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UNIVERSITY OF CALIFORNIA, SAN DIEGO

SAN DIEGO STATE UNIVERSITY

The Use of Self-Determination Theory to Foster Environmental Motivation  
in an Environmental Biology Course

A dissertation submitted in partial satisfaction of the  
requirements for the degree Doctor of Philosophy

in

Mathematics and Science Education

by

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Professor Joanne Lobato  
Professor Eric Riggs

2007



The Dissertation of Rebekka L. Darner is approved, and it is acceptable in quality and form for publication on microfilm:

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Chair

University of California, San Diego

San Diego State University

2007

## DEDICATION

I dedicate this dissertation to my husband, Angelo.  
Together we have built a life that surpasses my most ambitious dreams.

## EPIGRAPH

The human race is challenged more than ever before to demonstrate our mastery,  
not over nature but of ourselves.

*Rachel Carson*

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## ABSTRACT OF THE DISSERTATION

The Use of Self-Determination Theory to Foster Environmental Motivation  
in an Environmental Biology Course

by

Rebekka L. Darner

Doctor of Philosophy in Mathematics and Science Education

University of California, San Diego, 2007  
San Diego State University, 2007

Professor Alexander Chizhik, Chair

A scientifically literate person is one who understands the nature of science, its processes, products, and their appropriate application to decision-making contexts. The impetus to make informed decisions about environmental issues is environmental motivation. I examined students' environmental motivation, its relationship to scientific knowledge, and how environmental motivation can be fostered in a science classroom. This study took place in a college-level environmental biology course in which the instructor attempted to support students' basic psychological needs, as defined by self-determination theory (SDT). The first question was to what extent does an SDT-guided environmental biology course differ from a non-SDT-guided course in the degree to which it fostered self-determined motivation toward the environment. The

administration of a well-validated scale to two sections before, after, and six months following the end of the course indicated that SDT-guided instruction is a plausible way to foster environmental motivation in the classroom. The second question was what are the multiple influences on fostering self-determined motivation toward the environment in an SDT-guided course. Path analysis indicated that environmental motivation can be partially accomplished in an environmental biology course by conveying to students that they are cared for, are connected to others, and can trust others while solving environmental problems. The third question sought to characterize students' scientific conceptualizations as they solve environmental problems and the extent to which their conceptualizations relate to the satisfaction of their need for competence. Students were videotaped during in-class problem-solving, after which stimulated-recall interviews were conducted. Grounded theory and an established coding scheme were combined to analyze these data, which resulted in three grounded hypotheses about what characterizes students' scientific knowledge when they feel highly competent about solving environmental problems. The final research question sought to identify which classroom features students cite when they indicate that their basic psychological needs are being fulfilled or undermined. Grounded analysis resulted in seven features of the instructional environment. This dissertation marks the first application of SDT to a formal environmental education setting in which a goal was to foster environmental motivation. Several research prospects and a learning cycle based on findings are proposed.

## CHAPTER 1: INTRODUCTION

In this chapter, I will provide a rationale for why this study is needed.

First, I will briefly state why research is needed to motivate citizens toward pro-environmental behavior. I will summarize research efforts to date in attempting to do so and indicate shortcomings in those approaches. I will then propose an alternative to these approaches and present my specific research questions. For each research question, I will briefly describe the methodology that was undertaken to answer each question and how each question will likely contribute to the field.

### *Statement of Problem*

The industrial revolution brought many changes to our world, and perhaps the most substantial of those was environmental change. Environmental change in itself is not problematic; indeed, Earth has been continually changing for millennia. Human actions, however, have caused rapid, far-reaching, and unprecedented environmental change, leading to a multi-faceted problem that includes air and water pollution, biodiversity depletion, waste production, resource use and allocation, environmental injustice, and human population growth (Keller, 2000; Kump, Kasting & Crane, 2004; Smith, 1996; *Appendix I: The Global Environmental Dilemma*). Plausible solutions to these problems are rooted in science. Through scientific understanding, it is possible to analyze our roles in ecological and sociological systems. Such analysis allows us to specify which behavioral changes are likely to be successful in solving environmental



problems. If science educators were to successfully help students develop scientific understanding and if students were then able to successfully use that understanding to develop plausible environmental solutions, an educational solution to our environmental problem will still not have been achieved. This is because even if someone possesses deep scientific understanding and is able to devise plausible solutions for environmental problems, they still must possess an impetus toward behavioral change in order for those plausible solutions to ever be realized. The field of environmental education (EE) has been studying how to foster this impetus for about three decades (DeYoung, 2000; Hines, Hungerford, & Tomera, 1987; Leeming et al., 1993; UNESCO-UNEP, 1976; 1978).

*EE Attempts to Induce Behavior Change*

In the mid-1980s, Hines, Hungerford, and Tomera (1986-1987) published a pioneering article that proposed a behavioral change model (Figure 1) that recognized the complexities of human behavior and psychology. Up until that point, the dominant behavior change model posited a linear relationship between knowledge, attitude, and behavior (Hines, Hungerford, & Tomera, 1986-1987; Hungerford & Volk, 1990). Researchers quickly learned that even people who possess pro-environmental attitudes seldom behave in accordance with those attitudes (De Young, 2000; Finger, 1994; Jurin, 1995; Lane, 2000; Shultz, Oskamp, & Mainieri, 1995; Pelletier, et al., 1998; Stets & Biga, 2003). Therefore, Hines, Hungerford, and Tomera's (1986-1987) article was a critical contribution in which they introduced to the field of EE several psychological constructs that

have been shown to be predictive of pro-environmental behaviors. Their model has dominated research in EE since its publication, and while it has certainly progressed our understanding, no approach is without flaws.

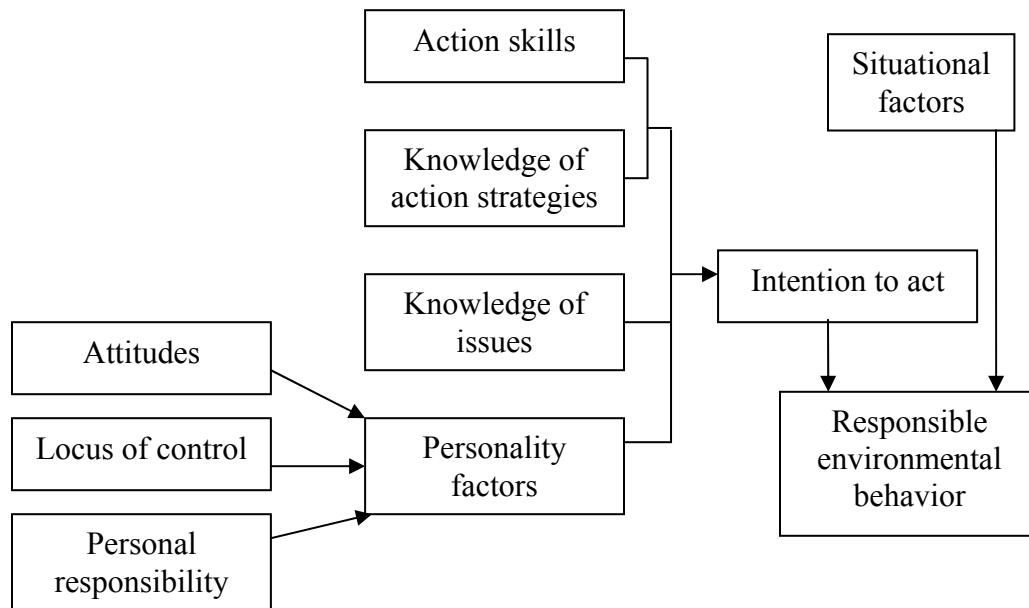


Figure 1. Early proposed model of responsible environmental behavior (adapted from Hines, Hungerford, & Tomera, 1986-1987).

The line of research inspired by Hines, Hungerford, and Tomera's (1986-1987) model has two shortcomings that must be addressed if the field of EE is going to continue to progress toward motivating responsible environmental behavior. First, intent to act has become a well-accepted proxy for behavioral change (Hwang, Kim, & Jeng, 2000). Researchers will often quantify one's intention to act in pro-environmental ways and use this measurement as the ultimate outcome variable. Because someone may possess an intention to act but never do so, researchers can overestimate subjects' actual pro-environmental

behavior. This research practice is understandable given how difficult it is to measure someone's actual pro-environmental behavior. A more worrisome issue, however, is that intent to act is not differentiated, as if it is assumed that if someone has an intent to act, it does not matter why someone intends to do so. Two people may have the same intention to recycle a plastic bottle, but one may intend to do so for the cash refund, while the other does it because protecting the environment through recycling is in line with his/her value system. EE researchers treat these distinct situations equally when they regard intent to act as a primary goal of EE instruction.

A second shortcoming of EE research inspired by Hines, Hungerford, and Tomera (1986-1987) is that it operates from a positivist perspective, seeking "to control (through prediction and reinforcement) certain ways of thinking and acting valued by the researchers" (Robottom & Hart, 1995, p. 7). In other words, the human mind is seen as a black box that reacts to stimuli to yield predictable behaviors (i.e., behaviorist), and researchers are able to directly observe these stimuli and behaviors and be objective and unbiased during analysis (i.e., positivist). This perspective is reflected in the classical experimental research designs predominantly used to conduct EE research (Robottom & Hart, 1995; De Young, 2000). For example, locus of control, a central element in the Hines, Hungerford, and Tomera's model (1986-1987; Figure 1), is defined in this line of research as "an individual's belief in being reinforced for a certain behavior" (Hungerford & Volk, 1990, p.12), thereby reflecting EE's behaviorist stance.

