transplant. The justifications given for their ranking order were analyzed qualitatively to identify common themes and trends. In part two, students were asked to identify scientific and emotive considerations that influenced their ranking of who should be awarded the organ transplant. A qualitative analysis of students' scientific and emotive considerations was conducted to identify common themes and trends. Results of the quantitative analysis conducted for Part I will be presented first. Results of the themes discovered from the qualitative analysis of students' justifications for their ranking order will follow. Qualitative results identifying common themes and trends from Part II of students' scientific and emotive considerations will then follow.

The third research question was answered using a qualitative analysis. Students were given two cases dealing with Huntington disease to read, discuss, and determine a course of action for an individual who is pregnant and a carrier of the allele for Huntington disease (See Appendices F and G). The following table is provided as a summary of the research questions, sections and parts that are associated with each question, the types of analysis that is associated with each question, and the results as they are presented.

Table 6

*Summary of research questions, sections, and analysis*

Research Questions	Section 1	Section 2	Section 3
1. What relationships exist between secondary school students' emotive reasoning and their abilities to evaluate evidence related to thoughts on socioscientific issues?	Part 1a—Quantitative: Scales 0-100 for 6 questions  Part 1b—Qualitative  List of questions from students about “Why” of question 6	Student formulated questions analyzed to identify Trends & Themes	Analysis of responses to semi structured interviews
2. What relationships exist between secondary school students' use of emotive reasoning and their decision-making regarding socioscientific issues?	Part I—Quantitative: Ranking of who should be awarded organ transplant?	Part II—Qualitative: Themes and Trends about the justification of ranks  Students' scientific and emotive considerations	
3. In what ways do students integrate scientific content knowledge in the process of reasoning about socioscientific issues?	Huntington Disease Case 1— Qualitative  Themes and Trends	Huntington Disease Case 2— Qualitative  Themes and Trends	

**Results for Research Question 1**

What relationships exist between secondary school students' emotive reasoning and their abilities to evaluate evidence related to thoughts on socioscientific issues?

**Evidence Evaluation Section 1**

The evaluation of evidence questionnaire examined students' responses to a fictitious story on the use of stem cell treatments to restore vision in rats (*See Appendix D*). This

questionnaire was divided into three sections. Section one contained seven questions. The first six questions required students to select a number that ranged from 0 - 100 for their answers to the questions. Findings from the quantitative analysis of sub-section Part 1a are presented first, followed by the themes and trends that were discovered from the qualitative findings of sub-section Part 1b.

**Quantitative Findings of Evidence Evaluation (Sub-Section Part 1a).** Kruskal-Wallis tests were conducted to evaluate differences between the pre-test and post-test scores for the treatment and comparison groups on the above questions (questions 1-6, p 99). Results for the different tests are summarized in Table 7.

Table 7

*Kruskal-Wallis Results for Treatment vs. Comparison Groups Pre/Post Tests Scores*

Wilcoxon Scores (Rank Sums) for Variable Difference Classified by Variable GROUP			
Questions	Groups	N	p-value
Beliefs in the conclusion	Treatment	25	.098
	Comparison	20	
Experience/Knowledge of Topic	Treatment	25	.088
	Comparison	20	
Interest in the Topic	Treatment	25	.039
	Comparison	20	
Using Scientific Knowledge to Judge	Treatment	25	.080
	Comparison	20	
Using Emotions to Judge	Treatment	25	.945
	Comparison	20	
Rating Ability to Evaluate	Treatment	25	.028
	Comparison	20	

All tests were corrected for tied rankings. An alpha level of .05 was used for all statistical tests. Of the six tests that were conducted, the only tests that produced statistically significant results were students' interest in the general topic that stem cells can be used to restore impaired vision in rats (Kruskal-Wallis test,  $p = 0.039$ ). The other significant test result was how students rated their abilities to evaluate evidence (Kruskal-Wallis test,  $p = .028$ ).

**Qualitative Findings of Evidence Evaluation (Sub-Section Part 1b).** Results from the qualitative analysis that was conducted on question 7, which tapped students' ability to evaluate evidence, will be presented below. First, the question is as follows:

Question 7: Please provide a brief explanation as to why you rated your ability to evaluate evidence the way you did in question 6.

The researcher and two research analysts conducted inductive analysis on students' written responses and identified three major categories common among students from the comparison group. As shown in Table 8, students in the comparison group used new information learned from their exposure to the lessons on genetics to help in their abilities to evaluate evidence. While this was the case for some students, there were others who stated they lacked the scientific background knowledge necessary to adequately evaluate any evidence on the topic of genetics. Students who did not use new information or background knowledge stated they used emotions to evaluate the information because they believed stem cells are dead fetuses. The imagined scenario of researchers killing fetuses to help in the research caused them to become emotional to the extent they had difficulties deciphering what is considered evidence and what the researchers were actually saying (see table 8 below).

Table 8

*Representative explanation given by members of the comparison group for evaluating evidence in (question 6).*

Categories	Pre-Test Explanation	Post-test Explanation	Researchers' Interpretation
New Knowledge	“Lack of understanding.” (#15LC)	“From what I have learned, totipotent which means it can turn into any type of cell, so embryonic stem cell could have been put to the eye parts of rats so that the stem cell can form into the cell that makes animals see and restore eyesight.” (#15LC)	Student expressed lack of understanding of the topic in the pre-test response. On the post-test, this student suggested that the new knowledge he had gained led him to believe that the use of embryonic stem cells does have the potential to correct vision, since these cells do transform into different body parts.
Emotion	“Stem cells are dead fetuses, which is a little emotional for me. This makes me mad.” (#18LC)	“I have difficulties at times to decipher what is evidence and what the researchers are trying to say. They are killing fetuses which is too emotional.” (# 18LC)	Student used the emotion of anger to express the belief that stem cells are dead fetuses. The student expressed the difficulties she experienced in trying to evaluate the evidence because of the emotion the subject arose.
Lack of scientific background	“I rated myself a zero because I don't believe I have the scientific knowledge to evaluate something on a level such as this experiment.” (#19LC)	“I am not a scientist and I am unable to evaluate evidence.” (#19LC)	Student expressed very little confidence in his ability to act as a scientist and evaluate evidence.

Students' responses from the treatment group are represented below. Table 9 provides a summary of the analysis of students' responses from the treatment group and the three major qualitative categories: 1) New Knowledge; 2) Experience on the topic; and 3) Lack of Scientific background knowledge.

As shown in Table 9, students in the treatment group stated they used new information learned from their exposure to the lessons on genetics to evaluate evidence. Moreover, students used prior experiences gained from doing research to assist them in evaluating the evidence regarding how embryonic stem cells can be used to repair rats' vision. However, there were those who stated they simply lacked the background knowledge necessary to adequately evaluate any evidence on the topic of genetics.

Despite the many similar responses identified among the students, the treatment and comparison groups' differences were apparent in the data. The integrated SSI curriculum contributed to the discussion and debates of students, while impacting their confidence regarding evaluating evidence. For example, students in the treatment group researched the pros and cons of adult stem cells usages and learned about both the ethical concerns surrounding stem cell research and the potential benefits of stem cell therapy. Then students took a position on the issue of stem cell isolation and used this research to defend their position. The experiences gained from these activities appear to have impacted their confidence in evaluating the evidence that stem cells can be used to repair rats' vision. This sentiment was echoed by student #5LT who stated, "I rated my ability to evaluate evidence at an 80 because of my experience with evaluations and experiments. I am capable of evaluating evidence in a thorough way, yet not at an expert level. Therefore, that is why my rate was an 80."

Table 9

*Representative explanation given by members of the treatment group for evaluating evidence in question 6.*

Categories	Pre-test Explanation	Post-test Explanation	Researchers' Interpretation
New Knowledge	“I rated my ability to evaluate evidence the way I did because I think I can add to my ability to do a better job at evaluating evidence.” (#3LT)	“I rated my ability to evaluate evidence the way I did because as I am reading I make observations that support the hypothesis and I look at the evidence.”	In the pre-test explanation, this student suggested that if he gets the teachings on how to evaluate evidence, then he could become better at doing so. After being exposed to the treatments, his confidence and ability to evaluate became better. He stated he now looks for evidence to support the hypothesis when he is asked to evaluate a claim.
Experience on the topic	“I rated my ability that way because I have been asked before to evaluate evidence.” (#4LT)	“I rated my ability to evaluate evidence the way I did because of what I already know about stem cells.”	In the pre-test explanation, this student felt she was capable of evaluating evidence because of past experiences at evaluating evidence. In the post-test explanation, this student suggested that she already knew about stem cells. The result of her past experience in addition to her new knowledge on stem cells, gave this student confidence in her ability to evaluate the claim that embryonic stem cells was used to restore rats' vision.
Lack of scientific background	“I rated my ability because I don't have the background knowledge and this article was very short. In order to know the true potential and all the steps done in this experiment, I would have to do further research.” (#16LT)	“I rated my ability to evaluate evidence because this article gives a brief explanation about the research behind this discovery. However, when evaluating evidence, I need more background knowledge.”	In the pre-test explanation, this student suggested she lacked the scientific background knowledge necessary to adequately evaluate the evidence. She also stated that the article she read did not provide enough information on the research methods.

Students in the comparison group relied more on emotions when evaluating the evidence regarding the use of stem cells to repair rats' vision and made statements such as, "I have difficulties at times to decipher what is evidence and what they are trying to say. This is too emotional." This statement does suggest there were some students from the comparison group whose emotions impeded their abilities to evaluate the evidence regarding the use of embryonic stem cells to repair rats' vision. Students from both the treatment and the comparison groups stated they lacked experience /knowledge with the topic of embryonic stem cells to adequately evaluate the claim that embryonic stem cells were used to repair rats' vision. This statement corroborates the non-significant results from the Kruskal-Wallis test on students' pre/post test scores of their experience /knowledge of the topic of stem cells ( $X^2(2, N = 45) = 0.022, p = 0.881$ ). The statement also confirms Kruskal-Wallis non-statistical significant test results ( $X^2(2, N = 45) = 0.064, p = 0.800$ ) of students' use of scientific knowledge to judge the researchers' claim.

A comparison of the responses from the two groups of students suggests no major differences exist between the students who were exposed to the integrated SSI curriculum and those who were exposed to the traditional curriculum. The opportunities that the SSI curriculum provided for students to engage in research and debates on issues such as cloning did help, but the results also showed that the traditional curriculum helped the students as well.

## **Evidence Evaluation Section 2**

In section two of the evidence evaluation questionnaire, students were required to generate a list of questions they would want answered before they decided whether the conclusion made by members of the research team in Health and Medical News Weekly was true (*See Appendix D, Section 2*). Students were required to provide answers to each question,



identify the types of emotions they experienced with regards to each question, and explain if such emotions may have influenced how they evaluated the researchers' claim. A total of 45 students provided answers to these questions. Students asked questions about the species of rats involved in the research, the research institution involved in the investigation, funding sources for the research, the researchers' credentials, the possibility for human trials, and the morality and ethics that are associated with human trials. An inductive analysis of students' written responses identified confusion, concern, fear, grief, hope, and anger as emotions that influenced the above questions. Student question categories and types of emotions expressed by them are identified in table 10 (comparison group) and table 11 (treatment group) below. These tables identify common pre and post test questions, categories of those questions, emotions that influenced those questions, and researchers' interpretations of each group.

An analysis of the data from the treatment group resulted in four categories: research method, research institution, cost of conducting the research, and the credentials of the researchers. In addition, sadness, hope, fear, and anger were identified by the students' responses as emotions that influenced their questions. Students also identified curiosity as an emotion that influenced their question. While students also identified curiosity as an emotion that influenced their questions, it should be noted that curiosity is more aligned with a mindset aimed at inquisitive thinking. Curiosity is defined as a desire to know, to see, or to experience that motivates exploratory behavior directed towards the acquisition of new information (Litman & Jimerson, 2004; Loewenstein, 1994). However, being curious may impact one's emotive reasoning—reasoning in which individuals employ sympathy, empathy, or concern for the well-being of others to guide their decisions or course of action (Sadler & Zeidler, 2005b). Those students who identified curiosity as an emotion were predominantly skeptical about the

credentials of the researchers. The students also wanted to know if the researchers were more interested in the pursuit of profit rather than the pursuit of science. Students whose questions were influenced by anger were more concerned about morality and ethics associated with the use of human embryos to conduct the research.

Table 10

*Pre/Post test questions, reasons, and emotions expressed by students in comparison group*

Categories of Questions	Pre-test Questions and Reasons	Post-test Questions and Reasons	Emotions Pre/Post	Researchers' Interpretation
Method used in the experiment	<p>“What did they do to fix the impaired vision of the rats? Knowing how they do it would give me a general idea on whether it is possible to fix the rat’s vision.” (#2LC)</p>	<p>“How bad is the rats’ eyesight? What method did they use to fix the bad eyesight?” (#2LC)</p>	<p>Sadness (Pre-test emotion)</p> <p>Sadness (Post-test emotion)</p>	<p>In the pre-test, the student inquired about the method employed to repair vision problems in the rats. This student listed curiosity as contributing factor that influenced the emotion of sadness expressed. The reason the student gave for this question suggested the question was influenced by a desire to learn about the methods the researchers used in their experiments. In the post-test, the student inquired about the degree of damage to the rats’ vision and the method the researchers used to repair the damage to the rats’ eyes. The student again identified sadness as an emotion that influenced this question. The student’s comment following this question suggested that skepticism might have being factors that influenced this question.</p>

Table 10  
(Continued)

Potential of the experiment being successful	“Will this actually help human eyesight? I just want to know how it works.” (#9LC)	“Does it work? I hope it will work and help me with my vision problem.” (#9LC)	Hope (both pre and post-tests)	In the pre-test, the student inquired about the potential of this experiment actually helping people with vision problems. In the post-test, the student pointedly asked would it work. The student expressed hope in getting his perfect vision and said he would be grateful if it would aid him with his eyesight. The student suggested that hope was the main emotion that influenced such questions.
Source of stem cells	Where would you get the stem cells? (#18LC)	“How many embryos are being destroyed in this process?” (#18LC)	Anger (Pretest emotion)  Sadness and pity (Post-test emotions)	In the pre-test, the student inquired about the source of the stem cells. The student listed anger as an emotion that influenced such question. In the post-test, the student inquired about the number of embryos destroyed in this process and listed sadness and pity as emotions that influenced such question. The thought of the researchers destroying embryonic stem cells to conduct the research arose the emotion of anger among the student.
Side Effects	“What are the risks of this medicine?” (#14LC)	“What are the side effects on humans?” (LC#14)	Fear (both pre-test and post-test emotion)	The student’s pre and post questions revolved around the risks that are associated with this experiment. The student’s questions indicated that if health risks were involved, then the research might not be worth it.

The questions students in the comparison group asked were grouped into four categories: 1) Methods used in the experiment; 2) Potential of the experiment being successful; 3) Source of stem cells; and 4) Side effects. Students' decision to ask these questions corroborates earlier results that were discussed from the Korpan et al. (1997) study. In their investigation, Korpan et al. (1997) reported that the majority of students in their investigation asked questions about how the research was conducted and why the results might have occurred. Korpan et al. (1997) further reported that students asked questions about relevance, including requests for information about value or applicability of the research. While these questions may have been influenced by emotions, Korpan et al. (1997) did not identify any such emotions. The students from the current investigation were specifically asked to identify the emotions that influenced the questions they asked, as they evaluated the evidence. The students in both the comparison and the treatment groups identified anger, fear, sadness, hope and pity as emotions that influenced the questions they asked, as they evaluated the claim that embryonic stem cells were used to repair rats' vision. For example, when students questioned the method used by the researchers and the possible side effects from the treatment, they often identified sadness and fear as emotions that influenced their questions. These students were saddened by the harm that was done to the rats and were also fearful about the possible side effects of this experiment on humans. Students who questioned the source of the embryonic stem cells identified anger, sadness, and pity as emotions that influenced such question. The influence of emotions is not new to the science education community, as investigations on the influence of feelings on moral reasoning on contentious issues have identified emotions like sympathy, empathy, compassion, and love as important components of moral judgment (Hoffman, 2000; Powell et al. 2012; Turiel, 2006; Walker, 2004; Zeidler & Sadler, 2005b; Zeidler et al. 2011).

Table 11

*Pre/Post test questions, reasons, and emotions expressed by students in treatment group*

Categories of Questions	Pre-test Questions and Reasons	Post test Questions and Reasons	Emotions Pre/Post	Researchers' Interpretation
Research method	<p>“What kinds of rats were used? Maybe different kinds of rats have different reactions.” (#1LT)</p>	<p>“What kinds of rats were used? To know if it worked better on some rats and not others.” (#1LT)</p>	<p>Sadness (both pre-test and post-test emotion)</p>	<p>In the pre-test, the student inquired about the species of rats that were used in the experiment and suggested that different species of rats may produce different results. In the post-test, the student again inquired about the kind of rats used and suggested that the treatment might actually work better on some rats. This student suggested that sadness was the main emotion that influenced such questions. The student's questions indicated the understanding that different species of rats may respond differently to the same treatments. Though an understanding of the importance of conducting controlled experiments is not all there is to know about scientific experimentation process, the questions the students raised and the reason given indicate that this student valued the importance of controlled experiments in any scientific investigation.</p>

Table 11 (Continued)				
Research institution	<p>“Where are these experiments being conducted? Helps to know where in the world this experiment will impact.” (#5LT)</p>	<p>“Are families being affected by the embryonic stem cells? Can become a huge emotional toll on the research.” (#5LT)</p>	<p>Concern (Pre-test emotion)  Concern (Post-test emotion)</p>	<p>In the pre-test, the student inquired about where the experiments were being done. This suggests that this student does understand the potential impact the research institution may have on what gets reported in the research findings. In the post-test, the student inquired about the potential impact of stem cells on families. Such a question does suggest that this student understands the potential impact that public outcry may have on any research study. Concern was the emotion that influenced such questions.</p>
Research method	<p>“Would human subjects have to be used in order to determine if this procedure would work for humans? To determine if the experiment is ethical.” (#16LT)</p>	<p>“Was the drug that was used to damage the lens and optic nerve in rats harmful to other parts of the animal? The answer would help to explain how inhumane this research is.” (#16LT)</p>	<p>Concern (Pre-test emotion)  Anger and disgust (Post-test emotions)</p>	<p>The student inquired about the subject and method that were involved in the research. The student questioned how ethical it was to subject human beings to this type of experiment. Clearly, the student’s response seems to highlight the importance of moral and ethics in the decision-making on ill-structured problems. In the post-test, this student inquired about the potential impact the drug would have on the optic</p>

Table 11 (Continued)				
				nerve in rats. Although this student did not verbalize it, considerations of potential side effects of this treatment on other body organs were important. This student stated that disgust and anger were two emotions that influenced the above question.
Research cost and researchers' credentials	"If the hypothesis were accurate, how much would the procedure cost? The team of researchers may be trying to swindle people." (#23LT)	"Who conducted the experiment? Need to know the qualifications of the researchers in an effort to accept the conclusion." (#23LT)	Concern (Pre-test emotion)  Trust (Post-test emotion)	The student was skeptical about the motive of the researchers. The suggestion was that these researchers might be interested in cheating people out of their hard earned cash. Such skepticism influenced the student's concern. When evaluating evidence, skepticism is an important element. Skepticism will allow students to dig deeper in an effort to get more clarity. In the post-test, the student inquired about the qualifications of the researchers. This is also an important element to consider when evaluating any research findings. The emotion of trust influenced such inquiry.