Behavior change is indeed a major goal of EE, so it is understandable that behaviorism, which emphasizes behavior change, has been the frame in which research has been conducted. However, behavior is rooted in culture (Vygotsky, 1978), and people's cultural ways of understanding, which includes scientific understanding, must give rise to their roles in environmental solutions in order for those solutions to be effective and long lasting (DeYoung, 2000; Robottom & Hart, 1995). Therefore, efforts to change behavior must embrace culture rather than attempt to factor it out of the equation. This not only has broad implications for EE practice; it also implies that EE researchers need to embrace methodologies that abandon the positivist tradition and allow them to consider the role that culture plays in analyzing data and determining appropriate pro-environmental behaviors.

#### *An Alternative Attempt at Behavior Change*

Social psychologists have also been attempting to address the issue of how to induce behavior change toward pro-environmental behaviors through Ryan and Deci's self-determination theory of motivation (SDT; Ryan & Deci, 2002). In order to understand what SDT can contribute to EE research, let us return to the example of the two people with the same intention to recycle a plastic bottle. SDT research has shown that when someone intends to act pro-environmentally because of some external force, such as to receive a cash refund, the person is less likely to maintain that action when the external force is no longer present (Pelletier, 2002). In other words, when the person recycling for the cash refund

goes on vacation to a place that does not offer such a refund or if the refund program ceases, the person no longer possesses the impetus to recycle. According to SDT, this person is extrinsically motivated toward pro-environmental behaviors because the action is performed “because it leads to a separable outcome” (Ryan & Deci, 2000a, p. 55). SDT proposes a continuum between extrinsic and intrinsic motivation (Figure 2). Intrinsic motivation is an impetus toward a behavior “because it is inherently interesting or enjoyable” (Ryan & Deci, 2000a, p. 55). Although it is possible that someone recycles because s/he finds it inherently enjoyable, it is more likely that the action of recycling coheres with the person’s value system (Osbaldiston & Sheldon, 2003), as is the case with the second person in our example. According to SDT, this person recycles because his/her behavior is controlled through integrated regulation, and s/he experiences self-determined motivation, according to the SDT continuum (Figure 2). Such a person’s actions are regulated by his/her value system, which has integrated pro-environmental values that were once external but are currently seen as arising within the self (Ryan, 1995). According to SDT research, this person is much more likely to continue recycling if it becomes more difficult (Green-Demers, Pelletier, & Ménard, 1997) and less likely to experience resentment when recycling, which is common when someone is extrinsically motivated toward a behavior (Ryan & Deci, 2000a). This implies that when individuals experience this type of motivation toward the environment, pro-environmental behaviors will be longer lasting, and thus more effective, because they do not breed ill feelings.

Therefore, the question becomes how can individuals come to integrate pro-environmental values into their value systems so that pro-environmental behaviors are seen as arising from within the self and are thus self-determined?

Motivation	Amotivation	Extrinsic				Intrinsic
Regulation		External	Introjected	Identified	Integrated	Intrinsic
Behavior	Nonself-determined				Self-determined	

Figure 2. The Self-Determination Continuum (adapted from Ryan & Deci, 2002).

Research across numerous settings has produced a general answer to the question of how people come to experience self-determination. People feel more self-determined when their basic psychological needs are fulfilled (Ryan & Deci, 2002). According to SDT, all humans have three basic psychological needs: the needs for competence, autonomy, and relatedness. The need for competence refers to a person's need to feel like his/her actions are effective in bringing about desired outcomes (Ryan & Deci, 2002; Deci & Ryan, 1990). The need for autonomy refers to a person's need to feel like his/her actions originate from the self rather than some external force (Ryan & Deci, 2002; Deci & Ryan, 1990). Finally, the need for relatedness refers to a person's need to feel a sense of belonging in a social group, as if his/her input into the group is needed and appreciated by others in the group (Ryan & Deci, 2002; Deci & Ryan, 1990). Preliminary research indicates that when these needs are satisfied in particular

contexts, individuals become more self-determined to behave pro-environmentally (Pelletier, 2002).

Although this line of research obviously has interesting implications for EE, shortcomings exist here too. Most importantly, SDT has never been used to guide research in the EE setting. Therefore, we are unaware of what specific aspects of EE instruction support students' basic psychological needs so that they become self-determined toward pro-environmental behaviors. Secondly, researchers applying SDT to motivation toward pro-environmental behaviors outside the EE setting claim that individuals' need for competence is supported by non-coercively providing "information about specific actions to solve a problem" (Pelletier, 2002, p. 221). To understand why this is problematic, let us explore Deci and Ryan's (1990, p. 243) definition of the need for competence: "The need for competence encompasses people's strivings to control outcomes and to experience effectance; in other words to understand the instrumentalities that lead to desired outcomes and to be able to reliably affect those instrumentalities." Non-coercively providing information about specific actions sounds much like telling as a mode of teaching. Telling as the sole teaching action is undesirable because it can minimize instructors' opportunities to learn students' ideas, focus too heavily on procedure rather than explanation, portray the instructor as an authority of knowledge, minimize students' opportunities to engage in problems, and communicate that there is only one acceptable solution (Lobato, Clarke, & Ellis, 2005). In other words, telling students about actions, even non-coercively,

probably does not help learners understand why actions may be beneficial and will not likely cultivate skills that allow them to reason about new environmental problems. Therefore, students are unlikely to “understand the instrumentalities that lead to desired outcomes” (Deci & Ryan, 1990, p. 243). Furthermore, simply providing information to learners without fostering understanding compels learners to rely on providers of information (e.g., teachers) for telling them what actions should be taken. In this scenario, the learner may perceive the source of the action as external (i.e., from the teacher), rather originating from oneself. Thus, such an approach could potentially undermine two basic psychological needs – competence and autonomy, and therefore fail to lead to self-determined motivation toward pro-environmental behaviors.

It seems that in order to support students’ basic psychological needs, research on students’ scientific understanding should be put to use because this type of understanding is likely to allow students to better understand why their actions are effective. This claim is made with a caveat; if we want students to understand why their actions are effective in Earth systems, then we must recognize humans as players in those systems, and students must see themselves as active agents within those systems. Unfortunately, science is usually taught in such a way that separates humans from the ecosystems under study. If science education is going to be effective in partially supporting students’ need for competence, this deficient view of ecosystems must be abandoned in favor of a



human-inclusive conception of ecosystems in which humans are active players capable of bringing about their desired environmental outcomes.

### *Statement of Purpose*

Currently, environmental educators are in a challenging but exciting situation. EE research has become somewhat insular due to a narrow line of inquiry almost entirely inspired by a single model of behavior change (Hines, Hungerford, & Tomera, 1986-1987; Figure 1). The field is dominated by a positivist view of research that is limiting the research questions being asked, the methodologies being utilized, and the relevance and usefulness of findings. Application of SDT to EE research has the potential to resolve the first of these issues, but it too has its limitations. Specifically, how researchers have characterized competence support regarding pro-environmental behaviors (Pelletier, 2002) does not seem to fit within the original delineation of SDT, nor does it cohere with what is known about how students learn. Finally, a human-inclusive conception of ecosystems is required for EE students to understand their own environmental potential.

This study was undertaken in an attempt to address these challenges. I attempt to answer four research questions that assess the appropriateness of the application of SDT to EE research, provide support for an alternative characterization of competence support regarding pro-environmental behaviors, and explore what classroom features are likely to support students' basic psychological needs in an environmental biology course. These questions were

answered using both qualitative and quantitative methods, recognizing that while classic experimental designs have a place in educational research, they do not provide all the answers we need to address the challenges we face.

### *Research Questions*

In the first question I ask is to what extent does a SDT-guided environmental biology course differ from a non-SDT-guided course in the degree to which it fosters self-determined motivation toward the environment. This question is answered by comparing two sections of the same environmental biology course with the Motivation Toward the Environment Scale (MTES; Pelletier, et al., 1998) at the beginning, end, and six months following the course. The non-SDT-guided section was taught as it always is by the usual instructor, while I taught the other section using an approach guided by SDT. I use a quasi-experimental design that is combined with results from remaining research questions to give rise to a broad perspective on the utility and characterization of SDT in a formal EE setting.

In the second research question, I ask what the multiple influences are on fostering self-determined motivation toward the environment in an SDT-guided environmental biology course. I use path analysis to describe how students' perceptions of support for their basic psychological needs and students' need satisfaction interact to give rise to self-determined motivation toward the environment. In essence, the answer to the second question provides empirical

evidence for a theoretical path of causality that explains what leads to self-determination toward the environment in an environmental biology course.

In the third research question, I address two inextricable issues. I ask what characterizes students' scientific conceptualizations as they solve environmental problems and to what extent do their conceptualizations relate to the satisfaction of their need for competence. To answer this research question, I combine a coding scheme developed by Engle (2006) and grounded theory methodology to infer students' conceptualizations as they problem-solve, which I then link to their reports of competence in stimulated-recall interviews. The outcomes of this research question are grounded hypotheses about what supports students' sense of competence support as they engage in environmental problem-solving. This not only recharacterizes competence support in an EE setting but also recognizes the importance of environmental problem-solving in the development of scientific knowledge and self-determined motivation toward the environment.