In an attempt to decide whether the conclusion made by the members of the research team in the Health and Medical News Weekly was true (See Appendix D, Section 2), both groups of students raised important questions, as they attempted to evaluate the claim. There were no major differences in the questions students from either group asked. For example, students from both groups inquired about the research method that was used in the study. When students in the comparison group inquired about the research methods used by the researchers, they mainly asked how the researchers carried out the different steps to repair the rats' vision. For example, a typical methodological question posed by students in the comparison group was, "How did they fix the impaired vision of the rats?"

The integrated SSI curriculum contained a lesson that challenged the students from the treatment group to distinguish between science and pseudoscience. This lesson appeared to prepare these students to think critically about questions they would want to have answered before they determine if the conclusion made by the research team was true. As a result, these students were able to ask probing questions as they evaluated the evidence. Questions like, what species of rats were used in the experiment? What effects on other body parts did the drug that was used to damage the rats' optic nerve have? However, there is little difference between the two groups since both groups inquired about the methods used by the researchers.

Students from the treatment group also asked questions regarding the research institution where the research was conducted. This suggested that students understood that politicians and other members of society are sometimes biased towards research findings from larger prestigious research institutions. These students were also skeptical of the researchers' credentials and inquired if the research team was truly qualified to conduct this research. The students' skepticism conveys a sense of awareness of the difficulties conducting embryonic stem cell



research and the need to have truly qualified researchers to conduct this type of research.

Further, they questioned the researchers' motives and wanted to know if the researchers wanted a profit from their research at the expense of trying to help people all over the world, who are losing their vision daily due to eye diseases.

Questions from the students in the comparison group regarding the potential of the experiment being a success, the source of the stem cells, and the side effects from the experimental treatment were questions influenced by their emotions. For example, when they inquired about the potential success of the research, they identified hope as the emotion that influenced their question. Students mainly asked how the research would help their own vision problems. Similarly, other students from the comparison group also stated they were angered by the thought that the researchers were destroying human embryos to conduct embryonic stem cell research. As a result, they were too emotional to evaluate the evidence that stem cells can be used to repair rats' vision.

However, the integrated SSI curriculum did not prove to be much better than the traditional curriculum. While students in the treatment class identified emotions they thought about while they formulated their questions, those emotions rarely impacted their abilities to ask questions necessary to evaluate the researchers' claim. The students who were exposed to the traditional curriculum appeared to have dictated their questions to the point where they missed several opportunities to ask probing questions that were necessary to evaluate evidence. The results would suggest that emotions such as anger prevented many of these students from asking probing questions as they attempted to evaluate the claim that stem cells can be used to repair rats' vision.

## **Distribution of the Common Categories of Requests Among Groups**

Inductive analysis was used to identify and group students' questions into common categories of requests. The coding scheme used by Korpan et al. (1994) was used and resulted in the identification of four categories of requests in the comparison group and six categories of requests in the treatment group. These included: social context requests, agent requests, methods, data and statistics, relevance of the agent, and requests about related research. Social context pertains to identifying who conducted the study, the agent refers to the treatment described in the news brief (i.e., the 'thing' that produced the outcome), methods refer to the procedures used in the experiments, data and statistics includes requests about the data collected in the research and the statistics used to analyze the data, relevance of agent refers to agent effects to other subjects, species or environment, and requests about related research involves inquiry about similar studies that have already been conducted (Korpan et al., 1994). The volume of requests from students in the treatment group (64 in pre-test and 52 in post-test) was slightly more than the number of requests made from students in the comparison group (29 on pre-test and 36 for post-test).

### **Evidence Evaluation Section 3**

**Semi-Structured Interview.** Three students were randomly selected from each group to conduct interviews using a semi-structured interview protocol (*See Section 3 of Appendix D*) regarding the reasons behind the questions students generated, as they evaluated the claim that stem cells can be used to repair impaired vision in rats. The number of students selected was due to time constraints because the teacher needed to begin her pending annual reviews for the standardized biology assessment.

The researcher conducted all interviews with each student individually in order to allow for further clarification of statements made on the evidence evaluation questionnaire. Each student was asked to participate in two interviews: one that sought clarification to the question they raised on the pre-test evidence evaluation questionnaire (*See Appendix, D*) and another that sought to clarify students' post-test questions. The same questionnaire was used to gather pre and post-test data. The interview protocol required students to ask three questions they would want to have answered before deciding if the researchers' claim that embryonic stem cells can be used to repair rats' vision was true. However, during the interviews, it was discovered that students tended to invest most of their cognitive energy answering the first question and then repeated themselves, when answering the second and third questions. In instances when this occurred, the interviewer asked further probing questions; however, the students would then become silent or simply repeat their responses. As a result, only the first sets of questions from students' pre-tests and post-tests are included from the interview data. At the start of each interview, students were given the questionnaire with their written responses to refresh their memory. After students read through their questions and responses, the interviewer started the interviews. The results of the interviews from the comparison group are described below.

### **Identifiable Categories of Students' Questions from Comparison Group's Interviews**

An inductive analysis was conducted on students' transcribed interviews. Analysis of the data resulted in two categories of questions students posed as they evaluated the evidence. These included: methodology used by the researchers in the experiment and the results they obtained. Students also identified the emotions that influenced their questions as hope, sadness, and empathy. The categories produced from students' responses of the comparison group interviews are shown below. In these remarks, the "I" indicates the interviewer, while the "S" refers to the

students. Key words and phrases in each interview categories are italicized for identification purpose. The interviews' excerpts below exemplify the methodological category and the emotions identified.

### **Interview: Methodology Category**

I: You inquired about the *number of times* this experiment has been tested. Why did you ask such question?

S: I asked this question because I wanted to know *how many times* the experiment was conducted in order to see the *probability* of the experiment being successful. (Student LC #1, pre-test interview)

I: Can you tell me about any *emotions* that influenced such a question?

S: I was just *curious* to know the *number of times* this experiment was done. (Student LC #1, pre-test interview)

I: You asked *how many times* the hypothesis has been tested. Why did you ask such question?

S: If the hypothesis has been *tested only once*, the results could be by fluke. The hypothesis should be tested *more than once* for accuracy. (Student LC # 20, post-test interview)

I: Can you tell me about any *emotions* that influenced such a question?

S: It would make me *sad* if the scientists didn't take the time to test the hypothesis more.

These two students inquired about the methodology that was used by the research team. Such inquiry is important since it may provide details about how the researchers conducted their study. Knowing the methods used may provide the transparency necessary for other researchers to replicate the research and facilitate the evaluation of any scientific claim. On one hand,

students' questions about the methodology in the research were largely influenced by emotion such as sadness. On the other hand, students conflated curiosity with critical reasoning when they suggested they were curious to know the number of times the experiment was completed. In general, curiosity (inquisitive thinking), which is not an emotion, and sadness, which is considered an emotion, influenced these students to ask about methodology. Knowing about the methodology is important when one evaluates a scientific claim. Knowing the design used to conduct the research, the duration of the study, and how variables are controlled in the research are paramount in helping to evaluate and make an informed decision about the claim made.

The two interviews below provide the examples of the category that was coded as results for students in the comparison group and the emotions that influenced students' questions.

#### **Interview: Result Category**

I: You asked if the *animals* may be able to *see*, and can they *see clearly*? Why did you ask this question?

S: I asked the question because if the surgery improved their vision, I wanted to know if their *vision was clear or still fuzzy*. Did the surgery give them 20/20 vision or what?

(Student LC #10, pre-test interview)

I: Can you tell me about any *emotions* that influenced such a question?

S: I have *empathy* for the rats just because I have such bad eyesight. (Student LC #10, pre-test interview)

I: You asked if there were any *negative side effects* that resulted from the experiment. Why did you ask such a question?

S: I wanted to know the *adverse effects* that could happen. (Student LC #1, post-test interview)

I: Can you tell me about any *emotions* that influenced such question?

S: Mostly *curious*.

When evaluating experimental claims, it is important to recognize the facts of the claim reported. Doing so may allow for easier recognitions of any flaws in the claims that are made. The emotion that influenced students' questions included empathy. However, students again incorrectly called curiosity (inquisitive thinking) an emotion. For example, student LC # 10 empathized with the rats whose vision was damaged by the research methods. However, the student was also hopeful for the success of this research, since it may mean that her own poor vision may be helped from the research. Student LC # 1 used inquisitive thinking to learn about the negative side effects of the treatment and wanted to know if and when humans were given the treatment, if the same outcomes would occur.

### **Identifiable Categories of Students' Questions from the Treatment Group's Interviews**

An inductive analysis was conducted on students' transcribed interviews and two categories resulted from the questions students posed as they evaluated the claim. These categories include: methodology used by the researchers in the experiment and the results that they obtained. Students identified anxiousness, concern, and sadness as emotions that influenced their questions. The interview excerpts below exemplify the methodological category and the emotions identified from such category for students in the treatment group.

#### **Interview: Methodology Category**

I: You ask do *embryonic stem cells* have to be used from a *human embryo*. Why did you ask this question?

S: I asked that question because it is important to know how they got the stem cells and what exactly they did with it in the experiment. Knowing this will save a lot of *emotional*

and *religious controversy*. There is already controversy surrounding human embryos in stem cell research. I would personally support this research because I am not an advocate for abortion. If the stem cells are going to be destroyed, we might as well use them.

(Student LT # 16, pre-test interview)

I: Can you tell me about any *emotions* that influenced such a question?

S: I felt very impatient and *anxious* to know the answer to my question.

(Student LT # 16, pre-test interview)

I: You asked would the transfer of stem cells *majorly* affect humans. Why did you ask this question?

S: I asked this question because it is a big factor in how they are getting these embryos. *If families are affected by how they are getting these embryos. Are they just going in and taking them, do they have to sign?*

(Student LT #5, post-test interview)

I: Can you tell me about any *emotions* that influenced such a question?

S: *Sadness* because, just thinking about if families are affected by embryonic stem *cells*.

The findings from the interviews described above identify exemplars of students' inquiry in regard to the methodology that was used by the research team. Again, such inquiry is important since it may provide details about how the researchers conducted their study. Knowing the methods used by the researchers may provide the transparency necessary for other researchers who repeat the study and make it easier for others to evaluate any scientific claim. However, students' questions about the methodology in the research were largely influenced by emotions such as anxiousness and sadness. Students who identified anxiety as an emotion that influenced their question stated they wanted to see this study become a success, so that people

from around the globe could get the medical attention needed to help repair their vision problems. Those who identified sadness as the emotion that influenced their question stated that the thoughts of giving up embryos, so that they can be destroyed, became a bit overwhelming.

### **Interview: Result Category**

I: You asked what *evidence* you have to support your *hypothesis*. Why did you ask this question?

S: In the article, there was *no evidence* presented. If there was *more evidence*, I would be more willing to accept this hypothesis. (Student LT #23, pre-test interview)

I: Can you tell me about any *emotions* that influenced such a question?

S: I was *skeptical* due to the lack of evidence, but *curious* as to what the evidence was. (Student LT #23, pre-test interview)

I: You asked what *tangible evidence* there was to support the claim? Why did you ask this question?

S: I questioned how tangible the evidence is because if provided, it would *influence* my *susceptibility*. (Student LT #16, post-test interview)

I: Can you tell me about any *emotions* that influenced such a question?

S: I was *concern* about the evidence. That is what influenced my question. (Student LT #16, post-test interview)

The category of results about the questions students asked, as they attempted to evaluate the claim, is identified above. Students used curiosity and skepticism as factors to influence the questions they asked. Again, when evaluating experimental claims, it is important to recognize the facts that support those reported claims. Such knowledge may allow for easier recognitions of any blunder in the claims that were made.



## **Comparison of the Treatment and the Comparison Groups Results**

A Kruskal-Wallis test that evaluated the difference between the pre-test and post-test scores showed no significant difference ( $p = .945$ ) between the treatment and the comparison groups use of emotions to judge the conclusion drawn by the research team that embryonic stem cells can be used to repair rats' vision. This result indicates that both groups of students relied on emotions, when they were asked to evaluate the evidence.

The results from section two of the evidence evaluation questionnaire, which required students to generate a list of questions they would want to have answered before they decided whether the conclusion made by the research team in Health and Medical News Weekly was true showed no significant difference in students' abilities to evaluate evidence. An analysis of data for students from the treatment and the comparison groups showed that the questions students generated, when they attempted to evaluate the claim that embryonic stem cells can be used to repair rats' vision, were largely influenced by emotions that included sadness, pity, concern, fear, grief, hope, and anger. These findings would indicate that emotions play a major role in students' abilities to evaluate evidence. Similar to the aforesaid findings were the results of the semi-structured interviews, which also indicated that students' from both the treatment and the comparison groups used similar emotions such as anxiety and sadness, when they questioned the methodologies used by the researchers. In addition to anxiety and sadness, when students inquired about the results of the study, the emotions of concern, empathy, and sympathy were also demonstrated. The results obtained from the three sections for the first research question indicated that emotions influenced the students' abilities to evaluate evidence. For example, there were students in the comparison group who used anger as an emotion. The students

suggested that if the experiment hurt the rats, then it didn't matter if it would cure sight and researchers should not be allowed to conduct these types of research.

**Research Question 2.** What relationships exist between secondary school students' use of emotive reasoning and their decision-making regarding socioscientific issues?

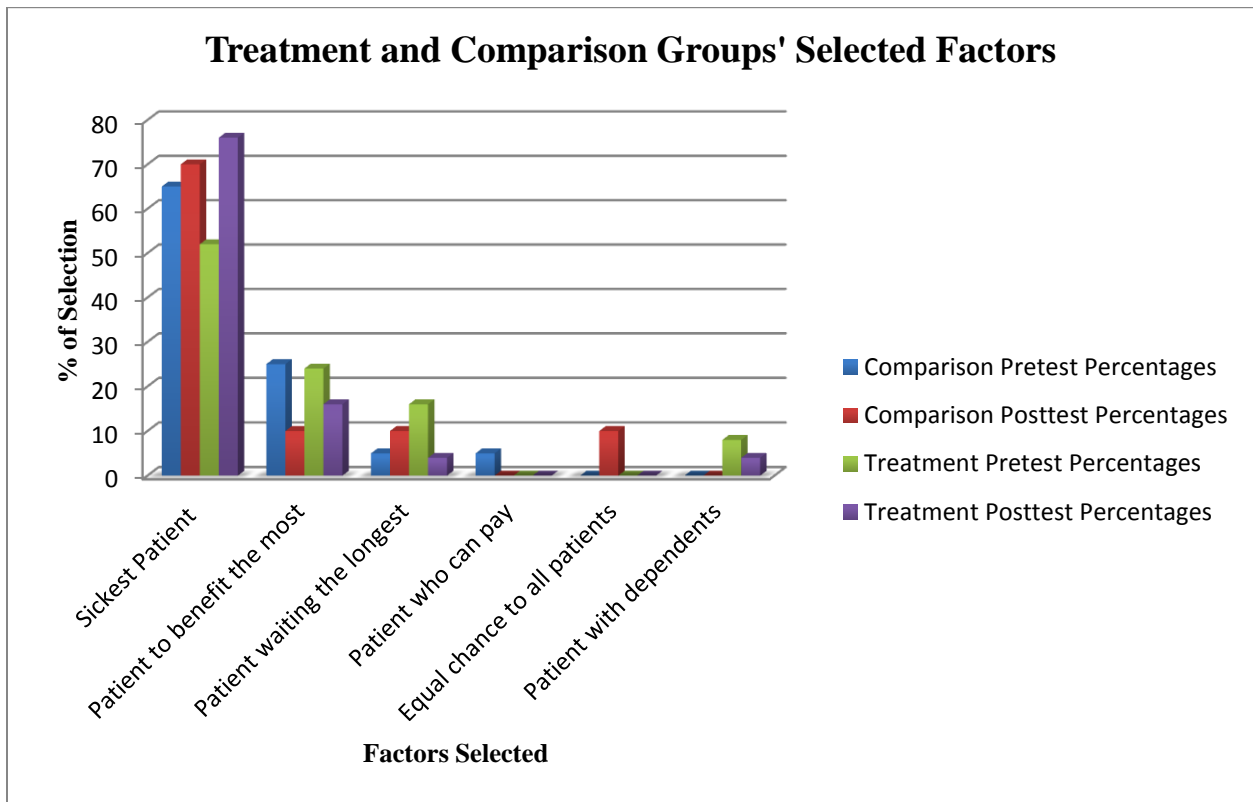
### **Decision-Making**

Students' decision-making regarding SSI was captured and discussed in two parts below. Part I outlines the results of students' ranking order of the factors they believed should be determined prior to receiving an organ transplant. Students' ranking and ordering of factors was analyzed quantitatively as well as qualitatively through the identification of common themes and trends from the justification students gave to support their ranking order of factors (*See Appendix E*). In Part II of the decision-making about SSI, students' scientific and emotive considerations, which influenced their decision to rank the patients who should have received the organ transplant, are discussed (*See Appendix E, Part II*). In Part 1, students' first choice options were included in the research results, since it was discovered that students tended to repeat themselves as they provided justification for their ranking and ordering of who should be awarded the heart transplant. This was done to reduce redundancy in the reporting of data.

#### **Part I: Treatment and Comparison Groups Ranking of Transplant Recipients**

Students from both the treatment and comparison groups mainly selected the sickest patient, followed by the patient that would benefit the most from the transplanted organ, and then the patient who is on the waiting list the longest. Selections for the patient who has the capacity to pay and selection of the patient on the basis of their importance for the well-being of others accounted for a minority of the selections, as did students' choice to give all patients on the

waiting list an equal chance. Figure 2 below highlights the percentages of selections from both the treatment and comparison groups.



**Figure 2.** Percentages of selected factors for treatment and comparison groups

**Comparison Group: Part I Pre-test Results of Decision to Ranking the Order of Patients who should receive an Organ Transplant**

In the pre-test, students in the comparison group selected the sickest patient, the patient who will benefit the most, the patient on the waiting list the longest, and the patient who has the ability to pay to receive the transplant. The researcher and the two-research analysts independently read and re-read students’ explanations about why they selected the four factors listed above. The following are the representative categories that were derived from the analysis: 1) Degree of illness; 2) Optimal use of the organ; 3) Fairness; and 4) Cost. Table 12 highlights

the factors selected, categories generated from students' explanations for their selections, representative students explanation, and the researchers interpretation of students' explanations.