In the final question, I ask what classroom features exist when students indicate that their basic psychological needs are being fulfilled or undermined. This question sought to describe relevant socio-contextual features that occur regularly across the times when students indicate that the satisfaction of their basic psychological needs is being supported or thwarted. This will aid environmental educators in constructing classrooms that are more likely to support students' basic psychological needs so that they come to engage in self-determined pro-environmental behaviors.

The collective results of these research questions constitute the first attempts to apply SDT to a formal EE setting. This introduction of an alternative model of behavior change to the EE field provides a fresh approach to inquiry. Finally, this study models a mixed methods design that is needed to bring about the kinds of solutions environmental educators are trying to achieve.

## CHAPTER 2: LITERATURE REVIEW

This study brings together findings from several communities of inquiry to provide a much-needed alternative approach to environmental education (EE) research. To begin this chapter, I will describe EE's history and main objectives. These objectives will be related to the concept of environmental literacy, and the relationship between environmental literacy and scientific literacy will be discussed in order to gain perspective on how this study fits into the overall goals of science education. I will then synthesize the state of EE research today, which will then be used to support the claim that EE research needs to take a new direction. Self-determination theory (SDT) will be suggested as a possible avenue to facilitate this new direction and inform EE instruction so that it is more successful in motivating students toward environmental protection. An exploration of SDT will give rise to several hypotheses to be investigated in this study, one of which questions the kind of scientific knowledge one must have in order to experience self-determined motivation toward pro-environmental behaviors. Using socio-cultural theory as a guide, research on scientific understanding, SDT, and EE will be synthesized to imagine what this type of instruction might look like. This chapter will conclude with a description of each research question and how findings will contribute to our collective understanding of how motivation toward pro-environmental behaviors might be fostered in an EE classroom.

*EE History & Environmental Literacy*

Recognizing the magnitude of the global environmental dilemma (*Appendix I*) and a need for EE, attendees to the 1972 United Nations Conference on the Human Environment held in Stockholm, Sweden first developed the notion of EE. In October 1975, over 90 environmental and educational experts from about 60 countries gathered in Belgrade, Yugoslavia for the International Workshop on Environmental Education, a follow-up to the Stockholm conference. The attendees of this meeting developed a framework and a set of goals for global EE; the summary of this meeting became known as the Belgrade Charter (UNESCO-UNEP, 1976). These goals were officially adopted and further specified a year later at the Intergovernmental Conference on Environmental Education in Tbilisi, Georgia, which produced the document recognized as the official statement of what constitutes environmental education: the Tbilisi Declaration (UNESCO-UNEP, 1978). These important documents state the general goal of environmental education is “to develop a world population that is aware of, and concerned about, the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones” (UNESCO-UNEP, 1976, p. 3).

The collection of such knowledge, skills, attitudes, motivations, and commitments has come to be known as environmental literacy. Environmental literacy is a primary goal of all of EE, and it partially comprises scientific literacy.

Alternative conceptualizations of what it means to be scientifically literate have existed for several decades, but a generally agreed upon definition of a scientifically literate person is one who understands the nature of science, its processes and products, and the appropriate application of those processes and products to decision-making contexts outside of the science classroom (Laugksch, 1999). This is recognized in the *National Science Education Standards* when they state, “everyone needs to use scientific information to make choices that arise everyday” (NRC, 1996, p. 1). Perhaps the most pressing of those decision-making contexts in today’s world are those circumstances that require us to make decisions about the environment, which is why environmental literacy is an important component of scientific literacy. Because nearly everyone agrees that fostering scientific literacy is a primary goal of science education, as stated throughout numerous documents, including the *National Science Education Standards*, and because environmental literacy is an important component of scientific literacy, we cannot accomplish our primary goal of scientific literacy without ample attention paid to environmental issues and our decisions that involve them (Figure 3).

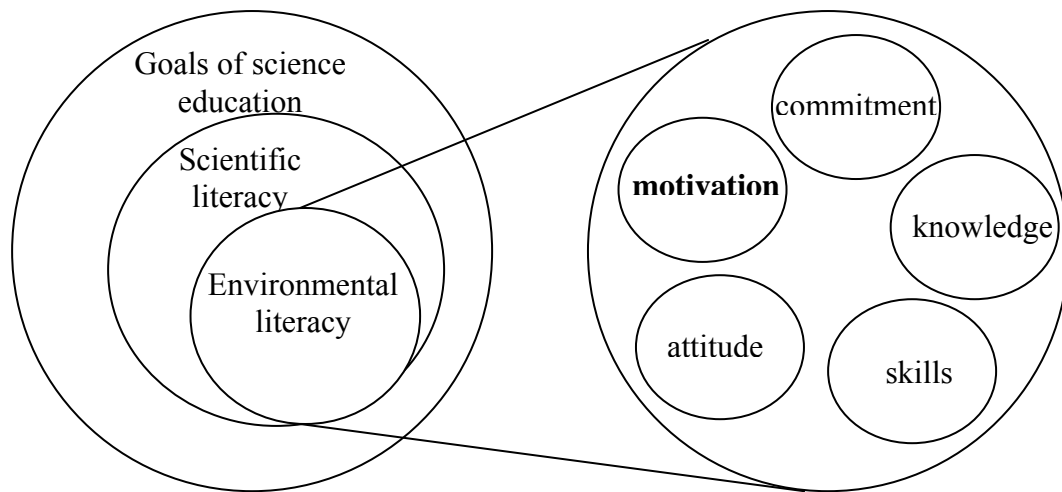


Figure 3. Goal structure of science education showing how the goal of motivating students toward protecting the environment relates to the goals of environmental literacy and scientific literacy. This study focuses on environmental motivation, shown in bold-faced type.

The question then becomes, how do we foster scientific literacy? Most educators recognize that education is part of the framework of society and is one means for socializing students to fit into that framework (Andrew & Robottom, 2001; Bingle & Gaskell, 1994; Wells & Claxton, 2002). Disconnections and contradictions, however, between students' cultural ways of knowing and scientific ways of knowing are common (Aikenhead, 1996). To overcome this challenge, Andrew and Robottom (p. 778, 2001) recommend a "meeting of the discourses" in which ethical and cultural considerations are encouraged and juxtaposed to science in the science classroom. I agree that this juxtaposition is necessary in the science classroom in order for environmental literacy, and thus scientific literacy, to be successfully fostered. If the connections between the culture of science and students' cultures are not made explicitly, I predict science



will remain disconnected from students' lives, thereby making scientific literacy impossible.

When considering a major component of what it means to be scientifically literate – to make informed decisions regarding socio-scientific issues – it becomes clear that possessing the motivation to make informed decisions is required. The global environmental dilemma (*Appendix I*) is the most pressing socio-scientific issue about which everyone makes decisions on a daily basis. Therefore, finding ways to instill in students motivation toward the environment is a core contemporary challenge that science education faces.

### *EE Successes*

The EE effort now has a long history that includes the well-known Earth Summit in Rio de Janeiro in 1992 and the World Summit on Sustainable Development in Johannesburg in 2002. Most recently, UNESCO has declared the decade spanning from January 2005 to December 2014 the United Nations Decade of Education for Sustainable Development (Combes, 2005). In this declaration, education for sustainable development (ESD) has been established as an offshoot of EE and is defined by a broader effort encompassing three strands of education: environment, society, and economy (McKeown & Hopkins, 2005). Although ESD has its own set of goals, a shared objective between EE and ESD is to motivate behavior change towards more environmentally friendly lifestyles (McKeown & Hopkins, 2005). Two features of the EE movement will be of principle focus throughout this dissertation. First, it is still an explicit goal of EE

to change behavior in order to minimize human's destructive impact on the environment. Second, such behavior arises from a particular type of motivation, as alluded to in the first formulation of EE (UNESCO-UNEP, 1976), and fostering this motivation is a critical component of EE.

The field has experienced several practical successes since its beginning. Several states have begun to construct comprehensive EE programs that fulfill the sixteen minimum criteria for a successful statewide EE program put forth by Ruskey and Wilke (1994). As of 2001, no state had yet to enact all 16 criteria, but ten states (i.e., Florida, Kentucky, Louisiana, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, Washington, and Wisconsin) have achieved at least ten of the components and are working towards improvement (Ruskey, Wilke, & Beasley, 2001). Disinger (2001) documents efforts to improve teacher education so that practitioners are more prepared to integrate EE into K-12 curricula. Plevyak, et al.'s (2001) study investigating the effectiveness of such efforts indicates that when pre-service teachers are trained to implement EE, they indeed implement EE more often and more confidently in their classrooms when they enter the workforce than teachers who do not receive such pre-service training. Many colleges and universities have also integrated EE into their general studies programs with the intent of developing an environmentally literate citizenry (Wilke, 1995). These studies offer promising evidence that EE is finally

being integrated into public educational systems and that it is effective according to some measures.