Students considered the degree of the patients' illnesses and the optimal use of the organ as justifications for granting the transplant most often. Some students felt that those who had been waiting the longest should be awarded the transplant, because it is not fair for someone who only waited a short period of time to get the transplant ahead of someone who had been waiting longer. Other students expressed that since there is a cost for everything in life, one should only be able to get a transplant, if they are in a position to pay for it.

Table 12

*Pre-test justification for organ transplantation ranking order comparison group*

Factor Selected	Category	Student Responses	Researchers' Interpretation
Sickest patient	Degree of illness	If someone is about to die, and you have the chance to save him or her with an organ transplant, then I think that's the right thing to do. (ID # 17A)	A patient who is suffering and has a chance to live if granted an organ transplant deserves to be awarded an organ transplant. This will prevent death.
Patient who will benefit the most	Optimal Use of Organ	If you give a patient a transplant and they only live for two more weeks than they would have without it, then it's just a waste. (ID # 10B)	Care should be taken not to waste a scarce medical resource. Obtaining a heart for a transplant is difficult because of the scarcity of such an organ. As a result, individuals who are selected to receive a heart transplant must be able to have a long life after receiving the heart transplant. If not, it is considered wasting a scarce medical resource.

Table 12 (Continued)			
Patient on the waiting list the longest	Fairness	My first choice is selecting the patient who has been waiting the longest. If someone else comes along, they should not jeopardize the person who has been waiting for a chance to get a transplant. That would not be fair.	It is not fair to give the transplant to someone who has not been waiting long. Student's response seemed to disregard all the other important factors that must be considered before an organ transplant is granted to a patient.
Ability of the patient to pay	Cost	It costs money to do a transplant. Things are not free, so the patient must be able to pay.	Student believes there is a cost that is associated with everything. One cannot expect to get the transplant for free.

**Comparison Group: Part I Post-test Results of Decision to Ranking the Order of Patient who should receive an Organ Transplant**

Table 13 below highlights the factors that students in the comparison group selected in the post-test. Again, students awarded the heart transplant to the sickest patient because they were concerned about the degree of patients' illnesses. Students felt those who can live longer without the transplant, should be allowed to wait so those who are dying can have the chance to receive an organ transplant. In justifying their selection of the other factors, students suggested that the organ should not go to waste, the selection processes should be fair to everyone, and that everyone should have an equal chance for the transplant.

Table 13

*Post-test justification for organ transplantation ranking order comparison group*

Factor Selected	Category	Student Responses	Researchers' Interpretation
Sickest Patient	Degree of Illness	The sickest patient should be awarded the transplant because the whole point is to save lives. (ID # 3A)	Transplant should be awarded to the patient whose death is imminent without the transplant.
Patient who would benefit the most	Optimal Use of the organ	Why put it in someone who will only get a year, why not put it in someone who will get at least three years out of it?	Organ should not be wasted. It must be given to those who will have a long life after the heart transplant.
Patient on the waiting list the longest	Fairness	The patient on the waiting list the longest has paid their dues and waited a while, so they deserve the transplant.	Student has suggested that the patient who has been waiting the longest deserves the transplant ahead of everyone else, since they paid their dues by waiting the longest.
Equal chances	Equity	We are all equal. Equal chance to everyone.	Everyone should have an equal chance to eliminate any favoritism.

**Treatment Group: Part I Pre-test Results of Decisions to Ranking the Order of Patient who should receive an Organ Transplant**

For their pre-test selections, students in the treatment group selected the sickest patient, the patient most likely to benefit based on medical or other criteria, the patient on the waiting list for the longest period of time, and the patient who others are depending on to receive the organ transplant. Table 14 highlights the factors selected, categories of the selected factors, and

common reasons students provided for their selections of who should be awarded the organ transplant. Representative examples of student responses for each category are provided below.

Table 14

*Pretest justification for organ transplantation ranking order treatment group*

Factor Selected	Categories	Student Responses	Researchers' Interpretation
Sickest patient	Degree of Illness	If someone is about to die because they're in need of a transplant, then they should be the first priority. (ID# 3A)	The transplant should be given to those who will die soon without it. The student placed priority on those who would die without receiving a transplant.
Patient who would Benefit the most	Optimal use of the organ	I chose B because the heart transplant should be given to someone who would benefit more from it, instead of giving it to someone who could fail and waste the organ. (ID# 17B)	The organ should be given to someone who gets the most use out of it. The student believed that scarce medical resources should never be wasted. The student's response suggested it is counterproductive to give someone an organ transplant that will die sooner. The student believed the organ should be given to the best available candidate.
Patient Longest on waiting list	Fairness	If you have been waiting patiently for weeks, months, or years, it is very unfair to be skipped for someone who hasn't been waiting for long. (ID# 23C)	It is not fair to give the transplant to someone who has not been waiting long. The student's response seemed to disregard all the other important factors that must be considered before an organ transplant is granted to a patient.
Patient who others are depending on	Means-to-an-end Community Leader	The transplant should go to the people of importance to their community or country. Save who is going to worth it, rather than somebody who's not going to benefit the community or country as a whole. (ID# 14E)	The transplant must be given to someone who will contribute to society.

Students' pre-test results showed that they felt the degree of illness should be considered as a major factor when determining who gets treated for an organ transplant first. Students believed that the organ should not go to waste and that the patients who would benefit the most from the organ transplant should be awarded the scarce medical resource. Students believed that patients on the waiting list for the longest time should be given priority over those who have been waiting for a short period of time. When considering people who have contributed to society such as presidents, students supported and argued that these individuals should be considered for the organ transplant first.

### **Treatment Group: Part I Post-test Results of Decisions to Ranking the Order of Patient who should receive an Organ Transplant**

In the post-test, students in the treatment again selected the sickest patient for the majority of the selections (76%) of who should be awarded the transplant. Students also selected the patient who would benefit the most based on medical or other criteria, the patient on the waiting list for the longest period, and patients on the basis of their importance for the well-being of others.

Students' decisions to award a transplant to the sickest patient generally based their decision on the need to prevent imminent death. Students suggested that the sole purpose of a transplant is to save lives. Students who did not want to see the transplanted heart going to waste, suggested it should only be awarded to the patient who would benefit the most from the transplant. In general, there were no significant differences between students from the treatment and the comparison groups' rankings of who should be awarded an organ transplant.

Table 15 highlights the selected factors, categories of the selected factors, and common explanation students gave for their selections of who should be awarded the organ transplant.



Table 15

*Post-test justification for organ transplantation rank ordering treatment group*

Factor Selected	Category	Student Responses	Researchers' Interpretation
Sickest Patient is suffering	Degree of Illness	The main reason for selecting the sickest person for a transplant is because they are suffering and may die, so they deserve at least a chance with a new organ. They may recover and no longer be in need of constant care. (ID # 17A)	Those patients who are suffering deserve to be awarded an organ transplant. This will lessen their suffering and need for constant care.
Patient who would benefit the most	Optimal use of the organ	It is pointless to do a transplant for someone it won't benefit. It would be a waste of the heart. (ID 6B)	The organ should be given to someone who will be able to get the most use from it.
Patient on waiting list the longest	Fairness	If they have been on the waiting list, they have a right above all. (ID 8C)	Students believed that making it on the waiting list for an organ transplant does provide a protection or right to that patient to receive the organ transplant. Someone who was not on the waiting list has no right to the organ transplant ahead of a patient who has been waiting. This response seemed to ignore all the scientific decision that must be considered prior to determining who should be awarded an organ transplant.
Patient who others are depending on	Means-to-an-end	My first choice is you have to save the people who are most important; it's the first priority (ID 14E).	In deciding on who should receive an organ transplant, priority must be given to those with VIP statuses. Again, this student seemed to ignore all the important decisions such as organ compatibility, age, blood type, etc. that must be considered prior to determining who should be awarded an organ transplant.

## **Quantitative Analysis of Students' Justification for Awarding the Organ Transplant**

Students from both the treatment and comparison groups provided justification for their pre-test and post-test decisions to award the organ transplant in Part I. A Kruskal-Wallis Non-Parametric Analysis of Variance (ANOVA) statistical test of mean ranks was performed on students' first and second choice justification scores resulting in non-significant differences among students' scores ( $X^2(2, N = 45) = 0.061, p = 0.801$ ). Students' first and second choice rankings were used because others have suggested that students invest most of their cognitive energy in discerning between these two moral choices (Zeidler et al., 2013). A scoring rubric and technique employed by Zeidler et al. (2013) was used to score students' responses from 0 to 3 for each of these justifications in terms of their level of sophistication. Students' responses could range from 0 to a maximum of 6 points (See Appendix I for rubric).

## **Comparison Group: Part II Results of Scientific and Emotive Consideration Used to Award the Organ Transplant**

Part II of the decision-making questionnaire (See Appendix E, Part II) asked students to identify scientific and emotive considerations that may have influenced their decisions to the ranking order of patients for a heart transplant. An outline of the scientific considerations that influenced students' decisions to select the patient who should be awarded an organ transplant will be presented first in Table 16. The emotive considerations that influenced students' decisions to award the organ transplant to the sickest patient, the patient who would benefit the most, and the patient on the waiting list the longest were then be highlighted in Table 17.

## **Scientific Considerations of Students from the Comparison Group**

An inductive analysis of students' pre-test scientific considerations influencing their decisions to the ranking order of patients for the heart transplant resulted in one category of

question: organ compatibility. The analysis of students' post-test decisions produced three categories of questions: 1) probability of the surgery being a success; 2) the compatibility of the organ to be transplanted to the patient's body, and 3) the length of recovery time. Students who inquired about the probability of the surgery being successful pointedly asked, "Is it a 50:50 chance that the surgery will be successful?" The students who questioned the organ compatibility stated that the blood type of the donor and the organ recipient must be a match for the surgery to be successful; thus these students asked if the blood type of the organ recipient matched with the blood type of the organ donor. Students who questioned the length of the recovery time, asked if the patient would be healthy enough to live past the recovery time post-surgery? Summaries of the different categories of scientific consideration are presented below in Table 16.

Table 16

*Scientific considerations used for determining the heart transplant recipient from the comparison group*

Scientific Considerations	Pre-test Scientific Questions	Post-test Scientific Questions
Probability of Successful Surgery	X	Is it a 50:50 chance they survive the surgery?
Organ Compatibility	Give the organ to someone who it is compatible with.	Is the organ compatible with their blood type?
Length of Recovery	X	How long is the recovery and is the patient healthy enough to have a prolonged life span?

### **Pre-test Scientific Considerations of Students from the Comparison Group**

An overwhelming number of students (95%) in the comparison group did not provide any scientific considerations. Many of these students repeated some of the factors from the list of

seven factors that were provided on the decision-making questionnaire as their scientific considerations. Instead of identifying scientific considerations that may have influenced their decisions to rank and order the patient who should receive the transplant, many students suggested that they made their decisions based on what is right and how they felt. The only scientific consideration students expressed in the pre-test concerned the compatibility of the organ to the patient's body system.

The decision to award the heart based on compatibility suggested that the student understood the need for organ compatibility to prevent rejection. This student's response suggested a clear understanding that the lack of compatibility of the organ, with that of the recipient's body chemistry, would result in a total rejection of the organ.

#### **Post-test Scientific Considerations of Students from the Comparison Group**

In the post-test, more students (20%) used scientific considerations of: 1) organ compatibility; 2) patient's safety and recovery time; and 3) the probability of the surgery being a success to influence their decision of who should be awarded the organ transplant. Students who decided to award the transplant based on compatibility believed the heart should not go to waste. Students stated that without a guarantee that the transplanted heart would improve the patient's health, it would be a waste to award the transplant. The student who inquired about the 50:50 chance of the surgery being successful seemed content with such probability.

#### **Emotive Considerations of Students from the Comparison Group**

An inductive analysis of students' pre-test and post-test emotive considerations that influenced their decision to the ranking order of the patients for the heart transplant produced two emotive categories: 1) sympathy for the young, sick, and their loved ones; and 2) empathy. Summaries of the different categories of emotive consideration are presented below in Table 17.

Table 17

*Emotive considerations used for determining heart transplant recipient comparison group*

<b>Patient Selected for Transplant</b>	<b>Emotive Considerations</b>	<b>Pre-test Emotive Explanation</b>	<b>Post-test Emotive Explanation</b>
Sickest Patient	Sympathy	I thought about the family suffering with each scenario.	You have to be sympathetic for the sickest. I thought about what would save the most people.
Sickest Patient	Empathy	I think about how I would want them to treat my family member and me if we needed a transplant.	You have to be empathetic towards the sickest.
Patient to benefit the most from the transplant	Empathy	I put myself in the situation and come up with my answers. We can sometimes never really understand something without living it.	Me wanting to save the most lives and help the sickest. I put myself in it and value how precious life is. I want to do everything to save a life.

### **Pre-test Results of Emotive Considerations for the Comparison Group**

Comparisons between students' pre-test and post-test selections of factors used to determine who should be awarded the heart transplant showed no major differences. In the pre-test, students selected the sickest patient first (n = 13), followed by the patient that would benefit the most from the transplanted organ (n = 5), then the patient who was on the waiting list the longest (n = 1), and finally the patient who had the capacity to pay (n = 1). In the post-test, students made similar selections: selection of the sickest patient (n = 14); selection of the patient who would benefit the most from the transplanted organ (2); the patient on the waiting list the longest (n = 2); and finally selection of the patient based on the basis that all patients on the waiting list should have an equal chance of selection (n = 2).

Students who made similar selections and decided to award the organ transplant to the patient most likely to benefit based on medical or other criteria, identified empathy as the emotive consideration that influenced such decision. This was the case in both the pre-test and the post-test. On the other hand, students who awarded the organ transplant to the sickest patient identified both sympathy and empathy as emotive considerations that influenced their decision. Students were generally sympathetic towards the sickest patient and their loved ones, when they considered the amount of suffering that the sickest patient must be experiencing, as they waited for the organ transplant.

Students who used empathy as the basis to award the transplant generally suggested they put themselves in the patient's shoes. These students often suggested that we could never really understand something without living it. They proposed that if they were in the patient's situation of needing a transplant, then they would want the medical professionals to grant them the transplant. Clearly, these students were able to empathize with those who were in need of an organ transplant.

There were instances when students suggested that they used their own sense of fairness as the basis to award the heart transplant. Though fairness is not an emotion, students suggested that the patient who had been waiting the longest deserved the transplant ahead of everyone else. They generally suggested it was not fair for someone who had not been waiting to come along and get the transplant ahead of someone who had been waiting the longest. For these students, fairness means first come, first served.

### **Post-test Results of Emotive Considerations for Comparison Group**

Students who used sympathy as the basis for awarding the transplant predominantly wanted to save lives and believed that people in general are important; therefore, seeing people

suffer and die because they needed organ transplants, became difficult for these students. As a result, these students were sympathetic to the person who was in need of an organ transplant.

Students who used empathy as the basis for awarding a transplant suggested that all life is precious. They stated that because of the value they place on life, they are able to put themselves in the role of the patient and experience what they may be going through. As a result, they want to do everything in their power to save lives.

### **Treatment Group: Part II Results of Scientific and Emotive Considerations Used to Award the Organ Transplant**

Part II of the decision-making questionnaire (See Appendix E, Part II) asked students to identify scientific and emotive considerations that may have influenced their decision to the ranking order of the patients needing a heart transplant. An outline of the scientific considerations that influenced students' decisions to select the patient who should be awarded an organ transplant will be presented first in Table 18. The emotive considerations that influenced students' decisions to award the organ transplant to the sickest patient, the patient who would benefit the most, and the patient on the waiting list the longest were highlighted in Table 19.

### **Scientific Considerations of Students from the Treatment Group**

An inductive analysis of the pre-test and post-test scientific considerations that influenced students' decisions to the ranking order of the patient for the heart transplant produced four categories of questions: the probability of the surgery being a success, overall health of the patient, compatibility of the organ to be transplanted to the patient's body, and the age of the patient who would receive the transplant. Students who used probability to help in their determination of who should be awarded the organ transplant questioned the percentage chance of the surgery being successful. Those who questioned the overall health of the patient inquired

if the patient had other serious health issues such as cancer. Those who inquired about the compatibility of the organ to the patient's body questioned the blood types of the patient and the donor. Finally, students who considered age suggested that younger, healthier people should be awarded the transplant ahead of the elderly. Summaries of these categories of scientific consideration are presented below in Table 18.

Table 18

*Scientific considerations used for determining the heart transplant recipient treatment group*

Scientific Considerations	Pre-test Scientific Questions	Post-test Scientific Questions
Probability of Successful Surgery	What is the probability of survival and success of the patient?	Is there a high chance that it (surgery) is going to work?
Overall Health of the Patient	What is the overall health of the patient? What other health problems do they have besides having a bad heart?	Is the patient healthy enough to have the transplant? Are there other serious health problems such as cancer?
Organ Compatibility	Are the donor and patient's body compatible?	Would the patient's body reject the organ? Are the blood types the same?
Age	What is the age of the patient? Younger patients should be first.	What is the age of the patient? Younger healthier patients who are younger and healthier should be awarded the transplant.

**Pre-test Scientific Considerations of Students from the Treatment Group**

In the pre-test, the majority of the students (60%) from the treatment class struggled to identify scientific considerations that influenced their decision to the ranking order of the patient the way they did for the heart transplant. Of the students who were able to provide scientific considerations, their inquiries centered mainly around the probability of surgery being



successful, the overall health of the patient, the compatibility of the organ to the patient's body, and the age of the patient.

Students who based their decision on the probability of survival and success of the transplant seemed to understand that there are many factors that may prevent a patient from having a successful surgery. As a result, the students used the probability of the surgery being successful to determine who should be awarded the heart transplant. Some students suggested that the purpose of a transplant is to improve one's health, which influenced them to base their decision of awarding the transplant on the overall health of the patient. Thus, these students saw it as counterproductive to give the transplant to someone who had other health issues, which may compromise the heart transplant. These students believed that granting the transplant to someone who may not benefit the most from the transplant would result in wasting scarce medical resources.

Students who based their decision to award the transplant on the basis of the compatibility of the organ to the recipient, understood the need for organ compatibility to prevent rejection. Students' responses suggested a clear understanding that the lack of compatibility of the organ with that of the recipient's body chemistry, would result in a total rejection of the organ. For example, students were aware of the possibility of the transplanted organ being rejected, when there are mismatched blood types.

Students who believed that the transplant should be awarded based on age, suggested that the transplant should be awarded to the young and fit. Students commented that patients who are old and weak might not be able to live long after the transplant; therefore, granting the transplant to individuals who are old and weak would result in wasting an organ.

### **Post-test Scientific Considerations of Students from the Treatment Group**

In the post-test, students expressed similar scientific considerations when determining who should be awarded the heart transplant. However, there was a slight increase in the number of students (48%) who were able to identify scientific considerations that influenced their decision of ranking order for the patients the way they did for the heart transplant. Students awarded the transplant based on probability of the surgery being successful, the overall health of the patient, the compatibility of the organ to the patient's body, and the age of the patient. Students who decided to award the organ transplant based on probability of the surgery being successful believed that without a guarantee that the transplanted heart would improve the patient's health, then awarding the transplant would be a waste. Students argued that granting a scarce medical resource such as a heart would be irresponsible if it was going to be wasted.

Students who made their decision to award the heart transplant based on the overall health of the patient suggested that if the patient has a medical condition that may compromise the surgery, then granting the surgery to such patient is a waste of time and of a scarce medical resource. Students who decided to award the transplant based on compatibility believed that the heart should not go to waste. These students suggested it should be given to the patient whose body is compatible with the organ. Otherwise, it would result in a total loss if the patient's body rejected it. Students who decided to award the transplant based on age, suggested that a transplant should be awarded to the younger patients who have their whole lives ahead of them.

### **Emotive Considerations of Students from Treatment Group**

An inductive analysis of the pre-test and post-test emotive considerations that influenced students' decisions to the ranking order of the patient for the heart transplant, produced two emotive categories: 1) sympathy for the sick and their love ones; and 2) empathy. The

summaries of the emotive consideration, pre-test emotive explanation, and post-test emotive explanation are presented below in Table 19.

Table 19

*Emotive considerations used for determining the heart transplant recipient with the comparison group*

<b>Patient Selected for Transplant</b>	<b>Emotive Considerations</b>	<b>Pre-test Emotive Explanation</b>	<b>Post-test Emotive Explanation</b>
Sickest Patient	Sympathy	Feeling sad and sorry for people who have to go through things like this.	Sympathy for the family members who will lose a loved one because they cannot get a heart transplant.
Sickest Patient	Empathy	You have to be empathetic towards the sickest patient. I would want others to do the same for me.	My personal experience influenced my decision. Empathy and my personality.
Patient to benefit the most from the transplant	Sympathy	If you transplant something, you want the patient to live for a long time. I have sympathy for people who have to go through this.	My reason is that the transplant should not be wasted. Whoever has the most life ahead of them should be chosen, because I have sympathy for them.
Patient to benefit the most from the transplant	Empathy	My own feelings. I put myself in the patient, doctor, and family role and thought about the way I would feel and what I would want.	I can easily imagine being so sick or watching someone I care for slowly deteriorate in front of my very eyes.

### **Pre-test Results of Emotive Considerations for the Treatment Group**

In the pre-test, a slight majority of students (56%) from the treatment class used emotive considerations to influence their decision to rank the order of the patients who should receive the heart transplant. Students based their decision on sympathy towards the sick and their loved

ones as well as empathy for the patient. Students used sympathy and empathy to award the organ transplant to the sickest patient. They also used similar emotions to award the organ transplant to the patient most likely to benefit based on medical or other criteria.

Though fairness is not an emotion, students often stated they used fairness to award the organ transplant to the sickest patient or to the patient who had been waiting on the transplant list the longest. Students who used fairness suggested that the first person on the list must be seen ahead of everyone else. Students who used fairness to award the transplant to the sickest patient generally suggested that it is not fair to allow the sickest patient to die, before being awarded the transplant.

### **Post-test Results of Emotive Considerations for the Treatment Group**

In the post-test, students used similar emotive considerations to influence their decisions of who should be awarded the heart transplant. However, the use of emotive considerations was slightly less (52%) than what was used in the pre-test. Students based their decision on the emotions of sympathy and empathy towards the sick and their loved ones, as well as the patient who would benefit the most based on medical or other criteria.

### **Comparisons between the Treatment and the Comparison Groups' Results**

The results obtained for Part I of students' decision making regarding their ranking order of the factors they felt should be determined for receiving an organ transplant produced three major categories, which were similar among students from both the treatment and the comparison groups: 1) Degree of illness; 2) Optimal use of the organ; and 3) Fairness. A Kruskal-Wallis Non-Parametric Analysis of Variance (ANOVA) statistical test of students' first and second choice justification scores of who should be awarded the organ transplant found no significant differences among students scores ( $X^2(2, N = 45) = 0.061, p = 0.801$ ).

Part II resulted in a slight difference between the treatment and the comparison group regarding students' use of scientific considerations that influenced their decision to rank the patient that should be awarded the transplant. In the comparison group's pre-test and post-test, only 5% and 20% of the students were able to identify scientific considerations regarding their decision of who should be awarded the organ transplant. In the treatment group, overall, only 40% and 48% of the students were able to identify scientific considerations that influenced their decision of who should be awarded the transplant.

Students in the comparison group who decided to award the organ transplant to the sickest patient were influenced by emotions such as sympathy and empathy. However, their decisions to award the organ transplant to the patient most likely to benefit based on medical or other criteria, were influenced by empathy only. The decision of students in the treatment group to award the organ transplant to the sickest patient and to the patient most likely to benefit based on medical or other criteria decisions were influenced by the emotions of sympathy and empathy.

**Research Question 3.** In what ways do students integrate scientific content knowledge in the process of reasoning about socioscientific issues?

### **Use of Scientific Content Knowledge to Reason about SSI**

The students' abilities to integrate and use scientific content knowledge in their reasoning about SSI were assessed using writing assessment tasks adopted from Zohar and Nemet (2002). Students were given two cases to read and were asked to respond to questions about each case (See Appendices F and G). For Case I, students were asked to respond to three questions. The overall analysis of students' responses to the three questions showed no unique differences between the students from both groups' abilities to integrate scientific content knowledge in their

reasoning about what Miriam should or should not do. Below is an outline of the questions that students were asked to respond to in case I. An analysis technique that was conducted on students' data and then a reporting of the findings that were discovered follow.

### **Case 1**

For case 1, students were given basic information on what Huntington disease is and included the age for onset of symptoms (*Appendix F*). Additionally, the students were provided background information pertaining to a woman who wanted to test if she was a carrier of the defective gene for Huntington disease. After reading the case, students were asked to formulate an opinion of the woman regarding whether she should be allowed to get the test. Upon formulating their opinion, students were asked to clarify their position on the issue in small group settings. Following discussing their position on the issue, students were asked to respond to three questions.

**Question 1.** What are the chances that Miriam, a family member from a family that had been stricken with Huntington disease, is a carrier of this disease?

An analysis of students' written responses to question 1 resulted in two common categories: 1) Miriam having a small chance of being a carrier of the defective allele for Huntington disease; and 2) Miriam having a fifty percent chance of carrying the defective allele. Students from both groups believed that Miriam had a small chance of carrying the defective allele for Huntington disease. Although both groups of students did not quantify what small meant, it was interpreted as a number that was below 50%. This suggests that background information that was presented to the students was not taken into consideration. For example, Miriam's family history of Huntington disease and what Huntington disease is were not considered. The fact that students simply stated, "Miriam's chances are probably small for carrying this disease," indicated that

these students might not have understood how the alleles for genetic diseases, such as Huntington, transfer from parents to offspring. This would indicate that explicit instruction on how genetic information is transferred from one generation to the next is warranted for these students. For those students who suggested that Miriam had a 50% chance of being a carrier, understood that both parents are responsible for transferring one set of chromosomes. They used what they knew about chromosome pairs to help them in determining the chances of Miriam being a carrier. Some of the students from both groups who suggested Miriam had a 50% chance, stated that the defective allele is present on one chromosome and since both parents donate either one of two chromosomes, the chance that Miriam being a carrier was 50%. For example, a student stated, “There is a 50% chance that Miriam is at risk and carrying the disease since the allele is on one chromosome and it is dominant.” Such a statement suggested that this student understood that there is a 50% chance that the defective allele gets passed on, since either parent donated one set of chromosomes. The student used the term dominant, which indicates that there is an understanding that since the disease is caused by a dominant allele, once it is present, the person has the disease. There were other students who suggested that Miriam had a 50% chance and provided no justification.

**Question 2.** If it turns out that Miriam is a carrier, what are her chances of giving birth to an affected child?

An analysis of students’ responses to the above question resulted in two categories: 1) 50% chance; and 2) 100% chance that Miriam would give birth to a child who is affected by Huntington disease. Table 20 outlines the categories from students’ data and examples of students’ quotes.

Table 20

*Chances of giving birth to child with Huntington disease*

Categories	Treatment Group	Comparison Group
50% Chance	50% chance because it depends on the father, if he is also a carrier.	There is a 50% chance since this disease runs in the family.
100% Chance	There is a 100% chance of her giving birth to an affected child, since the trait is dominant.	100% because she has a dominant gene.

A constant comparative analysis of the data from both groups of students showed no major differences. Students from both the treatment and the comparison groups who stated that Miriam has a 50% chance of giving birth to a child, who has Huntington disease, based their decisions on Miriam’s family’s history of Huntington disease. These students did not take into consideration whether Huntington disease is caused by dominant or recessive traits.

Students spent time in class going over the differences between the terms dominant and recessive. Students who stated that Miriam had 100% chance of giving birth to a child who has Huntington disease seemed to understand that there are no carriers of a disease that is caused by a dominant gene. These students seemed to use their understanding of dominant and recessive genes to suggest that everyone who has the genetic error gets the disease, because the bad gene is dominant. Students seemed to understand that Huntington disease causes symptoms later in life, so some people may be unaware that they have the defective allele for the disease in their early years of life; however, this is not the same as being a carrier because people with the defective gene have the disease. Overall, the students from both groups who stated that Miriam has a 100% chance of giving birth to a child used correct scientific knowledge to make their determination. These results indicate there was no difference between the students from both groups in regard to



the use of scientific knowledge of this question.

**Question 3.** What should Miriam do? Why should she do it? Write the two practical options that Miriam faces. Each of these two options corresponds to one of two options, or in the language of argumentation, to one of two statements or conclusions. As you probably remember, statements must be justified by reasons.

Forty-five percent (45%) of the students in the comparison group suggested that Miriam’s two options were to get tested and not to get tested. Of the remaining students, 35% suggested that she should be tested while the remaining 20% suggested that she should not be tested. In contrast, one hundred percent (100%) of the students from the treatment group suggested that Miriam’s two options were to get tested and not to get tested. Highlights of the justifications students gave to support Miriam’s options are presented in table 21.

Table 21

*What should Miriam do? Why should she do it?*

Categories	Treatment Group	Comparison Group
Get Tested	Right to know her future Plan for obstacles Settle or live life to fullest Don’t have kids to pass on trait	Future planning to live life to fullest Travel the world. Enjoy last years. Don’t have kids to pass on disease.
Not Get Tested	Knowing will ruin her life Have children without worry	Knowing will cause stress. Your time to die is your time.

Inductive analyses of the data revealed that students from both groups decided on two options for Miriam. In option one, students recommended that Miriam should be tested for Huntington disease, and in option two students recommended that Miriam not to be tested. A comparative analysis of the data showed no significant difference between the two groups of students. Students in the comparison group decided that Miriam should be tested in order for her

to live the life she wants to live, without worrying about the unknown. Students in the treatment group who wanted Miriam to get tested for Huntington disease were influenced by their desire to see Miriam live life to the fullest, without worrying about anything. These same students were adamant that if she was tested and the results were positive for Huntington disease, then Miriam should not have children because the children would pass on the defective allele for Huntington disease for generations. Consequently, this would allow the defective allele for Huntington disease to remain in society and create suffering for those who would have to eventually live with this disease.

Both groups of students believed that if Miriam knew she had the defective allele for Huntington disease, it would cause her to live life in fear of death. On the contrary, both groups of students believed that if Miriam knew she didn't have the allele for Huntington's, she could enjoy her life and plan accordingly. They suggested that if Miriam wanted to have children, then she should. However, other members of the treatment group believed that having children would permit the defective allele for Huntington disease to persist in society. The overall analysis of both groups of students' responses to the three questions above showed no unique differences between their abilities to integrate scientific content knowledge in their reasoning about what Miriam should or should not do. With the exception of their correct use of scientific knowledge to suggest that there are no carriers for a disease that is caused by a dominant gene, students generally did not express any scientific knowledge that influenced their decision on what Miriam should do.

## **Case 2**

Data collected from Case 2 was analyzed to assess students' abilities to integrate scientific knowledge to justify their decision on SSI. Case 2 represents the post-test results from

both groups. This case (See Appendix F) describes a situation in which a 28-year-old woman and her 50-year-old father both carry the allele for Huntington disease. The woman is pregnant and the test shows that the fetus is a carrier of the allele for Huntington disease. Students from both groups provided responses to the three questions identified below. After providing their responses to the questions, students were asked to discuss their opinion and justification in groups of three. Individual students then wrote a final conclusion and provided justification on what this woman should do. Students' responses to the three questions, their conclusions, and justifications are shown below.

**Question 1.** When abortion is considered, is it significant that in the case of Huntington disease a person may live a normal life until the age of 50? (Mean life expectancy is 75 years. How much of a difference does 25 years make?) Please explain.

There are many reasons for an individual to decide upon having an abortion. While many of the reasons for having an abortion may be personal, some of the decisions to abort a fetus is also scientific. For example, people oftentimes decide upon an abortion because of health risks to both the mother and the fetus. In responding to the question above, students from both groups did not use any scientific justification in their explanation; they simply took a pro-life stance and suggested that living for fifty years is worth not having an abortion. Students from both groups overwhelmingly stated that getting the opportunity to live for fifty-five years was worth the parents not aborting the fetus. They believed that an individual with Huntington disease could still have a long time to live and enjoy life. As a result, students from both the treatment and comparison groups took a pro-life stance on this question. Table 22 highlights the stance students took on this question.

Table 22

*How much difference does 25 years make?*

Treatment Group	Comparison Group	Researchers' Interpretation
Well, if they were born and not aborted they could be able to experience life. Every unborn child should have the opportunity to life. Unborn babies can't speak for themselves, so somebody has to unless the baby is hurting inside the womb.	Twenty-five is no difference to me. A life is a life, no matter how old you live to be. You have at least some time to live.	Students from both groups suggested that the fetus should be given the opportunity to live. The student in the treatment group suggested that the unborn fetus could not advocate for itself, so it was important for someone to advocate for it. Both students used their prolife views to advocate that the fetus should be allowed to live regardless of if they have a disease or not.
Yes, the person might live a normal life until the age of 50 because the disease does not affect you until you are in your early 30's. It is not a big difference of 25 years because you still live your 25 years and it's a lot of years.	I think 25 years is not enough of a reason to abort a child. Some people die at 50 for other unexpected reasons. They could still have a good childhood and grow up and have a good life.	Students from both groups suggested that having the opportunity to live life for twenty-five years is a big accomplishment. Students seemed to believe that living for twenty-five years is a lot, since some healthy people unfortunately do not get a chance to live that long.

**Question 2.** Do you think there is a difference between such a disease and other diseases in which the onset of symptoms begins at birth? Please explain.

Students in both groups concurred that there was a difference between diseases that show symptoms at birth and those that show symptoms later in life. While students from both groups believed that diseases in general do lead to pain and suffering, whether they are manifested at birth or later in life, more students in the treatment group (28%) suggested those diseases that

show symptoms at birth lead to a lifetime of pain and suffering. They believed that diseases manifested later in life might cause less suffering. A small number of students (10%) from the comparison group suggested that diseases manifested at birth might lead to a lifetime of pain and suffering. These students mainly suggested that either way there will be pain and suffering and that Huntington disease will only bring about pain and suffering later in life. Table 23 shows common comments of students from both groups.

Table 23

*Differences between diseases with symptoms at birth and those with symptoms later in life*

Treatment Group	Comparison Group	Researchers' Interpretation
No, because both diseases could cause suffering, just at different times.	No, because either way the child will suffer at some point.	Students from both groups believe there is no difference between diseases that show symptoms at birth and those that show symptoms later in life. Students expressed that both cause people to experience unnecessary and unbearable sufferings.
The difference would be that if it starts at birth, then the baby would suffer through life. When it doesn't start at birth, the child can have a normal life for 50 years before any suffering.	With Huntington you won't suffer until later on in life.	Students in the treatment group suggested that a disease that shows symptoms at birth results in a lifetime of suffering. However, both groups of students suggested that those diseases that show symptoms later in life only cause sufferings later in life. Thus, an individual with Huntington disease will have the opportunity to live a period of time without any suffering.

Students from both groups gave yes and no answers and similar justifications. For example, students who answered no believed that diseases that are manifested at birth often lead to a lifetime of pain and suffering. Those who answered yes suggested that the only difference would be that those diseases that are manifested later in life will only delay the pain and sufferings that are brought about by those diseases. Either way, both groups of students believed that those who are affected would experience pain and suffering.

**Question 3.** Is the expected suffering a reason to decide upon abortion? Please explain. Students in both groups gave varying reasons why Gila should or should not have an abortion. However, none of the students from either group integrated scientific content knowledge in their reasoning on what Gila should do. An analysis of data from students who were in the comparison group produced four common reasons why the expected suffering should or should be a reason to decide upon an abortion: 1) No, with enough care the suffering should be minimal; 2) No, Gila should have known the disease was a possibility; 3) Yes, don't put the child through a life of pain and suffering; and 4) Yes, abort if there will be pain and suffering. Students did not integrate any scientific reasoning in their justification of why Gila should or should not abort the fetus.

An analysis of the data from students in the treatment group also produced four common reasons why the expected suffering should or should not be a reason to decide upon an abortion: 1) No, something will eventually kill you; 2) No, the baby will experience 50 years of life; 3) The baby deserves a chance to live; and 4) Yes, abort if there will be suffering. Table 25 outlines the students' responses to the question whether the expected suffering is a reason to decide upon abortion?

Students from both groups gave varying reasons as to why Gila should not have an abortion. Some suggested that we are all going to die one day so aborting a fetus because of health reasons was unacceptable. Students even cast blame on Gila and suggested that she should have known there was a high risk of passing on the defective gene for Huntington disease to her offspring. Therefore, she should have to deal with the consequences of having to care for an individual with the disorder. On the other hand, students also suggested that no one should be allowed to put another human being through the ordeal of living with such a disease. As a result, these students suggested that they would have aborted the fetus. While the reasoning students gave varied, there was not much difference between the two groups of students.

**Question 4.** Now let us discuss the question: What should Gila do? To conclude, please write down your final conclusion and the justification it is based upon (individually).

Students were arranged into groups of three and asked to discuss their decisions on what Gila should do (Should she abort or keep the fetus?). After they had discussed their decisions in small groups, they were asked to individually write a conclusion and provide justification. An inductive analysis of the written responses from both groups of students produced two decisions: 1) Gila should not abort the fetus; and 2) Gila should abort the fetus. Table 24 illustrates exemplar decisions and justifications from both groups of students.