Success has also been achieved on the research front. Much of the early EE research did not take place in educational settings and did not explicitly examine environmental behaviors. Although encouraging pro-environmental behaviors was a stated goal of EE from the beginning, the assumed behavioral change model posited a linear relationship between knowledge, attitude, and action (Hines, Hungerford, & Tomera, 1986-1987; Hungerford & Volk, 1990). In other words, environmental educators thought that if students gain knowledge about the environment, they would develop a pro-environmental attitude, which would in turn cause them to act in environmentally friendly ways. Therefore, early EE research sought to document what experiences, knowledge, and attitudes characterized environmentalists (i.e., citizens with pro-environmental attitudes). An underlying assumption was that if these experiences could be replicated through EE, environmental attitudes would be fostered, and pro-environmental behaviors would result. From this line of inquiry, we learned that environmentalists generally share some combination of the following experiences: having childhood experiences in natural, relatively pristine, undeveloped areas (Chawla, 1998; Ewert, Place, & Sibthorp, 2005; Palmer, 1993; Palmer & Suggate, 1996; Tanner, 1980); being influenced from family, peers, and/or role models who cared for nature (Palmer, 1993; Tanner, 1980); witnessing the destruction of a beloved natural area or a similar negative experience involving environmental

destruction (Ewert, Place, & Sibthorp, 2005; Marshall, Picou, & Bevc, 2005; Palmer, 1993; Tanner, 1980); and participating in formal EE (Palmer, 1993).

This qualitative work attempted to describe characteristics shared among environmentalists, but it quickly evolved into quantitative attempts to find effective predictors of pro-environmental behaviors. Through these efforts, environmental educators soon realized that the simplistic, linear model assumed at EE's beginning would not suffice. An observation documented time and again was that even people who claim to possess pro-environmental attitudes seldom act in accordance with those attitudes (De Young, 2000; Finger, 1994; Jurin, 1995; Lane, 2000; Shultz, Oskamp, & Mainieri, 1995; Pelletier, et al., 1998; Stets & Biga, 2003). Jurin (1995) named this disparity between attitude and behavior symbolic environmentalism.

Hines, Hungerford, and Tomera (1986-1987) proposed a more complex model of factors leading to pro-environmental behaviors (Figure 1). In their model, several previously proposed constructs, including locus of control, personal responsibility, action skills, knowledge of action strategies, knowledge of issues, and intention to act, were synthesized into a single theoretical model. Since this seminal publication, EE research has investigated a broad range of topics, some not directly relevant to pro-environmental behavior. Therefore, only research specifically relevant to behavior will be discussed throughout the remainder of this section. The above constructs introduced by Hines, Hungerford, and Tomera have dominated the investigation of pro-environmental behaviors for

the past two decades. Most commonly, researchers measure some combination of these constructs and attempt to use them to predict pro-environmental behaviors. These studies typically generate statistical models that describe the relationships between the constructs under study. The constructs that have been most effective in such predictions are locus of control, environmental responsibility, and various characterizations of knowledge. Intention to act, another construct integrated into the Hines, Hungerford, and Tomera model, deserves special attention because it is often used as a proxy for pro-environmental action (Hwang, Kim, & Jeng, 2000). Because these have played such a significant role in research thus far, each of these constructs will be defined.

Locus of control was defined as “an individual’s belief in being reinforced for a certain behavior” (Hungerford & Volk, 1990). When an individual has an internal locus of control, the person expects reinforcement resulting from a particular behavior and thus, will be more likely to perform the behavior (Hungerford & Volk, 1990). Bringing about the desired outcome is thought to strengthen one’s internal locus of control through reinforcement (Hungerford & Volk, 1990). Conversely, when an individual has an external locus of control, the person believes no reinforcement will result from an action and therefore, the person is unlikely to act (Hungerford & Volk, 1990). Internal locus of control has been shown to be an important predictor of pro-environmental behavior (Culen & Volk, 2000; Dimopoulos & Pantis, 2003; Hwang, Kim, & Jeng, 2000; Hsu, 2004; Kollmuss & Agyeman, 2002; Newhouse, 1990; Sivek & Hungerford, 1989-1990).

Environmental responsibility, or the amount of personal responsibility or sense of duty toward the environment one assumes, was another construct integrated into Hines, Hungerford, and Tomera's model and has received investigative attention. Generally, environmental responsibility correlates positively with intention to act in environmentally friendly ways (Hsu, 2004; Kaiser et al., 1999; Kollmuss & Agyeman, 2002; Newhouse, 1990). Even before Hines, Hungerford, and Tomera's influential article, environmental educators recognized the importance of environmental knowledge, but it is now characterized more specifically. One may have knowledge of environmental action strategies, environmental issues, and/or possess skills needed to implement strategies. Generally, one's perception of one's own knowledge and/or skills positively correlates with one's intention to act pro-environmentally (Culen & Volk, 2000; Dimopoulos & Pantis, 2003; Hines, Hungerford, & Tomera, 1986-1987; Hsu, 2004; Hsu & Roth, 1999; Kaiser et al., 1999; Kollmuss & Agyeman, 2002; Newhouse, 1990; Sivek & Hungerford, 1989-1990). Finally, intention to act refers to one's desire to behave in accordance with several factors, including locus of control, environmental responsibility, and environmental knowledge (Hines, Hungerford, & Tomera, 1986-1987). Intention to act originates from Ajzen and Fishbein's (1980) model of reasoned action, which claims that one's intention to act has a direct effect on behavior. Given this assumption, it seems reasonable why intention to act is often used as a proxy for behavior.

A second family of studies has examined various curricula or EE treatments that attempt to foster the desired characteristics that have been predictive of pro-environmental behaviors (e.g., internal locus of control, personal responsibility for the environment, knowledge of issues and action strategies, intention to act). We have learned from this line of research that when EE is successful in promoting intent to act in environmentally friendly ways, it involves several factors. Students are involved as active, rather than passive, participants in learning processes (Hewitt, 1997; Siemer & Knuth, 2001; Zelezny, 1999). Formal EE is generally more effective than informal EE (Zelezny, 1999), and longer EE programs are more successful (Bogner, 1998; Zelezny, 1999). The incorporation of community-wide efforts (e.g., a school-wide recycling program) into classroom efforts is supportive of students' intent to act pro-environmentally (Tung, Huang, & Kawata, 2002). Finally, EE that incorporates action training is most successful in encouraging intention to act (Boerschig & DeYoung, 1993; Ramsey, 1993).

Three significant challenges exist in the research documented thus far. First, EE research has provided us with a collection of potentially useful predictors of pro-environmental behavior, but the field has yet to agree on an optimal set of predictors. Often studies contradict one another regarding the predictive value of a construct. For instance, Hwang, Kim, and Jeng's (2000) study claims that locus of control is the most important predictor, while Hamid and Cheng (1995) claim that past behavior and attitude predict behavior while locus of control does not. The second concern is that although we also have a list

of effective EE treatments, there is very little explanation about why these treatments are successful, except to say that it effectively fosters an internal locus of control, or other important factors. There is little effort to explore why an internal locus of control matters in the first place, except to reference Hines, Hungerford, and Tomera's influential article. Finally, it seems that intention to act in environmentally friendly ways has been adopted throughout the field as a satisfying outcome of EE. It seems that no EE study questions why someone possesses a particular intention to act in a certain way, except to say that the expected correlation is present between intention to act and other constructs, such as locus of control. Two people may have the same intention to act and locus of control but very different reasons for acting. For instance, one person may intend to recycle a plastic bottle in order to get a cash refund, while another person may intend to recycle a plastic bottle because the person is concerned about the consumption of fossil fuels in the production of plastics. Furthermore, both individuals may possess internal loci of control. Are these situations the same? An environmental educator would be inclined to say no, but as the field has approached changing environmentally significant behaviors, there seems to be no distinction between these two situations.

Robottom (1995) points out that the behaviorist perspective has overwhelmingly dominated EE research, and the field has viewed environmentalism as an individual endeavor, rather than one assumed within a broader social context. Exceptions to this generalization are studies like Kollmuss



and Agyeman's (2002) study, which included demographic factors, such as income, into statistical analyses, thereby adding more potential predictors to our collection. While this type of study attempts to examine broader social contexts, these attempts are still best described by behaviorism. I argue that the challenges discussed above result from this behaviorist approach. It is probable that a single set of effective predictors has yet to be determined because a single set is incapable of describing human behavior across various social contexts. In order to better understand human behaviors related to the environment, a more effective approach might be to explain behavior within social contexts rather than across them. DeYoung (2000) calls for a similar approach when he suggests context-based evaluations, which examine factors that moderate the effectiveness of a treatment, rather than outcome-based evaluations, which attempt to examine the effectiveness of a technique in isolation. Such an approach would not only require a departure from the behaviorist tradition, but also courage to qualitatively describe social situations, recognizing that sometimes it is not effective to reduce rich descriptions down to statistics alone. Although not conducted in the formal EE domain, Margai's (1997) study of an environmental outreach program is an example of an integration of qualitative and quantitative methods that allowed her to not only predict behavior, but also explain it by examining social constraints to recycling through focus group interviews. Such a departure from behaviorism in formal EE would allow us to open the black box and ask why particular EE treatments work and why students intend to act they way they do. In order to

progress EE towards this level of understanding, the field needs a fresh approach to inquiry. I suggest that this fresh approach can be achieved through the use of Deci and Ryan's self-determination theory of motivation and mixed methods that are strategically designed to not only predict behavior, but also explain it in socio-cognitive terms.

### *Self-Determination Theory*

#### *General Characterization & Definitions*

Individuals' experiences are used to construct higher levels of knowledge that represent the world and allow individuals to make sense of it (Cole & Cole, 1993). These higher levels of knowledge are organizational cognitive structures that serve as the context in which new experiences are understood, and they are continually modified to account for new experiences that do not cohere with one's current understanding of the world. This is at the heart of self-determination theory (SDT). Cognizing organisms possess an organizational cognitive function that causes individuals to strive for coherence between their cognitive structures and their experiences (Ryan & Deci, 2002). When an individual encounters an optimally challenging situation – an experience that disagrees with one's cognitive structure in a way that is resolvable, the learner modifies and elaborates his or her cognitive structures to integrate the challenge into one's understanding of the world. Successful elaboration is satisfying because it allows for more extensive cognitive organization (Deci & Ryan, 1990). This accounts for humans'

“natural” curiosity and tendency to seek out optimal challenges (Deci & Ryan, 1990).

While elaboration of organizational cognitive structures may be satisfying, the world that an individual is attempting to assimilate is saturated with social interaction. Deci and Ryan (1990) claim that social situations can be supportive of individuals’ tendency toward assimilation, thereby supporting humans’ curiosity and gravitation toward optimal challenges, or they can undermine it, causing diminished motivation toward elaboration of cognitive structures. Therefore, there is a dialectic struggle between active, cognizing individuals and the various factors, both within and between individuals, that can support or interfere with development. Deci and Ryan (1990) call this the organismic dialectic, which is why SDT is concerned with the particular social contexts that support or undermine humans’ tendency toward assimilation.

Humans’ tendency toward assimilation is not static and can be manifested in different ways, which are represented by various motivational processes (Ryan, 1995). Intrinsic motivation represents this human tendency in its purest form; behaviors that are intrinsically motivated are performed for no other reason but to elaborate one’s organizational cognitive structures through assimilating challenging experiences (Ryan, 1995; Ryan & Deci, 2000a; Ryan & Deci, 2000b). These behaviors are internally regulated, and attempts to control or reward intrinsically motivated behaviors (i.e., attempts to externally regulate them) have

a negative effect on the behaviors (Deci, Koestner, & Ryan, 2001; Deci, Ryan, & Koestner, 2001; Ryan, 1995; Ryan & Deci, 2000b). Most human behaviors, including pro-environmental behaviors, are not intrinsically motivated (Osbaldiston & Sheldon, 2003; Ryan 1995). When humans are socialized to adhere to rules of law and engage in social norms, humans learn to perform behaviors because they allow smooth existence in social relationships, not because they extend one's organizational cognitive structures (Ryan, 1995). This socialization occurs through a process called internalization; external behavioral regulations are assimilated into one's cognitive structure so that they are no longer understood as external regulations but originating from oneself (Deci & Ryan, 1990; Ryan, 1995; Ryan & Deci, 2002). That which is being internalized is to some degree determined by the culture and social context that gave rise to it, although the individual is active in integrating it into his or her organizational cognitive structure (Díaz, Neal, & Amaya-Williams, 1990; Ryan, 1995). As internalization progresses, the individual becomes increasingly more autonomous and is able to increasingly self-regulate his or her own behavior (Díaz, Neal, & Amaya-Williams, 1990; Ryan, 1995).

A continuum occurs between behaviors that are self-regulated and those that are regulated by forces outside the individual (Table 2.1; Ryan, 1995; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Ryan & Deci, 2002). This continuum gave rise to SDT's classifications of motivation: intrinsic motivation, extrinsic motivation, and amotivation. As previously discussed, intrinsically motivated behaviors are

regulated by the curiosity and inherent satisfaction arising from an individual's tendency to elaborate his or her organizational cognitive structure (Deci & Ryan, 1990; Ryan, 1995; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Ryan & Deci, 2002). Behavior arising from extrinsic motivation can be regulated in different ways, depending on whether the regulating force is originated as an external or internal force. Integrated regulation occurs when an individual has accepted externally imposed values and goals and has integrated them into one's organizational cognitive structure, which contains one's personally endorsed set of values and goals (Ryan & Deci, 2000). This form of behavioral regulation represents the ultimate degree of assimilation of an externally imposed regulation, and it describes a form of extrinsic motivation (Ryan, 1995). When an individual's behavior is regulated in this way, the person does not necessarily extract pleasure from performing the behavior but is happy to perform the behavior because it coheres with his or her value system (Ryan, 1995). Many pro-environmental behaviors would be categorized here (Osbaldiston & Sheldon, 2003). For example, although recycling is probably not enjoyable in its own right, many people who recycle certainly feel joy in doing it because it fits well within their personally endorsed set of values. Intrinsic and integrated regulation, which are collectively called self-determined motivation, allow for self-determined behaviors, or behaviors that originate from self and are not controlled by an external force (Deci & Ryan, 1990). For example, the individual who recycles because it coheres with his or her value system has internalized environmental

beliefs that value recycling; thus, the individual feels the recycling behavior is of his or her own volition, not out of coercion. Therefore, I seek to foster self-determined motivation in the EE classroom.

Identified regulation determines behavior arising from another form of extrinsic motivation in which an externally imposed behavior is accepted as personally important but it is not wholly integrated into the person's value and belief systems (Deci & Ryan, 1990; Ryan, 1995; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Ryan & Deci, 2002). Introjected regulation determines behaviors of a third type of extrinsic motivation in which an externally endorsed value is partially assimilated and thus not truly accepted as one's own; behaviors are performed in order to avoid guilt or shame or to attain an ego-boost (Deci & Ryan, 1990; Ryan, 1995; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Ryan & Deci, 2002). In other words, introjected regulation is linked to one's self-esteem, and actions are taken in order to avoid diminishing self-esteem in some way (Deci & Ryan, 1990; Ryan, 1995; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Ryan & Deci, 2002). External regulation is the final type of behavioral regulation arising from extrinsic motivation in which an individual is motivated purely by external factors, such as the threat of punishment or the possibility of a reward (Deci & Ryan, 1990; Ryan, 1995; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Ryan & Deci, 2002). Finally, amotivation characterizes an individual who is not motivated toward a particular behavior (Deci & Ryan, 1990; Ryan, 1995; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Ryan & Deci, 2002). The continuum along

describing these motivation and regulation types should not be considered a developmental continuum; progression through each type of regulation is not necessary for one to perform self-determined behaviors (Deci & Ryan, 2000).

Research utilizing SDT has largely sought to describe those social contexts that support the internalization process, thereby allowing behaviors to be more self-determined (Deci & Ryan, 2000; Ryan, 1995). According to SDT, three basic psychological needs support self-determined motivation: the needs for competence, autonomy, and relatedness (Deci & Ryan, 1990; Deci & Ryan, 2000; Reis, et al., 2000; Ryan & Deci, 2000b; Ryan & Deci, 2000c; Ryan & Deci, 2002; Sheldon & Elliot, 1999; Sheldon, et al., 2001). The need for competence refers to humans' need to control outcomes and feel effective in bringing about desired outcomes. The need for autonomy (sometimes referred to as the need for self-determination) refers to humans' need to feel that the origin of one's behavior exists within oneself. The need for relatedness refers to human's need to feel a sense of belonging to a social group. Self-determined behaviors that are determined through integrated regulation are only possible when socio-contextual factors fulfill all three basic psychological needs rather than thwart their satisfaction (Deci & Ryan, 1990; Deci & Ryan, 2000; Reis, et al., 2000; Ryan & Deci, 2000b; Ryan & Deci, 2000c; Ryan & Deci, 2002; Sheldon & Elliot, 1999).

Socio-contextual factors that support the fulfillment of basic psychological needs can be generalized to a limited extent. One's need for autonomy is generally satisfied in contexts in which one is able to make his or her own

decisions and is not controlled by another entity. Therefore, surveillance and unreasonable rules and demands that lack explanation are likely to be unsupportive of autonomy, whereas choice and explanation tend to support autonomy (Ryan & Deci, 2002). To satisfy one's need for competence, one needs to be in an optimally challenging situation – one in which one's skills are required but are also enhanced (Ryan, 1995). When a person's skills are required to solve a problem, the person is more likely to feel she or he is solving the problem effectively. The enhancement of a person's skills while engaging in a problem provides a satisfaction that fulfills all human's desire to extend their understanding. In order to satisfy one's need for relatedness, a person must feel free to be oneself and is accepted in the social group in which the person interacts (Ryan & Deci, 2002). This final need, although often overlooked, is the most significant of the three because if a person's need for relatedness is not being fulfilled, the person is unlikely to engage in the activities and relations that would lead to fulfillment of the other two needs. Regarding all three basic psychological needs, they are likely to be supported by these socio-contextual factors, but the factors themselves are irrelevant if the perceptions of the person/people under study are not taken into account. In other words, a person must perceive that she or he is competent, autonomous, and related, and these perceptions are what allow for self-determined motivation (Ryan & Deci, 2002).