A comparative analysis of students' justifications of why Gila should have an abortion showed no difference between both groups of students. They both suggested that Gila should not bring a child into a world in which it will grow up in a life of pain and suffering. None of these students integrate any scientific knowledge in their reasoning of what Gila should do.

Table 24

*Is the expected suffering a reason to decide upon abortion?*

Treatment Group	Comparison Group	Researchers' Interpretation
No, something is going to kill you, so you might as well be happy with what you get. 50 years is a long time to live.	No, because the child should still live and with enough care, love, and treatment, the suffering would not be as much. The reason for this is because symptoms will not appear until 50.	Students from both groups believed that the expected suffering was not enough to decide upon abortion. These students believed that we will all die one day, so having the opportunity to live for some time is all worth it.
No, when born, the baby would experience 50 years of life as opposed to never being born.	I think I can understand it if the baby would be suffering a lot and not have any chance for a normal life.	Students from both groups are against granting an abortion in this case. However, more student in the comparison group was more willing to say yes to an abortion, if the baby would suffer a lot from this disease.
I believe that the baby deserves a chance to live. No one should take another person's life. Medicine and technology have also advanced tremendously, which could help the baby cope with the disease.	No, because she knew if she ever had a kid that it would have a chance of inheriting Huntington disease. So, she should have gotten herself tested before getting pregnant.	Both students are against granting an abortion in this case. Students in the treatment group holds hope that medicine and technology will be able to help people cope with this disease. Students in the comparison group wanted to punish the mother for having a child, knowing that there was a possibility the child would inherit the gene for Huntington disease.
If the child is going to be suffering for most of its life, then I would have an abortion.	Yes, you know you will put your child through that.	Students from both groups believed it is not necessary to put the child through such pain and suffering.

The comparative analysis of why Gila should not have an abortion again showed no difference between the two groups of students. They both suggested that every life is precious



no matter the medical complications the fetus can expect to experience in life. Students from both groups also believed the baby would still have a chance to live a normal life, even if the allele for Huntington was present. Again, none of the students integrated any scientific knowledge in their reasoning.

Table 25

*What should Gila do? Why should she do it?*

Treatment Group	Comparison Group	Researchers' Interpretation
I believe she should have the abortion. The child may not suffer until he or she reaches the age of 50, but they will suffer. Plus, the child will be robbed of 25 years of life, good life.	Gila should abort the baby. It will cost too much for Gila and her kid to both have Huntington disease. Plus, her kid doesn't need to suffer later on in life. Let Gila enjoy the rest of her life.	Students from both groups believed that allowing the child to grow up to a life of pain and suffering is not worth it. Both students believed Gila should abort the fetus. Ironically, this student suggested that the child would be robbed of 25 years of life, but totally ignored the fact that an abortion will eliminate any chance life. Students in the comparison group had a different reason for granting the abortion and suggested that the abortion would free up Gila to enjoy the rest of her life and have fun.
I think she should have the baby and let it live life. The person should be happy and live life. When their time comes, it comes. Every unborn baby has a right to live.	Gila should have the baby. That is her responsibility since becoming pregnant. She knew there was a chance of the fetus having this disease. Also, just because the baby won't live a long life, it doesn't mean it will be a life without meaning.	Students from both groups believe that life is very precious, no matter the medical complications one would experience in life. As a result, these students believed the fetus should not be aborted. Students' strong prolife stance seemed to influence their decision of not agreeing that Gila should have an abortion.

Table 25 (Continued)		
I believe that Gila should not abort the baby. A person with this disease may have trouble, but they can also live a normal life with the help of advanced medicine and technology. The baby deserves a chance to live and no person should take another one's life.	I believe Gila should not abort the baby because there's no guarantee the baby will have the disease. Also, if the baby was to have the disease, 50 years is a long time to live, so I believe Gila shouldn't abort the baby.	Students believed there was a chance that the baby live a normal life, would although they may have some difficulties with their health. As a result, both students were against Gila having an abortion.

The results obtained from the students' responses to the questions in Case 1 showed no significant differences between students from both groups' abilities to integrate scientific content knowledge, in the process of reasoning about SSI. A comparative analysis of the data, from both groups of students, showed no observable differences. However, more students in the treatment group suggested that diseases caused by dominant allele will always be expressed once the allele is presented in an individual. In case 2, students' responses to the four questions also showed no major differences. Again, comparative analysis of the data showed no observable differences. These results would indicate that the integrated SSI curriculum had no effect on students' abilities to integrate scientific content knowledge in their reasoning about SSI. Because of the relatively small size of this study, generalized conclusions on the effects of the integrated SSI curriculum on students' abilities to integrate scientific content knowledge, when reasoning about SSI, are inappropriate. Therefore, it is possible that students may need explicit instruction on how to integrate scientific content knowledge, when reasoning about SSI, for a broader research understanding or application to be concluded. More research is also warranted in this area, which could lead to opportunities for generalizations for other similar populations.

## Summary of Results

In their responses to RQ1, students in the treatment class commented they used new knowledge gained from the class, along with their experiences on the topic to evaluate evidence. Furthermore, students spoke about how the article lacked adequate information necessary to evaluate evidence. Students in the comparison group suggested they used new knowledge and emotion to evaluate evidence. Many of these students also suggested they lacked the scientific background knowledge to adequately evaluate evidence. Students in the comparison class (pre and post) also used varied emotions, when they evaluated evidence. These emotions included but were not limited to pity, sadness, concern, fear, grief, hope, disgust, and anger. Students in the treatment class also expressed similar emotions in their justifications to the questions they asked as they evaluated the evidence. Overall, the integrated SSI curriculum did not seem to have much of a success, as there were no real differences in the results obtained from the treatment and comparison groups' pre and post-test results. However, the results also showed that students relied heavily on emotions to assist as they evaluated evidence.

In the semi-structured interviews, students were concerned about those who would oppose the use of embryonic stem cells based on their religious belief and values. Students inquired about the similarities in the genetic make-up between rats and human beings. Students also expressed a caring attitude for the families who donated the embryos for the stem cells to be harvested. The concern for the mental well-being of these families was of interest to the student who raised this concern.

The responses to RQ2 showed that students from both groups used similar justifications in their ranking order of who should be awarded an organ transplant. Students' ranking order of patients to receive the organ transplant was based on their survivability after transplant, the

patient's degree of illness, their sympathy for the patient, organ compatibility to the patient's body, and not wanting to waste the organ by providing the donated organ to a patient who would die within a short time, after receiving the transplant. Students from both groups had difficulties using scientific considerations to justify their ranking of who should be awarded the heart transplant. Again, there were no real differences between the treatment and the comparison groups' pre-test and post-test results. In regard to the students' use of emotions to decide who should be awarded an organ transplant, students from both classes used similar emotions. Students expressed sympathy for the patients who were in need of an organ transplant. They also wanted the transplant to be awarded in a fair manner.

The responses to RQ3 showed that students from both the comparison and treatment groups used similar rationalizations, when answering the questions in both case 1 and case 2. For example, in Case 1, when responding to the question of the chances that Miriam was a carrier of Huntington disease, students from both classes overwhelmingly suggested she had a 50% chance of being a carrier. However, a small group of students from the both treatment and the comparison groups suggested Miriam's chances of being a carrier were low. When responding to the question of the chances were that Miriam would give birth to an affected child, if she was indeed a carrier of the allele for Huntington disease, a greater percentage (48%) of students from the treatment group suggested that diseases caused by a dominant allele will always be expressed once the allele is present in an individual. Students in both groups also believed that the best way to prevent passing the defective allele for Huntington disease from one generation to the next was to not have children.

In Case 2, students who supported Gila having an abortion suggested the baby's whole life would be ruined by Huntington disease. Students suggested that it was better to abort the

fetus to prevent the pain and suffering that it would eventually endure. Students who opposed Gila aborting the fetus believed an abortion was not warranted in this case, because the child had the possibility of living for 50 years with Huntington disease. Students who were opposed to Gila having an abortion also blamed her for getting pregnant.

While students gave rationalistic justification in support for allowing one to live for 50 years before being overcome by Huntington disease, most notable in their responses to the questions above were the absences of any scientific arguments. In many instances, the use of their scientific knowledge to justify their claim was not evident in their argument. Instead, students oftentimes gave justification for their decisions that was emotive in nature. For example, students blamed Gila for becoming pregnant in the first place. Such suggestion would imply that these students were angered by her decision to become pregnant. Students also ignored the fact that this disease would eventually manifest itself once the defective genes were present in the individual and evoked hope that it would not become a problem for the infected individual. Students suggested there was a chance the baby would live a normal life, although it had affected genes.

## **CHAPTER FIVE: DISCUSSION**

### **Introduction**

Data from the first research question showed students from both the treatment and the comparison groups used emotions such as anxiousness, fear, grief, hope, disgust, and anger to assist in their evaluation of evidence. Data also showed students used sympathy and empathy to determine their rankings of who should be awarded an organ transplant in the second research question. Finally, the data collected on the third research question showed students from both the treatment and the comparison groups used anger as an emotion to justify their decisions on whether a fetus should be aborted. Chapter five presents a discussion of the above findings, implications for educational practice, recommendations for further research, and overall conclusions of this study. The chapter will expand the findings from chapter four, establish direct links between the results of this research and other pertinent studies, and offer directions for future research studies.

### **Discussion of the Findings**

This study examined the effects of emotive reasoning on secondary school students' decision-making in the context of SSI. A sixteen-week integrated SSI high school biology curriculum incorporating real world scientific problems which not only required scientific thinking, but also provided opportunities for students to engage in moral and ethical ways of thinking. The scientific problems used for the study regarded thinking that may impact their biological, physical, and social environment.

The guiding questions and accompanying discussion are shown below:

1. What relationships exist between secondary school students' emotive reasoning and their abilities to evaluate evidence related to thoughts on socioscientific issues?

Very few studies have focused on the role of emotive reasoning on secondary school students' decision-making relating socioscientific issues. To elicit students' responses to Part 1 (See Appendix D) of the research question above, students were first asked to use a scale that ranged from 0—100 to determine: 1) How likely they think embryonic stem cells are used to restore rats' vision; 2) How much experience with or knowledge of stem cells they have; 3) How interested they were in the topic of embryonic stem cells; 4) To what extent they used scientific knowledge to evaluate the claim that embryonic stem cells were used to repair impaired vision in rats; 5) To what extent they used emotions to judge the claim that embryonic stem cells can repair impaired vision in rats; and 6). How they rated their ability to evaluate evidence. The different scores between students' pre-tests and post-tests were analyzed using Kruskal-Wallis tests. A statistically significant difference between the treatment and comparison groups' interest in the topic of stem cell research (Kruskal-Wallis,  $p = .039$ ) and how students rated their ability to evaluate evidence (Kruskal-Wallis,  $p = .028$ ) was found.

Tomas and Ritchie (2012) conducted a recent study in which they used stories about embryonic stem cell research (BioStory) to investigate the role of affect on learning. In this investigation, fifty students ( $N = 50$ ) ages 15-18 years old completed two unfinished narratives about biosecurity through the provision of writing templates (Ritchie et al., 2012). In addition, students were also asked to compose their own stories about embryonic stem cell research. From their investigation, they reported that pride, strength, determination, interest, and alertness played key roles in students' participation in the assigned writing stories. Tomas and Ritchie

(2012) reported that students' interest increased, when they were asked to compose their own stories. Additionally, they reported that an analysis of video data revealed increased levels of social interactions among students, which further enhanced their interest and engagement in the lesson. Results from the Tomas and Ritchie study (2012) are consistent with the results reported in chapter four of my study. Students in the treatment group, who were exposed to the integrated SSI curriculum, were more interested in the topic of embryonic stem cells than students in the comparison group. Kruskal-Wallis tests showed statistically significant differences between the treatment and comparison group's interests in the topic of embryonic stem cells being used to repair rats' vision.

Results from the Tomas and Richie (2012) study also revealed that social interactions enhanced students' interest on SSI. This result confirmed some of what has already been reported in the literature review from the Turiel (1998) study that investigated social, emotional, and personality development. For example, it was reported students form ways of thinking through natural inclination as well as social experiences, which include substantive understanding of moral concepts like justice, rights, equality, and welfare (Turiel, 1998). When students are given opportunities to engage in discussion on issues that lack clear cut solutions (SSI), they generate judgments built on emotions including but not limited to: sympathy, empathy, respect, love, and attachment. This study revealed that students from the treatment class exhibited increased interest in the lessons and issues, when they debated issues surrounding stem cell research. Furthermore, students used emotions such as empathy to generate judgments about the claim that embryonic stem cells were used to repair rats' vision.

When students were asked to provide brief explanations of why they rated their abilities to evaluate evidence the way they did, students from the treatment group stated they used new



knowledge and experience on the topic to make their judgments. They also stated their lack of background knowledge of stem cells affected their abilities to evaluate the claim that stem cells were used to repair rats' vision. When students in the comparison group were asked to evaluate the claim that embryonic stem cells were used to repair rats' vision, they identified new knowledge and emotions as factors that influenced their ability to evaluate the claim. Students in the comparison group also stated their lack of background knowledge affected their ability to evaluate the claim. While it was evident students' lack of adequate background knowledge of stem cells impeded their ability to do a more thorough job of evaluating the claim that embryonic stem cells were used to repair rats' vision, the notion of students using new knowledge and experience to assist in their evaluation of evidence should be welcoming news to educators. This should encourage science education policy makers to infuse more SSI in secondary school science curriculum. Doing so may allow science teachers to provide students with the necessary opportunities to build background knowledge on topics such as embryonic stem cells. This approach will broaden students' background knowledge on contentious issues of the 21<sup>st</sup> century and beyond.

As suggested by students in the comparison group, emotions were a factor that influenced the way they rated their abilities to evaluate the claim that embryonic stem cells were used to repair rats' vision. This suggested that emotions were also equally important in students' learning. The use of SSI as a key pedagogical strategy can provide the forum where students become eager to use emotions to express their feelings and attitudes about different phenomena. This will then provide opportunities for their peers and teachers to get a better understanding of the impact of emotions on students' thought processes. In this investigation, students' use of emotions reaffirms the Blachette and Richards (2010) findings, which stated that affective

variables can have a large influence on higher-level cognitive processes. Blachette and Richards (2010) reviewed two decades' worth of empirical studies that have documented the influence of affect on judgment. They concluded that affect on judgment influences a wide range of emotions including anger, sadness, anxiety, and positive moods. In the current study, emotions heavily influenced the way students in the comparison group rated their abilities to evaluate evidence that stem cells were used to repair rats' vision. For example, when students in the comparison group were asked to provide a brief explanation about why they rated their abilities to evaluate evidence the way they did, some students stated they used emotions to evaluate the information because they were saddened by the use of stem cells in research. To them, stem cells are dead fetuses. Consequently, students reported that the thought of using dead fetuses to repair rats' vision was just too emotional for them, so they were unable to evaluate the claim of stem cells repairing rats' vision.

Section 2 of the evidence evaluation questionnaire required students to generate a list of questions they would want to have answered, before they decided whether the conclusion provided by members of the research team in Health and Medical News Weekly was true (See Appendix D, Section 2). Students were required to provide answers for each question, identify the types of emotions they experienced with regard to each question, and explain if such emotions may have influenced how they evaluated the researchers' claim. Students reported that emotions such as: sadness, anxiousness, fear, grief, hope, and anger influenced the questions they asked in their attempt to evaluate the claim. These results were similar to the findings from the Blachette and Richards (2010) investigation, which documented results outlining the influence of affect on a wide range of emotions including anger, sadness, anxiety, and positive moods.

While the students of this study used emotions to judge the claim they were presented, some of the students from the treatment group were able to use their emotions to influence the questions they asked, when they evaluated the claim. For example, sadness as an emotion influenced students inquires about the species of rats that were used in the experiment. Such inquiry is important since different species of rats may have had a different effect of the conclusion drawn by the research team. A small percentage of the students from this study's treatment group were able to use emotions such as hope, sadness, and anger to ask probing questions as they evaluated the claim that embryonic stem cells were used to repair rats' vision. These students also raised questions about where the research was conducted. Such inquiry showed students understood that politicians and other members of society are sometimes biased towards research findings from larger research institutions. Students also used inquisitive thinking (curiosity), which was influence by their skepticism to inquired about the researchers' credentials to assess if they were indeed qualified to conduct this research. Inquiring about the researchers' credentials would indicate that the students understood the difficulties that are involved in embryonic stem cell research. They also wanted to ensure that the researchers are really qualified to conduct this type of research.

Sadler and Zeidler (2005b) conducted an investigation that examines how individuals negotiate and resolve genetic engineering dilemmas. The researchers used two semi-structured interviews to collect informal reasoning responses to six genetic engineering scenarios from 30 college students. They reported that participants frequently relied on their feelings and emotions to solve dilemmas. More specifically, it was reported that the participants used care perspectives in which sympathy and empathy were the main emotions that guided their decisions throughout the SSI investigation.

The students in the present study reported the use of emotions such as sadness, pity, fear, grief, hope, and anger influence the questions they raised, as they evaluated the claim that embryonic stem cells were used to repair rats' vision. Some students expressed anger as an emotion as they evaluated the claim, because they believed it was unfair for scientists to destroy human embryos. These students expressed a sense of care towards the embryos and stated that emotions such as sadness and anger influenced the questions they asked, as they evaluated the claim that embryonic stem cells were used to repair rats' vision. The results from the current study corroborate the findings reported by Sadler and Zeidler (2005b), in the sense that students from both studies relied on emotions whether they were evaluating evidence or making decisions.

A recent article by Zeidler and Sadler (2008) provided a descriptive framework for how individuals approached socioscientific argumentation and how moral concerns were embedded in their reasoning and highlights the importance of emotions in students' educational growth. These researchers endorsed the importance of emotions in the science classroom and brought attention to the point by stating, "Science classrooms that deny emotive venues of discourse in the discussion of social-science issues curtail students' personal development" (p. 207). In the current study, students from both the treatment and the comparison groups used variety of emotions to judge the claim they were presented with. For many of the students, the destruction of a human embryo went against their moral beliefs, ethical values, or cultural background. For other students, the destruction of embryos to repair rats' vision undoubtedly tapped their emotions, to the extent that many of these students became saddened or angered by the example. Science instructions that exclude opportunities for students to use their emotions and morality in

their discussion on socioscientific issues can be expected to fall short of a functional understanding of scientific literacy (Zeidler & Sadler, 2008).

In the semi-structured interviews, the small number of students who were interviewed also identified various types of emotions that influenced the questions they asked as they evaluated the evidence. For example, when students asked about the method used by the researchers to conduct the study and the results that were obtained from those methods, these students' questions reflect emotions of hope, pity, sadness, empathy, anxiety, and concern to help in their abilities to evaluate evidence. Their questioning confirmed the results of the written documentation cited above. As reported in chapter four of this investigation, emotions played a major role on students' abilities to evaluate SSI.

The fact that emotions played such a prominent role in students' abilities to evaluate evidence in this study should come as no surprise to the science education community. In an investigation aimed at examining factors salient to science education reform and practice in the context of SSI, Sadler and Zeidler (2005b) highlighted the important role of emotions such as sympathy and empathy in students' reasoning by stating:

On a conceptual level, emotive considerations may be distinguished from other factors (personal, cognitive, social, etc.), but in practice it may be an academic point because of the persuasive influence emotions have on how students frame and respond to ethical issues. (Sadler & Zediler, 2005b, pp. 115)

2. What relationships exist between secondary school students' use of emotive reasoning and their decision-making regarding socioscientific issues?

Asking students to make decisions on contentious issues for which they may have entrenched beliefs, often evokes emotive reasoning (Powell et al, 2012; Zeidler et al., 2011). Emotive

reasoning entails one's ability to use sympathy, empathy, compassion, and love when asked to engage in discourse and self-reflection in order to determine right and wrong. One generally uses emotions whenever encountering significant relationships with others or with the environment (Barett & Campos, 1987; Frijda, 1986).

Part of this study examined students' decision-making on controversial issues, specifically, the distribution of scarce medical resources. These issues were captured and discussed in two parts. In Part I, students were asked to rank the order of factors they believed should be determined prior to a patient receiving an organ transplant. The tasks that students were asked to complete did not require them to select a particular patient over another; instead, the task entailed the development of a protocol in order to implement a policy for organ transplantation. The instrument addressed aspects of distributive justice by requiring the evaluation of criteria that are typically considered in situations that require the distribution of scarce medical resources (Armstrong & Whitlock, 1998, Zeidler et al., 2011). Students ranked the order of their decisions by giving considerations to the patient's health factors, including but not limited to, the degree of illness, ability to pay for transplant, and the patient's survival chance after receiving the organ transplant, when deciding which patients should receive an organ transplant. Part II of the decision-making about SSI required students to identify scientific and emotive considerations that influenced their decision to rank the patients who should have received the organ transplant.

Results from Part I indicated that both groups of students primarily awarded the organ transplant to the sickest patient, to the patient most likely to benefit based on medical or other criteria, the patient on the waiting list the longest, or to the patient on the basis of their importance for the well-being of others. Students' decisions to award the organ transplant in the

manner described were mainly influenced by their desires to care for the patient who was extremely sick and about to die, survivability of the patient who would receive the organ transplant, fairness for the patient who had been waiting the longest for an organ transplant, and the cost and value associated with getting a transplant. Students' arguments of caring and fairness support the notion that if someone was dying and there was a chance to save them, then the right thing to do would be to give them the organ transplant. This reasoning highlighted students' use of moral emotions and personal values expressed through sympathy and empathy to make their determination on the patient who was best suited for the organ transplant. These results corroborated earlier findings discussed from the Zeidler et al. (2013) study that reported caring, empathy, and value judgments as sub-categories of emotive reasoning that influenced students to determine the patient most suitable for an organ transplant. Students awarded the transplant on the basis of the patient's illness and generally ignored the many different medical and logistical characteristics that must be considered when determining the patient who is best suited to receive an organ transplant. Students rarely made mention of the blood type and size of the organ to the patient, the degree of immune-system match between the donor and recipient, or whether the recipient was a child or an adult. These are just a few of the criteria that must be examined prior to deciding on the best-match recipient for an organ transplant. Instead, students' decisions on awarding the organ transplant to the sickest patient were influenced by their emotions. For example, students made comments that included the idea that the sickest patient was suffering a lot and possibly in pain, so they must be helped first. Such justification suggests that students' decisions to give the organ transplant to the sickest patient was influenced by sympathy for the patient who was suffering and in need of the organ transplant, rather than

whether the patient was the best-fit candidate for such a transplant based on satisfying medical criteria.

Students who believed wasting the organ should not be an option, suggested that the heart transplant should be given to someone who would benefit the most from the transplant rather than giving such a scarce medical resource to someone whom the transplant would not benefit. This suggestion corroborates the category of pragmatism discussed in the Zeidler et al. (2013) study regarding how students placed a premium on the allocation of organs to those most likely to utilize the organ for the longest comparative time.

Students from both the treatment and the comparison groups made the decision to award the organ to the patients who contributed the most to society. Such recommendations confirmed that students made their decisions of who should be awarded the transplant on a means-to-an-end basis. Typical rationales given by students who used a means-to-an-end basis to justify their decisions include, “I believe the transplant should first go to the people of importance to the community or country. I would rather save somebody who is going to actually be worth the transplant, rather than someone who is not going to benefit the community or country.” Again, these statements suggested that students ignored important criteria such as organ compatibility, which must be considered before determining the best-fit candidate for a heart transplant. On the contrary, other students believed that felons should not be awarded the transplant over hard working people. They generally suggested that felons got their chance in life and did not make good use of it. Clearly, this suggestion is also influenced by emotions.

Part II of the decision-making about SSI required students to identify scientific and emotive considerations that influenced their decision to rank the patients who should have received the organ transplant. Results showed that students from both the treatment and the



comparison classes had difficulty identifying the scientific considerations that influenced their decisions on who should be awarded an organ transplant. These findings are consistent with Lee's (2007) issue-based study that involved 160 secondary school students, from two secondary schools in Hong Kong that investigated their decisions about banning cigarette smoking in public places. In his study, Lee (2007) reported that students do not always integrate scientific knowledge in their reasoning and decision-making. Although the students in this particular study were aware of the links between cigarette smoking and lung cancer death, they opted not to propose a ban on cigarette smoking in public restaurants because of the economic and social consequences that would result from such a ban.

Molinatti et al. (2010) conducted a study focused on how individuals make and justify claims and conclusion about an SSI issue. It was reported that students often had difficulties developing justifiable arguments for their decisions, because they relied on emotions to justify their decision against embryonic stem cell research. For example, the justifications proposed by students against embryonic stem cell research include arguments such as: an embryo is a future human being, human embryonic stem cell therapy is too risky, allowing embryonic stem cell research may lead to oocyte trading and the commercialization of life, and therapeutic cloning may lead to reproductive cloning. These arguments are similar to those proposed by some of the students in the current study, in which students used emotive considerations in place of scientific consideration when they made statements such as, "I made my decisions based on what is right and how I feel." Students also stated, "Scientific consideration did not influence my decision. Moral factors are important. You aren't dealing with an experiment. It's somebody who has friends and a family." These students' statements shed light on the difficulties students experience whenever they are asked to make decisions on issues that are contentious or lack

clear-cut solutions. Students' decisions to award the organ transplant based on what is right to them and how they feel clearly hinged on emotions such as sympathy. Being sympathetic towards those patients who are suffering was enough to make students ignore the importance of scientific considerations doctors generally consider prior to determining the best-fit candidate for a transplant.

Similar to scientific considerations, students from both groups mainly inquired about the post-transplant treatment on the patient's health and organ compatibility to the patient's body. These were the only scientific considerations students used to determine who should be awarded the organ transplant. Typical scientific considerations included students' statements such as "I considered the overall health of the patient and the likelihood of their survival after the transplant." While students from both groups had difficulties identifying appropriate scientific considerations that influenced their decisions on who to award the organ transplant, it was evident that the majority of students from both groups were unwilling to use scientific considerations or they simply had difficulties telling the difference between emotive and scientific considerations. In their attempt to state and identify the scientific considerations that influenced their decision, students would instead express emotions such as sympathy, empathy, as well as ethical and moral considerations when deciding to determine who should be awarded the organ transplant, instead of using scientific considerations. For example, students who used ethical considerations stated, "I relied solely on ethical conclusions based on personal ideology to rank the factors. I did not use scientific considerations."

Students' decision to award the organ transplant on the basis of moral factors, ethical considerations, and emotions such as sympathy and empathy, showed a link between moral judgment, moral and ethical decision making, and emotions. This result confirmed earlier

reports, which stated that moral judgments are emotional in nature (Berthoz, Armony, Blair, & Dolan, 2002; Moll, de Oliveir-Souza, & Eslinger, 2003; Prinz, 2006; Sanfey, Rilling, Aronson, & Nystrom, 2003). Students who used sympathy to make their determination claimed, “I made my decision based on what is fair and right. I have to feel for someone who is in this situation.” Those students who used empathy shared, “I made my decision based on how I would want to be treated. You have to put yourself in that patient’s shoes.” These students’ statements indicated that students predominantly used emotive considerations, when deciding on who should be awarded the organ transplant in place of scientific considerations. Students continued to report the aforesaid emotions when asked to identify any emotive considerations that influenced their decisions to the ranking order for the patient for transplant.

The students’ responses indicate that human emotions are surely to be tapped when ordinary citizens are confronted with the task of making decisions on SSI. For example, when everyday folks are confronted with the task of voting on whether their government should install septic systems in their communities that may pose potential health risks to residents, where to build landfills, whether to build nuclear power plants, and in whose communities natural gas pipelines should be constructed, many of their decisions will be influenced by emotions (Kolstø, 2001). Therefore, science educators must stand ready to tap into the emotional aspects of these issues that many people from within, as well as outside, these communities will tend to utilize as the morality of decisions concerning the fair distribution and potential costs and benefits of these ethically imbued issues.

Teaching students how to effectively reason and develop skills will allow them to evaluate evidence and make evaluative-based decisions on issues that are complex, have no clear-cut solutions, and require morality and ethics is extremely important. If our secondary

schools are to produce the next generation of graduates who can help solve many of our 21<sup>st</sup> century scientific problems, then policy makers and science educators cannot continue to overlook the importance of such teachings. Unfortunately, the current emphasis on assessment and accountability as a reform in our secondary educational institutions, seems to put added pressure on teachers to the extent they continue to ignore the role of emotions in students' learning for one in which high stake testing is the central focus (Lin, 2000; Lin, Graue, & Sanders, 1990).

3. In what ways do students integrate scientific content knowledge in the process of reasoning about socioscientific issues?

Today's society is impacted by many problems that are represented by social as well as scientific issues. In order for educators to develop a generation of students with the potential to help solve many of these issues, our educational institutions should give students opportunities to practice and develop competencies in solving these issues. Some science education researchers suggest that the ability to reason and make decisions about social dilemmas with conceptual, procedural, or technological associations with science (SSI) is regarded as an important component of scientific literacy (Driver, Newton, & Osborne, 2000; Ohman & Ostman, 2008; Roberts, 2007; Zeidler & Sadler, 2011; Zeidler, Berkowitz, & Bennett, 2011; Zeidler, Walker, Ackett, & Simmons, 2002).

Socioscientific issues have already been established as important for improvement in students' science content knowledge (Applebaum, Barker, & Pinzino, 2006; Sadler, 2009; Sadler, Barab, & Scott, 2007; Walker, 2003; Zeidler & Sadler, 2011; Zohar & Nemet, 2002). As a result, better understanding of the extent to which students integrate scientific content knowledge in the process of reasoning about SSI is important for policy makers, teachers, and

educational institutions to make informed decisions about how best to prepare pre-service teachers and students in our K-12 educational settings.

In this study, students were assessed on their abilities to integrate and use scientific content knowledge in their reasoning about SSI using two writing tasks. Students were given two cases (Case I and Case II) to read and asked to respond to questions about each case. In Case 1, students initially worked in groups of three to discuss a small excerpt outlining the effects of Huntington disease on a family. After their discussion, individual students were asked to use their scientific knowledge to address the following questions:

### **Case 1**

1. What are the chances that Miriam, a family member from a family that had been stricken with Huntington disease, is a carrier of the alleles for this disease?

Students in the comparison group were exposed to a traditional format of teaching that used textbooks to cover topics such as DNA and RNA transcription and translation and how genetic information gets inherited among family members. Students in the treatment group were exposed to lessons that required them to formulate and defend a position for or against genetic testing, while taking into consideration various kinds of information. For example, students were given facts on the number of women who are diagnosed with breast cancer annually, the names of the cancer genes that caused breast cancer, how the gene mutates, benefits of genetic information in research, and how the genetic testing is conducted. After being exposed to this information, individual students were required to encourage a young lady to get a genetic test for breast cancer. Students were required to tell what advice they would give to this young lady about taking or not taking the test and explain how a decision might affect the young lady cognitively, psychologically, and emotionally. Students in the treatment class were able to use

this lesson to help formulate a prediction to the question of, “What are the chances that Miriam is a carrier of the allele for Huntington disease?” While students from the treatment class had prior experience from their lesson on providing advice to an individual who is considering getting a genetic test, results showed that they along with the students from the comparison group did not elaborate on Miriam’s family’s history of Huntington disease, what causes Huntington disease, or how such disease gets transmitted among family members. Students from both groups simply responded to this question stating: 1) Miriam has a small chance of being a carrier of the defective allele for Huntington disease; and 2) Miriam has a 50% chance of being a carrier of the disease.

Students’ suggestion that Miriam had a 50% chance of having the disease is correct. The gene that causes Huntington disease is found on chromosome number 4. Because we inherit chromosomes from each parent, we end up with two copies of genes in our DNA; one copy from our mother and the other copy from our father. Because either parent will donate one set of chromosomes, there is a 50% chance of a parent who is infected with Huntington disease passing it down to their offspring. The students from both the treatment and the comparison groups who stated that Miriam had a 50% chance of having the disease were correct in making this determination. Therefore, this would indicate that these students used scientific knowledge gained from either the integrated SSI curriculum or traditional curriculum to make this particular statement. While some of these students were correct in saying Miriam had a 50% chance of having the defective allele for Huntington disease, there were a small number of students from both groups who suggested that Miriam had a small chance of getting the disease. These students did not quantify what small meant, but it was interpreted as a number that is less than 50, since students listed their largest percentage at 50. These confirmed the problems students

experience as they attempted to use scientific knowledge to explain scientific phenomena (Dawson & Venille, 2009, Sadler & Zeidler).

2. If it turns out that Miriam is a carrier, what are her chances of giving birth to an affected child?

An analysis of the data identified two dominant themes from both groups of students' responses. They stated that the child for certain would be affected and that the child had a 50% chance of being affected. Students' responses seemed to indicate they were able to use their knowledge of dominant and recessive alleles to make their decision. While this was the case, students in the treatment class were able to use the scientific knowledge they gained from the integrated SSI curriculum to outline the difference between dominant and recessive alleles. For example, students suggested that Miriam had a 50% chance of being affected by this disease, if her father had the gene for the disease. Students then pointed out that because the disease is caused by a dominant allele, once it is present, it means the affected individual will have the disease. Additionally, students suggested that the probability of passing the defective trait to one's offspring is 50:50. These responses suggest students understood there is no carrier for a disease that is caused by a dominant allele. They stated an individual would either have Huntington disease or not, and an individual will have the disease once the defective allele for Huntington is present. For example, a typical response from students in the treatment group was, "If it turns out that Miriam is a carrier, her chances of giving birth to an affected child are high because her grandfather had it and now she would pass it on to her child. In either case, you will get the disease if the allele is present." Clearly, the previous student's response indicated that s/he used his/her knowledge of the family history of this disease along with what s/he learned about Huntington disease and the difference between dominant and recessive alleles to determine

that Miriam would pass on the defective allele to her child. This argument also points out there is no carrier of a disease caused by a dominant allele. Students from both groups used their scientific knowledge to justify their reasoning on the probability of Miriam passing on the defective allele for Huntington disease to her offspring. This is in contrast to what was discovered in this research, when students were asked to identify the scientific considerations that influenced their decisions to award the transplant to the patient they selected. In those instances, students used emotions such as sympathy and empathy to justify their ranking of who should be awarded the transplant.

### 3. What should Miriam do? Why should she do it?

Students from both groups mainly stated that Miriam's options were to be tested or not to be tested. They overwhelmingly recommended that she should be tested to find out what was happening with her health. They conveyed that doing so would allow her to plan her future. However, a few students from both groups proposed that Miriam should not seek any testing. They either suggested that she should live her life without fear of the disease or that the knowledge of her having the disease would only ruin any good years of life she had left.

Results of the students' responses on the above questions suggest that while both groups of students were able to use scientific knowledge gained from the genetic lessons presented to them in the treatment and comparison classes, there were no major differences between the two groups of students. However, 48% of the students from treatment group and 35% from the comparison group provided similar statements on why Miriam should be tested. They stated, "She should be tested although if she is infected with the gene for Huntington disease she will eventually have the disease later in life because it is caused by a dominant allele. Once you have the allele, you will get sick in the long run." Statements on why Miriam should not be tested include, "It



doesn't matter if she get the test or not. Once she has the gene for Huntington disease, she will eventually become sick by the disease because it is caused by a dominant gene." Statements like these indicated the discussion that the students were exposed to on the difference between dominant and recessive traits had an impact on their decision that Miriam should indeed be tested to determine if she was a carrier of the defective alleles for Huntington disease.

## **Case 2**

In Case II, students read and discussed the issue of aborting a fetus that is a carrier of the allele for Huntington disease. After making their decision, individual students provided their justifications for their decision. Students were asked to respond to the questions below:

1. When abortion is considered, is it significant that in the case of Huntington disease a person may live a normal life until the age of 50? (Mean life expectancy is 75 years. How much of a difference does 25 years make?). Please explain.

Students from both groups used their pro-life stance and stated that the chance to experience any life, no matter how long it is, is well worth it. They shared that the chance to live life for 25 years is good, since people die all the time and do not get the chance to live long. Students from the both treatment and the comparison groups believed it is not necessary to abort a fetus that would eventually grow into an adult and live for 25 years. A few students from both the treatment and the comparison groups suggested that every unborn baby should be given a chance to life, so aborting a fetus because of a health issue should not be an option. This suggestion seems to be heavily influenced by emotions, rather than any scientific thoughts, as students did not consider any of the health issues that such fetus may have to endure.

2. Do you think there is a difference between such a disease and other diseases in which the onset of symptoms begins at birth? Please explain.

Students from both groups stated that there is a difference between diseases that are manifested at the onset at birth and those that are revealed later in life. Students from both groups expressed that those diseases, which are manifested at birth, may actually lead to a lifetime of pain and suffering. However, those that are demonstrated later in life may lead to pain and sufferings only from the time they are expressed. Students from both groups used their knowledge of Huntington disease to suggest that individuals with such a disease may only suffer ill effects from the disease after 50 years of life. They believed it is not worth aborting a fetus in this case, since 50 years is a long time to live. Some students suggested that they have lived 15 years of life so far and that is because their parents did not abort them. They suggested that living 50 years is worth not having an abortion.