It is important to note that need satisfaction can vary within individuals according to context, which is why need satisfaction can be measured generally



and on smaller scales (La Guardia, et al., 2000; Reis, et al., 2000). For instance, a person's needs may be quite satisfied in a relationship, allowing that person to experience self-determined motivation toward investing effort into the relationship. Simultaneously, however, the same person's needs may be unfulfilled in his or her life in general, leading to amotivation toward everything but the satisfying relationship. This within person variation in need satisfaction is particularly relevant to the EE classroom because it cannot be assumed that general need satisfaction will miraculously motivate pro-environmental behaviors. Rather, basic psychological needs must be fulfilled in specific, contextualized ways that lead to self-determined motivation toward pro-environmental behaviors. The question remains whether or not this important context can be created in the EE classroom alone or if other factors outside the classroom must be established to maintain self-determined motivation toward the environment after the EE course ends.

#### *SDT Applied to Pro-Environmental Behaviors*

Social psychologists have effectively used SDT to explain pro-environmental behaviors in the general public. Although this research has not been conducted in EE settings, it is important to outline their findings so that we may understand how SDT can be useful in EE to motivate pro-environmental behaviors.

Frequency and variety of pro-environmental behaviors correlate most highly with self-determined motivation, and as pro-environmental behaviors

become more externally regulated, they become less frequent (Green-Demers, Pelletier, & Ménard, 1997; Pelletier, 2002; Pelletier, et al., 1998; Séguin, Pelletier, & Hunsley, 1999). Incentives, rewards, and punishments for performing (or not) pro-environmental behaviors have not been successful in instilling long-lasting change in behaviors (Pelletier, 2002). This is because when such an externally regulated force is removed, the behavior only continues if the actors are self-determined to perform the pro-environmental behavior (Pelletier, 2002). In fact, when people possess self-determined motivation toward pro-environmental behaviors, their performance of those behaviors does not significantly vary according to difficulty of the behavior (Green-Demers, Pelletier, & Ménard, 1997). These studies indicate that if environmental educators want students to perform pro-environmental behaviors on a long-term basis and not be swayed by the various barriers against acting pro-environmentally (e.g., lack of a curbside recycling program), then there should be an effort to support students' development of self-determined motivation toward pro-environmental behaviors.

Social psychologists have also studied what social and contextual factors support self-determination toward the environment. Generally, self-determination is greater when people's basic psychological needs are supported. Relevant factors include not only organizational features (e.g., a municipality's recycling capabilities), but also behaviors of others in the immediate environment (e.g., classmates and teacher in an EE class), who have the ability to influence basic psychological need fulfillment on a daily basis (Pelletier, 2002). When people

understand what behaviors are pro-environmental, why they should engage in those behaviors, and how to engage in those behaviors, they feel more competent about the environment and are more likely to engage in pro-environmental behaviors (DeYoung, 2000). This provides significant explanatory power about why environmental action training is relatively successful in encouraging students to perform pro-environmental behaviors, as documented extensively in the EE literature. Such training likely supports their need for competence. Similarly, when government or interpersonal climate is perceived to contain features that support basic psychological needs, people are more likely to have self-determined motivation toward the environment (Pelletier, 2002; Pelletier, Legault, & Tuson, 1996). The importance of basic psychological need satisfaction is also supported by research on amotivation toward the environment. For instance, people who are amotivated toward the environment often have a sense of helplessness regarding the environment, indicating their need for competence is not being satisfied (Pelletier, et al., 1999). Although these studies are few and somewhat preliminary, they support the notion that in order to induce long-lasting pro-environmental behaviors, environmental educators could be quite successful if efforts were made to foster self-determined pro-environmental behaviors via basic psychological need support in the EE classroom.

Extending the above research to the EE classroom, we can begin to see what EE might include if it were successful in motivating self-determined pro-environmental behaviors. In order to support students' need for autonomy,

curricular activities would include ample opportunities for students to construct environmental action plans (EAPs) for environmental problems of their choosing. Such activities would not only give students choice in investigating environmental issues important to them, but the opportunity to construct EAPs would allow them to make their own decisions about how to act regarding the environment, rather than someone else telling them how they should behave. Students' need for competence might be supported by a thorough understanding of ecosystems that include humans. Additionally, curricular activities that require students to bring that understanding to bear to solve environmental problems may constitute those optimally challenging situations that SDT predicts will support one's need for competence. Conveniently, such problems may be the construction of EAPs for topics of students' choosing, which is also thought to support autonomy. Finally, students' relatedness might be supported by various features of the classroom community, including the co-construction of a classroom community that respects everyone's input and values the unique contributions that each member of the community makes to the whole. Classroom activities that connect students to their own communities are also likely to support relatedness. Such activities may integrate into the course students' cultural knowledge of nature, the environment, ecosystems, etc.; introduce students to environmental resources, such as activist groups or governmental organizations, present in their own communities; and involve potential role model environmentalists who share similar backgrounds as the students. This general description of what an EE course may look like if it

supports students' self-determined pro-environmental behaviors will form the basis for some of the hypotheses in this study.

Much research has also been conducted on how to support basic psychological needs in educational settings in order to support self-determined academic motivation. General autonomy-supporting teaching actions include listening more to students, talking less to allow students to talk through problems, offering time for independent work, scaffolding questions rather than giving solutions, praising quality of performance rather than inherent characteristics of students, offering choices to students, and providing explanations to students for rules, assignments, etc. (Reeves, 2002). Generally, competence-supporting learning situations include optimally challenging problems and informational feedback that is not insulting or demeaning (Deci, Ryan, & Williams, 1996). General relatedness-supporting situations are those that involve interpersonal involvement (i.e., group work), which make acknowledgement of individuals' unique contributions to collective functioning more likely (Deci, Ryan, & Williams, 1996). These pedagogical practices that have been documented to support students' self-determination will also be present in the research setting of this study and can be regarded as supportive of the efforts to support self-determined environmental motivation.

### *Understanding Ecosystems*

As I refer to above, one of this study's claims is that students' need for competence is satisfied when they are asked to use their thorough understanding

of ecosystems as they include humans in optimally challenging situations. In order to fully grasp the significance of this claim, we must first know what it means to thoroughly understand ecosystems as they include humans. Therefore, literature investigating how students come to understand ecosystems will be discussed next.

#### *Misconceptions Research*

Like most areas of science education, early ecology education literature thoroughly documents those misconceptions that are common among students. The misconceptions discussed here will be relevant to the following ecological constructs: food webs/chains, ecological niche, natural selection, carrying capacity, and interdependence. As humans physiologically and behaviorally participate in ecosystems, they mediate ecological relationships among organisms, thereby interfering with how these ecological constructs are realized in ecosystems. Therefore, if students are to be able to reason about how they participate in ecosystems, they must have reasonably scientific conceptions of these constructs, which is why these were chosen for discussion here. Common misconceptions can vary across age groups, so the literature drawn upon to devise this list focuses on high school or college students because they are most likely to reason similarly to community college students, the subjects of the present study.

Students most often understand feeding relationships in an ecosystem as a series of simple, unrelated food chains (Barman, Griffiths, & Okebukola, 1995;

Griffiths & Grant, 1985; Munson, 1994). Categorization into herbivorous or carnivorous feeding guilds occurs according to size and/or ferocity, rather than trophic level (Eilam, 2002). Students also tend to believe that animals at higher trophic levels have more energy (Adeniyi, 1985). Students also often think that populations are either constantly becoming larger or smaller, depending on their trophic level (Munson, 1994). Feeding relationships are sometimes understood as cyclic rather than as a web, and students sometimes include abiotic components into food chains/webs (Eilam, 2002). Decomposers are often seen as the last stem in any food chain, rather than participants at every level of a web (Eilam, 2002). When considering all other organisms, however, many students claim that animals at higher trophic levels eat all organisms at all levels below them, rather than there being differentiation of food items across potential competitors (Griffiths & Grant, 1985; Munson, 1994). In doing so, they seem to be relatively unfamiliar with the idea of ecological niche. Students generally understand the needs and roles of species at particular trophic levels as equivalent, and coexistence is possible because they get along with each other (Munson, 1994). This final point again emphasizes the lack of understanding of ecological niche. These misunderstandings are important because they only allow for an impoverished view of how humans interact within the ecosystems in which they exist, which likely would lead to behaviors that are destructive toward the environment. For example, students who think that animals at higher trophic levels eat all organisms at all lower levels would likely conclude that all high-order consumers

must directly compete for resources. If this is the case, then it is reasonable to conclude that it is in human's best interest to rid our ecosystems of our "competitors" (i.e., other high-order consumers, such as wolves and mountain lions). A more scientific conception, however, would allow one to understand that wolves and mountain lions are not really a threat to humans' abilities to secure resources for survival because we have differentiated ecological niches.

Bishop and Anderson's (1990) article thoroughly documents the numerous misconceptions that surround the concept of evolution by natural selection. While this subject may seem ancillary to ecology, it is important to remember that evolution is a central theme throughout all biological sciences, and unscientific understanding of evolution can have far-reaching effects in the understanding of other domains of biology (Sadler, 2005). Important natural selection misconceptions that have especially relevant effects on ecological understanding will be described here. Students often believe that organisms develop traits because they are needed, as if an organism can consciously decide to evolve (Bishop & Anderson, 1990). Traits are also seen as properties of populations rather than individuals, yet individuals are thought to be the unit that changes over time (Bishop & Anderson, 1990). In other words, all individuals in a population are understood as having the same traits, but when evolution happens, individuals change and pass on changes to offspring, rather than a gradual change in populations over time. Finally, fitness is often conflated with our colloquial use of the term to denote health, strength, and intelligence (Bishop & Anderson, 1990).