3. Is the expected suffering a reason to decide upon an abortion?

The majority of students from both groups decided that the expected suffering should not be considered as a reason to decide on having an abortion. Students commented that the baby deserves a chance to live regardless of having a defective gene, which causes pain and suffering. Again, such belief hinged on emotions rather than any scientific influence. This does affirm earlier reports in chapter four of this study that reported on students' relying on emotions such as sympathy to help in their decision-making. Students also suggested that medicine and technology have advanced extensively and that individuals who are born with debilitating genetic diseases in this day and age do have the potential to cope well and live. There were a small number of students from both groups who believed that allowing a child to experience pain and suffering brought on by a disease that could have been prevented by having an abortion is not a wise thing to allow. They advised that to prevent this from happening, an abortion is necessary. For example, students commented, "If the child is going to be suffering for most of

its life, then I would have an abortion.” Students’ responses on this question did not involve the use of scientific knowledge; rather their responses seemed to be emotive in nature because students felt sympathetic towards people who suffer from pain brought on by diseases and disorders. Students’ answers were mixed when asked the question: Is an expected suffering a reason to decide to have an abortion? There were other students who believed that bringing an infant into this world to suffer because of a genetic defect is irresponsible, because of the suffering that such child would endure. Others believed that in no circumstance should an abortion be allowed, because every child is a gift from God. Those who made such a decision did so because of the influence of their religious views and the emotions those views prompted rather than any scientific influence. They expressed sympathy as the main reason for not aborting the fetus.

4. Now let us discuss the question: What should Gila do?

Students from both groups provided two options for Gila. The majority believed that she should not abort the fetus, while there was a small number who suggested she should. Students who believed she should have the abortion used emotive considerations to influence their decision. For example, they gave common justifications such as, “I believe she should have the abortion. The child might not suffer until he or she reaches the age of 50, but they will suffer. Plus, the child will be robbed of 25 years of life, good life.” While students who suggested that the fetus should be aborted acknowledged that the fetus may grow up and live life for 50 years before the onset of Huntington disease, they just could not get over the fact that an individual with this disease will eventually experience some amount of suffering brought on by this disease. They did not take into consideration the 50 years that such individual may live before the disease becomes a problem, nor did they consider the many other things in life that may bring about pain

and suffering on an individual apart from Huntington disease.

The students who believed that Gila should not have the abortion, typically pointed to the advancements in medicine and technology and how these allow people with debilitating genetic diseases to live a long life. Related to this statement, students' comments included "I believe that Gila should not abort the baby. A person with this disease may have trouble, but they can live a normal life with the help of advanced medicine and technology. The baby deserves a chance to live and no person should take another one's life." The above comments seem to place sufficient faith on medicine and technology to help those in need because of medical problems that results from defective genes.

### **Implication for Theory**

The science education community has only recently recognized the important role that emotions play in students' reasoning and decision making on SSI (Lee et. al., 2011; Powell, et. al., 2012; Sadler & Zeidler, 2005b). With this in mind, this study sought to investigate the relation between students' emotive reasoning and their abilities to evaluate evidence and make informed decisions on contemporary scientific dilemmas. This study also investigated the extent to which students integrate scientific content knowledge during their reasoning about SSI. Results from this study showed that students from both the treatment and comparison groups used: 1) Sadness; 2) Concern; 3) Fear; 4) Grief; 5) Hope; and 6) Anger as emotions to influence how they evaluated the claim that embryonic stem cells can be used to restore rats' vision. These results corroborate the Blanchette and Richards investigation (2010), which reviewed two decades' worth of empirical studies and documented the influence of affect on judgment. Results from these studies led to the conclusion that affect influences a wide range of emotions, including anger, sadness, and anxiety which mirrors the findings from this study. These findings

also give further support to the results of other studies that have concluded that people in general rely on emotions when making decisions on issues that are contentious (Finucane et. al., 2000; Slovic, 1999), such as embryonic stem cell use.

Sadler and Zeidler (2005b) conducted a study that investigated the moral reasoning pattern of college students and found that these students used an emotive reasoning pattern that showed a “care” perspective, in which empathy and concern for the well-being of others was evident. The results of this study confirmed the findings in the current study that showed that students’ decisions to award the heart transplant were based mainly on emotions such as sympathy and empathy towards the patient who was the sickest. These results confirmed the results of other studies that have shown that people rely on emotions when making decisions on controversial issues (Finucane et al., 2000; Slovic, 1999).

In assessing what ways students integrate scientific content knowledge in the process of reasoning about SSI, results showed that students from both groups correctly used probability to determine Miriam’s chances of being infected with the defective allele for Huntington disease. Students also used probability to explain her chances of giving birth to a child with the disease. Other studies have reported association between the quality of informal reasoning and content knowledge (Sadler & Zeidler, 2005b; Venville & Dawson, 2010) and those results align with the results from this study. For example, Venville and Dawson (2010) conducted a study that explored the impact of classroom-based argumentation on high school students’ argumentation skills, informal reasoning, and conceptual understanding of genetics. These researchers reported significant improvement in the complexity and quality of the arguments generated from students in the experimental group. Venville and Dawson (2010) also reported that students in the experimental group gave more explanations, which showed rational informal reasoning.

Similarly, Sadler and Zeidler (2005b) also reported that students demonstrated evidence of rationalistic, emotive, and intuitive forms of reasoning when they were asked to negotiate and solve genetic engineering dilemmas. Although students in the current study struggled to use other scientific knowledge in their reasoning and decision making, the fact that students were able to discuss and use probability to determine Miriam's chances of being infected with the defective allele for Huntington disease, confirmed the findings from Sadler & Zeidler (2005b) and the Venville & Dawson (2010) study.

### **Implications for Practice**

The use of SSI based curriculum was utilized as the primary method of instruction over the course of the three units in two heterogeneous 9<sup>th</sup> grade Biology Honors classes, in a suburban high school from Tampa Bay, Florida. The treatment lasted for a total of 16 weeks. Research using SSI as a key pedagogical strategy over such an extended period with 9<sup>th</sup> grade biology students is not a common practice in the science education community. Therefore, this study has been useful because it presents an opportunity to the science education community to better understand the use of SSI as the key pedagogical strategy to enhance functional scientific literacy among students. A few studies highlighted the importance of developing students' morality and their moral reasoning skills, both of which are critical in developing functional scientific literacy among students (Zeidler & Sadler, 2011). These researchers reaffirm this notion by stating:

To develop functional scientific literacy among school age children, it is critical that students are given opportunities in their classroom settings to gain experiences dealing with social justice, tolerances for dissenting voices, mutual respect for cultural differences, and making evidence-based decisions with consideration on how those

actions may impact one's community and the larger environment (Zeidler & Sadler, 2011, p. 179).

Earlier studies have shown the difficulties students experienced when they are put in a position to formulate logical reasoning when evaluating evidence (Ratcliff, 1999; Sadler, 2004). In order for students to overcome these difficulties, they must be given opportunities to practice and learn how to formulate appropriate questions and generate logical reasons for those questions. The use of SSI as a key pedagogical strategy in the classroom can provide educators with the opportunity to help students garner the skills to properly formulate appropriate questions when evaluating evidence. While results from this study indicate that students do indeed use a variety of factors to evaluate evidence (observations skills, prior experiences, background knowledge, and new knowledge gained), it is also important to note that many students either said they lacked the ability to evaluate evidence or that they had never been asked before to do so. If students are to develop the necessary skills to evaluate evidence, then it is imperative that they are given opportunities to practice these skills.

In regard to students' abilities to make decisions on contentious issues that lack clear-cut solutions, studies have reported that students often have difficulties developing justifiable arguments for their claims (Molinatti, Girault, and Hammond, 2010; Zeidler, 1997). Students in general need close monitoring and guidance whenever they are asked to engage in inquiry activities on their own (Zeidler, Applebaum, & Sadler, 2011). In the absence of appropriate guidance, when students are asked to engage in inquiry activities and make decisions on issues that challenge their core beliefs, they may or may not be able to arrive at decisions through adequate rational thought. In this investigation, students in general and students in the comparison group in particular, had difficulties using their skills and knowledge to arrive at

scientific considerations and had difficulties determining who should be awarded an organ transplant. Instead, students regularly used emotive considerations in place of scientific considerations to make their decision on who should be awarded the organ transplant. In fact, there were instances where students suggested they used moral and ethical considerations to determine who should be awarded the organ transplant. Therefore it is sufficient to say, that in these instances students made no scientific inquiry into factors that may preclude someone from receiving an organ transplant. Instead, these students relied heavily on their emotions concerning the most suitable candidate for the organ transplant.

Socioscientific issues have already been established as important in improving students' science content knowledge (Applebaum, Barker, & Pinzino, 2006; Sadler, 2009; Sadler, Barab, & Scott, 2007; Walker, 2003; Zeidler & Sadler, 2011; Zohar & Nemet, 2002). Previous studies have suggested that SSI as a pedagogical strategy provides ideal opportunities for students to explore and apply ethical principles that are necessary for character development (Lee et al. 2012; Zeidler & Keefer, 2003). In this investigation, many students who were opposed to aborting a fetus that tested positive for Huntington disease suggested an abortion was not warranted, since health problems from the disease would not develop until later in life. These students believed that life is not guaranteed; thus, if a person will be able to live for fifty years, diseased or not, suffering or not, they should be given the opportunity to live. Students who were not in favor of allowing the fetus to live a life of suffering from the disease suggested that the fetus should be aborted. Students were able to use their scientific knowledge of inheritance of genetic disorders to help formulate their decisions on what should be done with the fetus that had tested positive for Huntington disease. Students also pointed to the belief that to prevent the passing of this defective gene from one generation to the next, it might be necessary to abort all



fetuses that have tested positive for the disease.

Scientific decisions cannot be made in the absence of moral reasoning and a concern for human values (Aikenhead, 2006). According to Berkowitz (2002), our values are driven by our character, which is bound by a set of psychological characteristics that collectively influence our ability and inclination to do what is right. Asking students to evaluate evidence and make decisions on contentious issues such as the use of human embryonic stem cells to repair rats' vision or should a fetus be aborted because it carries the defective allele for Huntington disease, will generally evoke moral and ethical considerations. When students are put in a position to reason and make decisions on these issues, core beliefs get ruffled and emotions arise; thus students tend to engage in emotive reasoning to assist in their decision-making. As a result, it can be expected that students use emotions that include, but are not limited to, sadness, anger, empathy, and sympathy.

### **Recommendations for Further Research**

The goal of this study was to design, implement, and evaluate a SSI curriculum that was used to examine details of students' emotive informal reasoning on their ability to evaluate evidence and make informed decisions on SSI, as well as to understand the degree to which students integrate scientific content knowledge in the process of reasoning about SSI. While results from this investigation confirmed that students rely on emotions to evaluate evidence and make decisions on contentious issues, more research is warranted to fully understand the driving force behind students' use of those emotions. Further research is also warranted to better understand the impact that emotions have on students' use of scientific content knowledge to make decisions on SSI. Both qualitative and quantitative data were collected and analyzed with the purpose of investigating the impact of emotions on students' abilities to evaluate evidence

and make decisions on contentious issues. Qualitative data was collected to understand the impact of emotions on students' abilities to integrate scientific content knowledge, when reasoning about SSI. Semi-structured interviews with larger samples of students may provide valuable insights into the effects of emotions on their abilities to evaluate evidence and make informed decisions.

### **Limitations**

Although this study revealed some significant findings, it was not without limitations. Most notably, the sample size used for this research is too small to generalize the findings. A larger sample size may have provided the opportunity to find statistically significant differences between groups, whereas this study was unable to detect such significance. Another limitation was that participants were only 9<sup>th</sup> grade students from one school; therefore, the findings cannot be generalized to suggest all students or even all 9<sup>th</sup> grade students. A limitation also resulted because the students in this investigation were being exposed to discourse on contentious issues for the first time. This may have impacted their responses to many of the questions in this investigation. Finally, semi-structured interviews were done with a very small number of students. Therefore, a rich understanding of the majority of the students' opinions on why they asked the questions they did when evaluating the claim that embryonic stem cells were used to repair rats may have not have been fully represented in this research.

### **Conclusion**

Earlier studies have shown that feelings like sympathy, empathy, compassion, and love are important components of moral judgments made by individuals whenever they are placed in positions to make informed decisions on controversial topics (Hoffman, 2000; Powell et al. 2012; Turiel, 2006; Walker, 2004; Zeidler & Sadler, 2005b; Zeidler et al. 2011). Results from

this investigation have shown that students used emotions in large part to evaluate evidence and make informed decisions on issues that were contentious. Further, results from this study show that students' emotions also affect their abilities to use scientific considerations, when making decisions on contentious issues. The results of this investigation suggested that students' emotions are tapped when they are put in positions to evaluate evidence and make decisions on issues that challenge their consciences and values. For students who do not support abortion, asking them to determine if a fetus that carries the defective alleles for Huntington disease should be aborted will surely cause them to express different types of emotions. The same is true for students who support abortion. As reported in this investigation, students relied heavily on emotions throughout this study as they provided answers to many questions that challenged their morality and core beliefs.

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## APPENDICES

### Appendix A: Introduction of SSI to Teachers

Slide 1



## **SOCIOSCIENTIFIC ISSUES TO ACHIEVE SCIENCE EDUCATIONAL GOALS**

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**Introduction to Socioscientific Issues**

Slide 2



## **Goals of Science Education**

### **Questions:**

1. In your views, what should the goals of science education be?
2. How do we achieve these goals?

## Appendix A (continued)

Slide 3

### Where are we?

#### Developing a Scientifically Literate Population

1. Scientific Literacy

#### Problems Associated with Scientific Literacy

1. Science education community does not agree on what constitutes scientific literacy.
2. There is no clear cut definition of what is scientific literacy (DeBoer, 2000; Solomon, 1998; Durant, 1994; Hunt & Miller, 2000; Roberts, 2007).

Slide 4

### Characterizing the Diversity of Views on Scientific Literacy (SL)

#### Vision I:

This gives meaning of SL by looking inward at the canon of orthodox natural science, that is, the products and processes of science itself. At the extreme, this approach envisions literacy (or, perhaps, thorough knowledgeability) within science...

#### Vision II:

Derives its meaning from the character of situations with a scientific component, situations that students are likely to encounter a citizens. At the extreme, this vision can be called literacy (again, read thorough knowledgeability) about science-related situations in which considerations other than science are important.

(Roberts, 2007, p. 730).

## Appendix A (continued)

Slide 5

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### Question

- What are some of the different situations that students are likely to encounter a citizens on which they will be required to make informed decisions?

Slide 6

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### Vision II and its Influence of Developing Scientifically Literate Individuals

- Vision II when adopted effectively give students opportunities to garner the abilities to confront, negotiate, and make decisions in everyday situations that involve science (Sadler, 2011; Eastwood, Schlegel, & Cook, 2011; Zeidler, Applebaum, & Sadler, 2011; Sadler, 2011).

Slide 7

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### Socioscientific Issues

- As an educational construct gives students opportunities to confront some of the issues and gain experiences negotiating their inherent complexities.
- Socioscientific issues (SSI) are controversial social issues with with conceptual and/or procedural links to science (Sadler, 2004).
- SSI are open-ended problems without clear-cut solutions, that tend to have multiple plausible solutions (Sadler, 2004).

## Appendix A (continued)

Slide 8

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### **Socioscientific Units**

#### **Sample SSI Unit Presented to Teachers:**

- Genetic Disorders

Slide 9

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### **Meeting the Classes**

- I will present a sample SSI unit to students from both experimental classes with the teachers in an observational role.
- Debrief with teachers-What went right what went wrong?
- Teachers will then teach their students 1 SSI unit each before starting this study. I will observe these units to give feedbacks to teachers.

## **Appendix B. Teacher Training adopted from Zeidler, Applebaum, & Sadler, 2011**

### Development of an SSI Unit

1. Topic/Subject Matter Introduction
  - a. Magazine headlines, articles, and advertisements
  - b. YouTube video presentation of controversy associated with subject matter
  - c. Photographs
  - d. Models
  - e. Other media formats
2. Challenging Core Beliefs
  - a. Contentious questions that “attacks” commonly held beliefs
  - b. Challenging “Common Knowledge” of subject matter
  - c. Misconceptions
3. Formal Instruction
  - a. Anatomy
  - b. Physiology
  - c. Related science information
4. Group Activity
  - a. Development of related, but unconventional topic/subject matter questions
  - b. Individual investigation of data and evidence
  - c. Small group negotiation of evidence
  - d. Group presentation of consensus understanding
5. Develop Contextual Questions
  - a. Fundamental science concepts of subject matter
  - b. Defeating misconceptions
  - c. Contemporary claims regarding subject matter
6. Class Discussion
  - a. Evidence reliability of contemporary content
  - b. Importance of specific knowledge for informal decision-making
7. Teacher Reiteration of Content/Subject Matter
  - a. Essential learning of subject matter content
  - b. Purpose and relevance of specific knowledge
  - c. Application of content knowledge
  - d. Negotiating contemporary issues

## **Appendix B (continued)**

8. Knowledge and Reasoning Assessments
  - a. Group presentations
  - b. Posters
  - c. Argumentation/debate activities
  - d. Paper production of selected topics
  - e. Written tests of subject matter



## **Appendix C: 2012-2013 Biology Timeline**

### Semester 1

Unit 1—Properties of Life and Chemistry Chapters 1-2

Unit 2—Cell Structure and Function Chapter 7

Unit 3—Cellular Energy Chapters 8-9

Unit 4—Ecology Chapters 3-6

Unit 5—Cellular Reproduction, DNA and Protein Synthesis Chapters 10 and 13

### Semester 2

Unit 6—Genetics Chapter 11-12 and 14-15

Unit 7—Evolution Chapters 16, 17, 19, and 26

Unit 8—Classification Chapters 20, 21, 22-24, 25, and 27-29

Unit 9—Human Biology Chapters 30-35

## Appendix D. Pre/Posttests Evidence Evaluation Instrument

Reprinted with permission from Health & Medical News Weekly, September 12, 2012

### RESEARCH NEWS

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#### STEM CELL TREATMENTS RESTORE VISION IN RATS

Millions of Americans have some type of vision disorder, and researchers haven't found a perfect solution to restore this valuable sense.

However, a team of researchers reported in the Journal of Nature that they have used embryonic stem cells to restore sight in impaired rats. But, these researchers have cautioned that more investigation is necessary before the technology can move to humans.

In this investigation, the researchers used a drug to chemically damage the lens and optic nerve in rats, creating a condition they called lens-optic maculation.

To investigate if the sight of these animals could be brought back, researchers used human embryonic stem cells, and applied biological factors to them that the human body would naturally use in its development. This coaxed them into becoming optic progenitor cells, which can differentiate into cells that function as photoreceptors.

These researchers then injected the progenitor cells into the rats to see if they would restore sight function. The rats in this investigation were then able to run through a maze to find the light source.

These researchers have suggested that plans are already in place to have this treatment available to human by next year.

In the news brief above, please pay special attention to the underline conclusion as you respond to the following five items in section 1 and the request in section 2.

Please use the scale below each question to assign a number value that indicates your response to the question.

## Appendix D (continued)

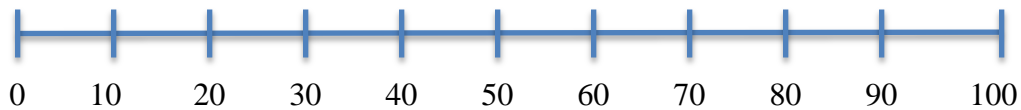
### Section 1

Please select a number from each continuum scale that represents your choice. If you think the use of a number that falls between the increments of 10 better reflect your views, please indicate that number on the continuum scale. Please note there are no right or wrong answers to these questions.

1. How likely do you think it is that the underlined conclusion is true?

Absolutely  
Untrue

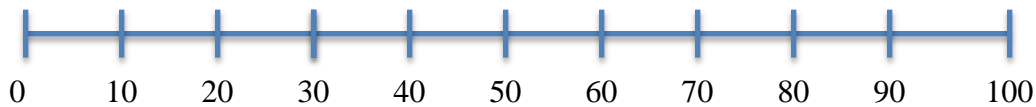
Absolutely  
True



2. How much experience with or knowledge of the general topic do you have?

No  
Knowledge  
Or  
Experience

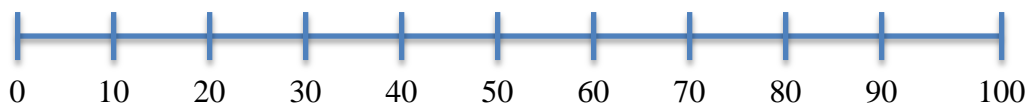
Advanced  
Knowledge  
and/or  
Experience



3. How interested are you in the general topic of the underlined conclusion?

No  
Interest

Extremely  
Interested

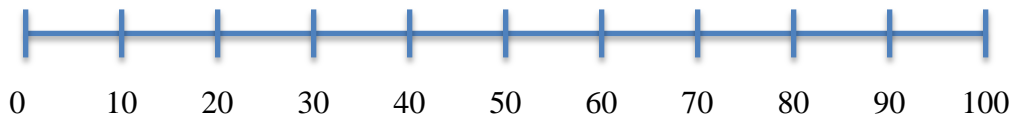


**Appendix D (continued)**

4. Please indicate the extent to which you used scientific knowledge to judge the conclusion.

No  
Scientific  
Knowledge  
Used

Extreme  
use of  
Scientific  
Knowledge



5. Please indicate the extent to which you used emotions to judge the conclusion.

No  
Emotions

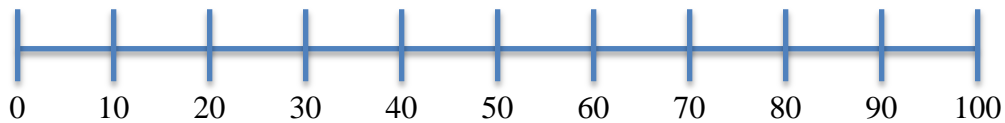
Extreme  
Use of  
Emotions



6. In general, on a scale of 0-100, how would you rate your ability to evaluate evidence?

No Ability  
To Evaluate  
Evidence

Well  
Rounded  
Ability to  
Evaluate  
Evidence



## Appendix D (continued)

7. Please provide a brief explanation as to why you rated your ability to evaluate evidence the way you did in question 6.

### Section 2

Suppose that the underlined conclusion is very important to you and that you must determine whether it is true. Please generate a list of as many questions as you can that you would want to have answered before you decide whether the conclusion made by members of the research team in Health and Medical News Weekly is true. Also, for each question you list, please indicate how you think the answer to that question would help you to evaluate the conclusion in the news brief. In addition, please indicate the types of emotions you may have experienced that prompted you to ask such question(s).

1. What is the most important question you would want answered?
2. How would an answer to this question help you to decide whether the underlined conclusion in the news brief is true?
3. What types of emotions, if any, did you experience with this question?
4. If you did experience any emotions in #3 above, did those emotions influence how you evaluated the claim? Please explain.
5. What is the second most important question you would want answered?
6. How would an answer to this question help you to decide whether the underlined conclusion in the news brief is true?
7. What types of emotions, if any, did you experience with this question?
8. If you did experience any emotions in #7 above, did those emotions influence how you evaluated the claim? Please explain.
9. What is the third most important question you would want answered?
10. How would an answer to this question help you to decide whether the underlined conclusion in the news brief is true?
11. What types of emotions, if any, did you experience with this question?
12. If you did experience any emotions in #11 above, did those emotions influence how you evaluated the claim? Please explain.

## **Appendix D (continued)**

### Section 3

#### Interview Protocol

1. Why did you ask such questions first? Second? Third?
2. Can you tell me about any emotions that influence such question(s)?
3. What is the significance of these emotions?
4. Can you see any potential benefits from you using these emotions to evaluate the claim?
5. Can you see any potential problems from you using these emotions to evaluate the claim?

## **Appendix E. Pre/Posttests *Decisions about Socioscientific Issues (Part 1)***

*Directions - Please read the following story and related information, and then respond to the questions that follow:*

*A new hospital has been built in a city close to where you live. An entire wing of the hospital has been built with the intention of hiring teams of doctors, nurses and support staff that specializes in organ transplantation, such as hearts, eyes, kidneys, lungs, pancreas, bones, cornea, tendons, veins and skin. Many of these operations are very expensive and there is a shortage of donors.*

*As a member of your community, you have been asked to be a member of public review committee to help create guidelines and policy for how the transplant program should operate. Below are several issues that could be used to determine which patients may receive an organ transplant. The following is list of seven issues (A – G) has a short explanation that you may or may not consider as being very important in making a decision about organ allocation. Please read the list below:*

*Given task: A rank ordering of factors to determine who may receive an organ transplant. The following is a list of seven factors with explanations that you may or may not consider as being very important in making a decision about organ allocation:*

### **a) Selection of the sickest patient.**

An offer of an organ is made to the patient most likely to die without it.

### **b) Selection of the patient most likely to benefit based on medical or other criteria.**

The major emphasis is placed on guaranteeing that transplanted organ and patient are able to survive for the longest time.

### **c) Selection of the patient on the waiting list for the longest period.**

Priority is given to the patient on the basis of length of prior waiting period.

### **d) All patients on the waiting list should have an equal chance of selection.**

Patients are selected for transplantation by a random ballot.

**e) Selection of patients on the basis of their importance for the well-being of others.** Potential patient given priority if others (such as a young family or a community leader) are dependent upon him or her for support.

### **f) Preference in selection to patients who have previously had one or more transplants.**

Patient who has already been a transplant recipient but who had the misfortune of a failed graft is given priority.

### **g) Capacity of the patient to pay.**

Patient may gain quicker entry to a program because of ability to pay thereby adding financial resources to that program.

## Appendix E (continued)

1. Please rank order below these factors from what you believe should be the most important to the least important reasons to consider in making a decision about who should receive a transplant, by placing the letter next to each number.

Most Important      1      2      3      4      5      6      7      Least Important

2. Please write a justification for your first choice (#1) and second choice (#2) describing the main reasons for your selections. (Use the back of this paper to write on if you need more room.)

### ***Decisions about Socioscientific Issues (Part II)***

Answer the following questions below. Please note there are no right or wrong answers to these questions.

1. What scientific considerations, if any, may have influenced your decisions to rank the patients for a heart transplant the way you did?
2. Why did you choose such scientific considerations?
3. Is there any factor you believe to be very important in making this decision not listed among your choices? If so, briefly describe the factor and why it is important.
4. What emotional considerations, if any, may have influenced your decisions to rank the patients for a heart transplant the way you did?
5. What are your reasons for considering such emotional considerations?



## Appendix F: RQ 3 Pre-test Qualitative Questionnaire

### Huntington Disease—a clicking time bomb

Huntington Disease is a dominant genetic trait. Carriers of the affected allele will develop symptoms at some stage of their life. The typical age for onset of symptoms is between 35 and 45. Sick people develop involuntary tremors of the limbs and personality alterations: outbursts of crying, unexplained anger, memory loss and sometimes-schizophrenic behavior.

Severity of symptoms at various stages of the illness differs from one patient to another. It is a fatal disease. Death occurs around the age of 50. In their final years patients are in a vegetative state.

***Please note:*** *Huntington is a dominant (and not recessive) trait. Still, patients are symptoms free until adulthood.*

### **Case # 1**

*Discuss the following dilemma in small groups. Each student should first clarify his/her own position and then discuss it with his/her peers. Please remember that the purpose of the discussion is to elucidate the issue by listening to each other and not to conduct a debate in which each participant tries to win.*

Grandpa Henry became sick with Huntington disease at the age of 45. His condition deteriorated from day to day with much agony. His son, Jonathan, took care of him with great affection and sadly followed the decline in his condition. Grandpa Henry passed away when he was 51 years old.

Miriam, Henry's granddaughter was witness to his painful process. Miriam is now 22 years old and is about to get married. She would like to be tested in order to find out whether or not she is a carrier of the disease. She wants to be able to decide how to plan her future. Should she invest several years in higher education, acquiring a profitable profession, or should she travel around the world in order to enjoy the few good years she still has left. Should she have children, or perhaps give up that experience.

***Remember our rule:*** *Before we can start thinking about ethical aspects of a dilemma, we must first understand the biological facts!*

- 1. Because Huntington is a rare trait we assume that neither Grandma (Grandpa Henry's wife) nor Miriam's mother are carriers. According to the information you have, what are the chances that Miriam is a carrier.*

Jonathan, Miriam's father, does not want to find out whether or not he is a carrier. He believes that if he were to discover that he will eventually become sick, this knowledge would destroy whatever good years he may still have. Jonathan therefore is opposed to Miriam getting tested.

## Appendix F (continued)

2. If it turns out that Miriam is a carrier, what are her chances of giving birth to an affected child?
3. The two questions you should discuss are: What should Miriam do? Why should she do it?

To facilitate a structural discussion, please observe the following instructions:

- a. Write the two practical options that Miriam faces. Each of these two options corresponds to one of two opinions, or, in the language of argumentation to one of two statements or conclusions. As you probably remember, statements must be justified by reasons.
- b. Write down as many justifications for the two statements as you can think of in your group.

## Appendix G: RQ 3 Post-test Qualitative Questionnaire

### Case # 2:

Gila is a 28-year-old woman who was recently married. Gila's father is 50 years old. He has been sick with Huntington for the past five years. Initially, Gila did not wish to be tested in order to find out whether or not she carries the gene for Huntington disease. However, now that she became pregnant, she felt that she must find out whether her fetus is a carrier. The test showed that her fetus is indeed a carrier of the allele for Huntington disease.

Should Gila abort her fetus?

*Before discussing this issue in your group, please answer individually the following three questions:*

- 1. When abortion is considered, is it significant that in the case of Huntington disease a person may live a normal life until the age of 50? (Mean life expectancy is 75 years. How much of a difference do 25 years make?). Please explain.*
- 2. Do you think there is a difference between such a disease and other diseases in which the onset of symptoms begins at birth? Please explain.*
- 3. Is the expected suffering a reason to decide upon abortion? Please explain.*

Now let us discuss the question: What should Gila do?

- First, let each member of your group express his or her opinions and their justifications. Listen to each other's opinions. At this stage please express only what you think and do not comment upon what your friends have said.*
- After all members of your group have presented their opinions, you may agree about your views.*
- To conclude, please write down your final conclusion and the justification it is based upon (individually).*

**Appendix H: RQ 1 Coding for Evaluation of Evidence Coding adopted and modified from Korpan et al. 1994**

<b>Social Context Request—factors that may influence quality and validity of data</b>			
Criterion	Pre Score	Post Score	Description
People	2	2	Two or more valid questions about people (i.e., researchers and interested parties)
	1	1	One valid question of people
	0	0	No valid question of people
Source of Information	2	2	Two or more valid questions about sources of information
	1	1	One valid question about source of information
	0	0	No valid question about source of information
Funding Issues	2	2	Two or more valid questions about funding issues
	1	1	One valid question about funding issues
	0	0	No valid question about funding issues
Identification of Research Institution	2	2	Two or more valid questions about research institution
	1	1	One valid question about research institution
	0	0	No valid question about research institution
<b>Agent Request—the thing that produced the outcome</b>			
Criterion	Pre Score	Post Score	Description
Agent Identification	2	2	Two or more valid questions that helps to get information about the agent
	1	1	One valid questions that help to get information about agent
	0	0	No valid questions that help to get information about the agent
Agent Mechanisms	2	2	Two or more valid questions that help to understand the mechanism, effects or side effects of agent
	1	1	One valid questions that help to understand the mechanism, effects or side effects of agent
	0	0	No valid questions that help to understand the mechanism, effects or side effects of agent
Alternative Agent	2	2	Two or more valid questions that helps to get information about other agent
	1	1	One valid questions that help to get information about other agent
	0	0	No valid questions that help to get information about other agent
<b>Methods</b>			
Criterion	Pre Score	Post Score	Description

Design	2	2	Two or more valid questions about design used to conduct the research
	1	1	One valid questions about the design used to conduct the research
	0	0	No valid questions about the design used to conduct the research
Procedure	2	2	Two or more valid questions about procedure used to conduct the research
	1	1	One valid questions about the procedure used to conduct the research
	0	0	No valid questions about the procedure used to conduct the research
Subjects	2	2	Two or more valid questions about subjects in the research
	1	1	One valid questions about the subjects in the research
	0	0	No valid questions about the subjects in the research

Appendix H (continued)

Data/Statistics			
Criterion	Pre Score	Post Score	Description
Statistics	2	2	Two or more valid questions about the statistics used to analyze data
	1	1	One valid question about the statistics used to analyze data
	0	0	No One valid question about the statistics used to analyze data
Relevance of the Agent/Research on the Agent			
Criterion	Pre Score	Post Score	Description
Generalizability	2	2	Two or more questions about whether the effects observed in reported research would occur outside this particular research
	1	1	One question about whether the effects observed in reported research would occur outside this particular research
	0	0	No question about whether the effects observed in reported research would occur outside this particular research
Practicality	2	2	Two or more questions about the practicality of using the findings of the research in the real world.
	1	1	One question about the practicality of using the findings of the research in the real world.
	0	0	No question about the practicality of using the findings of the research in the real world.
Recency of Research	2	2	Two or more questions about how current the research is
	1	1	One question about how current the research is

	0	0	No question about how current the research is
Research Findings/Conclusion	2	2	Two or more questions about the importance of the research findings to an audience or the general public
	1	1	One question about the importance of the research findings to an audience or the general public
	0	0	No question about the importance of the research findings to an audience or the general public
Audience Familiarity with the Agent/Research Findings	2	2	Two or more requests about how well-known the agent or research is to either researchers or to the general public
	1	1	One requests about how well-known the agent or research is to either researchers or to the general public
	0	0	No requests about how well-known the agent or research is to either researchers or to the general public
<b>Related Research</b>			
Criterion	Pre Score	Post Score	Description
Similar Domain of Study	2	2	Two or more requests about whether other studies have been done in the same domain and/or the number of other studies that have been done in the domain
	1	1	One request about whether other studies have been done in the same domain and/or the number of other studies that have been done in the domain
	0	0	No request about whether other studies have been done in the same domain and/or the number of other studies that have been done in the domain

## **Appendix I. Scoring Rubric for Justifications on Decisions about Socioscientific Issues**

### **Developed by Zeidler et al. (2011)**

- Decisions about Socioscientific Issues (Part 1): Item 2 (responses 2 and 3).

0 = one response attempted (short answer or full sentence(s)).

1 = response includes justification, evidence or example.

2 = response has justification, evidence or example that exhibits internally consistent logic, may also include more than one example.

3 = response has all features of 2 and 3, (4 may or may not be present), and consists of novel and creative ideas that go beyond the data provided, OR exhibits awareness of multiple viewpoints.

Note: Each of the 2 possible responses a student can write will be scored in this manner. Thus, responding fully to only one question would earn them a total of 3, while responding fully to both questions would earn them the highest score of 6 points.

### **• Decisions about Socioscientific Issues (Part 2): Item 3 (3 potential responses for Scientific Questions)**

0 = response does *not* exhibit a scientific basis in nature.

1 = one response attempted, some science content attempted, but justification absent, or not clear.

2 = response includes non-specific or general use of scientific content, with justification.

3 = response includes specific use (contextualized) of scientific content with justification.

**Note:** Each of the 3 possible questions a student can pose will be scored in this manner. Thus, responding fully to only one question would earn them a total of 3 points, while responding fully to all 3 questions would earn them the highest score of 9 points.

## Appendix J. Justification of Decision-making Questionnaire Coding

<b>Criterion</b>	<b>PRE Score</b>	<b>POST Score</b>	<b>Description</b>
Justifications (Zohar and Nemet, 2002)	2	2	Two or more valid justifications
	1	1	One valid justification
	0	0	No justifications offered

The above instrument was designed to measure argumentation skill based on specific criteria: number of justifications, the structure of argumentation, and subject matter knowledge. Zohar and Nemet (2002) provided the scoring for the structure of arguments. These researchers used a range of scores for number of justifications using a range of 0-2 points (0 = no justification, 1 = one valid justification, 2 = two or more justifications) and 0-2 points for the structure of argument (0 = no argument presented, 1 = a simple argument or conclusion supported by at least one justification, 2 = complex argument with justification which is supported by another reason).





December 21, 2012

Wardell Powell, M.S.  
Secondary Education 2116  
Shelbourne Court  
Wesley Chapel, FL 33543

RE: **Expedited Approval** for Initial Review  
IRB#: Pro00010333

Title: The Effects of Emotive Reasoning on Secondary School Students' Decision-Making in the Context of Socioscientific Issues

Dear Mr. Powell:

On 12/21/2012 the Institutional Review Board (IRB) reviewed and **APPROVED** the above referenced protocol. Please note that your approval for this study will expire on 12/21/2013.

Approved Items:

**Protocol Document:**

[Research Protocol](#)

**Consent/Assent Documents:**

[Assent Form.pdf](#)

[Parent Permission.pdf](#)

**Please use only the official, IRB- stamped consent/assent document(s) found under the "Attachment Tab" in the recruitment of participants.** Please note that these documents are only valid during the approval period indicated on the stamped document.

This study involves children; approved under 45CFR46.404: Research not involving greater than minimal risk. It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21 CFR 56.110. The research proposed in this study is categorized under the following expedited review categories:

(5) Research involving materials (data, documents, records, or specimens) that have been

collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis).

- (6) Collection of data from voice, video, digital, or image recordings made for research purposes.
- (7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval by an amendment.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

A handwritten signature in cursive script that reads "John A. Schinka, Ph.D.".

John A. Schinka, Ph.D., Chairperson  
USF Institutional Review Board