Students seldom understand that in evolutionary biology, fitness refers to an individual's ability to produce viable offspring. This ability may have little to do with overall health, strength, and/or intelligence. These misconceptions are relevant to ecological understanding because they can lead to a belief that organisms can adapt to environmental changes if they choose to and/or are smart enough to deal with their changing environments. There is little appreciation of the time frame in which evolution occurs, the relatively short time frame in which human effects on ecosystems are incurred, and evolution's dependence on randomness. This is confounded by a common misconception related to carrying capacity, which is the belief that at least some ecosystems are limitless (Munson, 1994). An individual possessing these misconceptions is likely to believe that biodiversity depletion is not real because organisms can easily adapt to human-induced environmental changes if they choose to or are smart enough. Considering this, it is not surprising that many students are not concerned about our effects on ecosystems.

A final group of ecological misconceptions deals with how ecosystems are affected by disturbances. Students often believe that a disturbance to one population in an ecosystem will only affect those other populations that are related to it through feeding relationships or will affect all other populations in the same way (Griffiths & Grant, 1985). Similarly, the dissipation effect is common (Griffiths & Grant, 1985; White, 1997). The dissipation effect refers to the belief that a disturbance in one part of the ecosystem diminishes as it moves throughout

the ecosystem, like the waves resulting from a disturbance in the surface of still water become smaller as they propagate out from the source of the disturbance (White, 1997). Students may also think that some disturbances will not have any effect on the ecosystem as a whole because some organisms are not required or important to the health of the ecosystem (Munson, 1994). This final group of misconceptions is relevant to the concept of interdependence; the notion that complex relationships in ecosystems mandate that all organisms are either directly or indirectly dependent on all other organisms in the ecosystem. This is relevant to the global environmental dilemma because when an individual believes in the dissipation effect, the resulting assumption is that one's behaviors do not have any truly harmful consequences because effects on other organisms in the ecosystem are lessened, depending on how far removed other organisms are from the individual in a food web.

### *Moving Beyond Misconceptions*

The misconceptions literature fulfilled two important roles in ecology education because it documented what students believe, and this is necessary if we are to help them develop conceptions that are more desirable. It also highlighted the difficulties that students have in understanding ecology; up until these studies were conducted, it was often assumed that ecological concepts were easy to understand and little instructional time was spent developing ecological concepts. Ecology educators have realized that it does not make sense to study

ecological understanding as discrete concepts, as it is treated by much of the misconceptions literature, because so much of ecology requires reasoning about causal relationships (Green, 1997; Grotzer & Basca, 2003; Hogan, 2000; Lin & Hu, 2003; Webb & Boltt, 1990). Therefore, another family of studies has investigated ecological reasoning; this will be described next.

Ecological systems are characterized by complex, causal relationships that are difficult to observe and can be quite removed from our human experience. While it is easy for students to realize the importance of feeding relationships, their reasoning regarding feeding relationships tends to be linear (Grotzer & Basca, 2003; Webb & Boltt, 1990), unidirectional (Green, 1997; Grotzer & Basca, 2003; Hogan, 2000), and only involve one or two steps (Grotzer & Basca, 2003; Hogan, 2000; Webb & Boltt, 1990). Food chains, rather than food webs, seem to pose few problems for students because they typically only require students to reason along a single, unidirectional line of only a few events. However, food webs, rather than chains, are more characteristic of ecosystems, but in order to understand them, one must be able to reason bi-directionally along several lines of events that circle back to form cyclic relationships. Obviously, a student who is only able to reason in one direction along a single line of events will be challenged. Therefore, several researchers have recommended a departure from teaching simple food chains (Webb & Boltt, 1990) and focusing more on the network-like structures of ecosystems (Hogan, 2000; Grotzer & Basca, 2003; Smith & Anderson, 1986).

Many ecology educators have also noted that while we are teaching students feeding relationships, students are missing the underlying ecology. Ecologists discuss feeding relationships because they are interested in the patterns of matter cycling and energy flow throughout an ecosystem. However, when only feeding relationships are taught, students are never allowed to make important connections between the feeding relationships and the matter cycling and energy flow. Understanding matter cycling is crucial to making environmental decisions because, as described in *Appendix I*, much of our global environmental dilemma is caused by our behavioral participation in matter cycling processes. For example, when we clear-cut tropical rainforests, we behaviorally participate in matter cycles occurring in tropical rainforests to the point that we change entire ecosystems. More specifically, our clear-cutting behavior, which usually involves burning the trees after cutting, releases carbon-containing molecules into the atmosphere, changes the landscape to an ecosystem that does not sequester carbon as efficiently, and destroys habitat for numerous organisms that scientists have yet to study. In order to understand why such interference with matter cycling is important, students must understand matter cycling processes and their direct connection to the energy flow processes upon which all life depends. Then, reasoning about these processes and human involvement in them can lead to plausible environmental solutions.

When learning matter cycling and energy flow, students encounter several obstacles. Lin & Hu (2003) claim that these are difficult even when students

understand mechanistic processes such as photosynthesis and cellular respiration. They claim the reason for this is because the macro-level processes involve multiple inter-relationships that are difficult to track all at once and go back and forth between biotic and abiotic components of the ecosystem (Lin & Hu, 2003). Eilam (2002) agrees that energy flow and matter cycling are difficult concepts, which he attributes to three obstacles. First, energy flow and matter cycling are molecular processes, unobservable, and understanding is often dependent on misunderstood physics concepts, such as matter conservation and molecular motion (Eilam, 2002). Ecosystem processes involve multiple related events that can occur simultaneously or across vast spans of time and space (Eilam, 2002). This complex dynamism across time and space is what poses the two additional obstacles posited by Eilam (2002). Another challenging concept related to energy and matter is the notion of transformation. Energy and matter are constantly being transformed as they pass or get recycled through ecosystems. However, many students envision consumption rather than transformation (Carlsson, 2002a, Carlsson, 2002b). This is similar to Eilam's (2002) findings, which highlighted the difficulty of these concepts because of a lack of understanding of conservation of matter. Regarding the notion of transformation, decompositional processes seem to be a crucial step (Hogan & Fisher-Keller, 1996; Leach, et al., 1992). It seems that although students recognize the importance of decomposition, it is seldom connected to the activities of microbial organisms or matter cycling (Hogan & Fisher-Keller, 1996).

The lesson to be learned from these studies is that the basis of ecological understanding is being able to reason through the causal inter-relationships in ecosystems that allow for energy flow and matter cycling and highlight organismal interdependence. Not only are these the basic ideas of ecology, but they are also the concepts that students find most difficult, so it makes sense that these receive the most attention in ecology instruction.

Although the above studies have helped us determine what better ecology education might look like, an important note to be made at this point is that few studies in ecology education attempt to understand how students understand ecosystems when humans are a part of those ecosystems. Likewise, ecology is seldom taught in such a way that recognizes humans as another organism participating in ecosystems alongside every other organism on Earth (Roberts, 1997). If the ecosystems that students come to thoroughly understand as a result of ecology education are absent of humans, they have an understanding that is of little use because there is not a single ecosystem on Earth that does not involve humans. Furthermore, humans' role in ecosystems is unique; the assumption that students who fully understand ecosystems that lack humans will simply be able to extend that understanding to ecosystems that include humans is erroneous. Therefore, it is necessary that from the very beginning ecology be taught in such a way that allows students to understand ecosystems as they include humans. Therefore, I argue that focusing on humans' unique ecological roles and how human decision-making influences those roles must be included in ecology

instruction if it is to be effective and useful in today's world. This is not to say that the informative ecology education literature should be discarded. Rather, it should be taken into account when developing instruction that aims to help students develop an understanding of ecosystems that is relevant to today's world – an understanding in which humans are integral players in ecosystems.

### *Theoretical Perspective on Learning*

Socio-cultural theory is especially appropriate to this type of ecology instruction because it contends the main objective of schooling is to develop the minds and identities of students so that they are equipped to participate in our ever-changing world (Claxton, 2002; Wells & Claxton, 2002). The socio-cultural perspective understands cognitive development as the means by which people come to effectively participate in communities. Communities are groups of people who share a culture, which is an accumulated set of values, beliefs, and material and psychological tools that have developed over generations and allow for problem solving. The problems to be solved vary in magnitude, from a one-year-old learning how to use a spoon to feed herself to an entire society trying to alleviate the destructive consequences of their actions on the environment.

Individuals become acculturated into the culture in which they are raised by appropriating it while participating in activities with other members of the community that shares their culture. Activities are organized around the culture of a community, and as individuals participate in the community's activities, their

meaning-making is framed by their shared culture. Vygotsky's notion of the zone of proximal development (ZPD) allows us to imagine how this framing occurs. The ZPD constitutes "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). As a learner participates in a social activity, others attribute (cultural) meaning to the learner's actions; provide running commentaries on (culturally relevant) events; provide (culturally appropriate) assistance through gestures, speech, facial expressions; and they generally focus the learner on what to pick up on in order to effectively participate in the given activity. These others were classically defined as more knowledgeable others. Classroom research, however, demonstrates that students working in collaborative groups can create powerful ZPDs (Carr, 2002; Wells & Claxton, 2002). The meaning-making that results accumulates across several experiences in which an individual participates in a community's activities, allowing the individual to become inducted into the ways that the community makes sense of the world (Vygotsky, 1978).

The tools of a culture can be material, such as a baby's spoon, or psychological, such as the theory of evolution when used to explain why an organism currently looks and behaves the way it does. Tools permit their users affordances and constraints during their problem solving efforts. For instance,



Ramsey, Hungerford, and Tomera (1981) proposed a categorization scheme of citizenship skills to guide action training toward pro-environmental behaviors. They claimed skills could be acts of persuasion, consumerism, political action, legal action, ecomanagement, or a combination of these. Use of this scheme during EE instruction could grant students affordances and constraints. This scheme constrains students' proposed solutions to those ideas that are likely to be successful; at the same time, the scheme provides affordances by indicating different forms of action that could be taken to solve an environmental problem. Therefore, Ramsey, Hungerford, and Tomera's (1981) categorization scheme of citizenship skills is an example of a psychological tool that simultaneously provides affordances and constraints on students' (and teacher's) problem-solving activities. Socio-cultural theorists would view the products of science as material or psychological tools that enable us to solve problems. It is the culturally appropriate use of these tools that we are trying to teach in school (Stetsenko & Arievidtch, 2002).

Although culture accumulates over generations, it does not do so unchanged. Cultures are continually changing because as an individual become acculturated into a culture, the person transforms the culture's tools, beliefs, and values for specific purposes, improves them, and uses them in novel situations. Because all of these transformations occur in collaboration with others, cultural transformations propagate throughout the community, evolving along the way.

Therefore, socio-cultural theory maintains that knowledge exists not only in individuals, but also in communities and across cultural tools. In investigating knowledge and learning, it is important to examine individuals and communities simultaneously, as they are mutually constitutive.

In today's world, practically no one exists in a single culture (Aikenhead, 1996, Lemke, 2002). For instance, when I am at work, I exist in a culture of academia where we value rigor and claims backed up with evidence. When I go home in the evening, however, I enter my familial culture where there are different beliefs, values, and tools. If I were to expect my family to adhere to the values of academia, my marriage would soon fall apart, and likewise, if I were to expect to have a successful academic career by employing my family values, I would soon be out of a job. The point is that our multicultural world requires us to traverse cultural boundaries and effectively participate in multiple communities, sometimes simultaneously (Lemke, 2002). We are able to do so because we assume an identity appropriate to our role in the particular community in which we are participating at any given moment (Lemke, 2002). This is another reason why researchers must take into account not only the learner, but also the community in which the learner has assumed a particular identity in order to participate in the activity under observation.

In the classroom, teacher and students are members of their own community of inquiry. Everyone in this community has their own identities,

values, beliefs, and tools that originate from the numerous cultural, linguistic, gender, and experiential differences between them. We have a long history of disadvantaging those who use tools and possess identities, values, and beliefs that differ from the mainstream culture. Socio-cultural theory claims that transformation of culture occurs as new solutions to problems are discovered through the continual evolution of cultural values, beliefs, and tools. Such modification is likely through cross-cultural transformation, when different cultural communities come in contact and are open to modification of their own culture to work toward effective solutions to shared problems. Therefore, when we maintain our habits of disadvantaging non-mainstream cultures, we are risking the eventual development of an impoverished society that lacks novelty. The obvious question that environmental educators face is: How do we support cross-cultural transformation in the EE classroom so that novel solutions to the global environmental dilemma can be discovered?

There are a few intuitive answers to this question. First, simply telling students what they should be doing for the environment is not productive because it does not allow them to understand why such behaviors are effective. If they lack the conceptual understanding to know why pro-environmental behaviors are effective, how are they going to be able collaborate to find novel ways of combating the global environmental dilemma? Another possible answer is that our instruction must recognize that all human activity is not only intellectual but

also social and emotional (Mahn & John-Steiner, 2002; Wells & Claxton, 2002). This was demonstrated in Sadler and Zeidler's (2005) study that documented students' use of emotive and intuitive reasoning, in addition to rationalistic reasoning, while making decisions about socio-scientific issues. Taking this into account, our instruction needs to pay attention not only to the intellectual development of our students but their social and emotional development as well. A third answer to our question stems from an observation made by millions of teachers; students, especially those from poor or ethnic minority backgrounds, are disengaged (del Río & Álvarez, 2002). A common but over-simplified instructional implication of socio-cultural theory is to do group learning activities, as if groups were a magic bullet to ensure learning. The success of collaborative groups, however, relies on the meaningfulness of the problem under study to the students (del Río & Álvarez, 2002). If the problem is not meaningful to the students, students are likely to be disengaged, so the problem needs to be changed (del Río & Álvarez, 2002). This translates into yet another call for the contextualization of the science curriculum (Dalton & Tharp, 2002; del Río & Álvarez, 2002).

Bourdieu's (1986) concept of cultural capital lends itself well to what can be done to support cultural transformation in the EE classroom so that novel solutions to the global environmental dilemma can be discovered. Bourdieu (1986) argues that one's culture mediates how one interacts with institutions, such

as schools and classrooms. Through this mediation, cultural resources, such as values, norms, activities, and tools, are transformed into cultural capital that can be used to attain privilege. Institutions do not equally value the cultural resources of different groups, and this differential worth results in varying levels of cultural capital among individuals, and thus varying amounts of privilege and success (Bourdieu, 1986).

Every student brings to the classroom their beliefs, values, and tools that enable them to participate in the activities of their community. Some of the students' beliefs, values, and tools are valued in the mainstream classroom culture, which allows for the transformation of their beliefs, values, and tools into cultural capital, which in turn is exchanged for academic success. Similarly, some of the students' beliefs, values, and tools cohere with the culture of the discipline into which teachers are attempting to acculturate them. In other words, some students' cultures may share some of the same tools as the culture of science. These students, therefore, possess more cultural capital to exchange for success in the science classroom, providing the science classroom values the culture of science. For those students whose beliefs, values, and tools are not valued in the classroom, they have very little cultural capital to exchange for success. If our classrooms are to going to be all-inclusive, all students' beliefs, values, and tools must be valued so that all students have opportunities to exchange their cultural capital for success. Many interpret this as a call to devalue the norms and

practices of long-standing disciplines, such as science. I suggest such epistemological pluralism should be seen as an opportunity to modify our institutionalized beliefs, values, and tools so that they are better suited to dealing with novel problems, namely the global environmental dilemma. Furthermore, inclusion of traditionally marginalized groups in inclusive environmental education allows the possibility that societal injustices, such as environmental racism, can be further resisted by those at risk of receiving the unfair treatment.

*Supporting Students' Pro-environmental Motivation: A Synthesis of the Literature*

Much ground has been covered in this literature review. I will begin this section with a description of the instructional environment that will serve as the primary research setting for this study. This environment will be a genuine attempt to synthesize the literature detailed in this review. I will conclude this section by revisiting the research questions that will be investigated in this study.

EE instruction should involve the development of a particular type of scientific understanding that recognizes humans' roles in ecosystems and attempts to cultivate understanding of energy flow and matter cycling (Carlsson, 2002a,b; Eilam, 2002; Hogan & Fisherkeller, 1996; Leach, et al., 1992; Lin & Hu, 2003); active student participation in environmental problem-solving (Ramsey, Hungerford, & Tomera, 1981; Hsu, 2004; Hsu & Roth, 1999; Ryan, 1995); ample choice offered to students throughout the curriculum (Ryan & Deci, 2002); role models, problems, and cultural resources from the local community (Bourdieu, 1986; del Río & Álvarez, 2002; Dalton & Tharp, 2002); and co-constructed

classroom norms that value everyone's perspectives. Theoretical reasons for each of these elements will be explained further.

SDT claims that in order for one's need for competence to be supported, one must understand why one's actions are effective in bringing about desired outcomes while engaging in optimally challenging situations. Therefore, a particular type of ecological understanding is thought to partially support one's need for competence. According much of the ecology education literature ecological understanding must be based on the causal structures of ecosystems (Carlsson, 2002a,b; Eilam, 2002; Hogan & Fisherkeller, 1996; Leach, et al., 1992; Lin & Hu, 2003). Such understanding, however, must be also be relevant to today's world, which is why human participation in ecosystems must be integral to this understanding. When learners are attempting to solve an environmental problem (e.g., an optimally challenging situation) and when they understand humans as part of ecosystems, they are likely to be able to reason about how human actions can bring about environmental solutions (i.e., desired outcomes) through humans' participation in the ecosystem.

For example, consider an individual who understands matter cycling and humans' participation in matter cycling through our production of non-biodegradable materials. The individual knows that through our behavior, we synthesize materials with matter that would not otherwise react and form new compounds. The person would know that these materials are non-biodegradable because decomposers are not adapted to using these materials as sources of

chemical energy. Finally, the individual would know that any reduction of our interference with matter cycling processes through the production of non-biodegradable materials might help to solve our waste production and management problem. Such reduction could be accomplished through recycling of non-biodegradable materials, using alternative materials that are biodegradable, and reducing the use of materials.

People with this type of understanding are more likely to experience satisfaction regarding their need for competence because their understanding of humans' participation in Earth's matter cycling processes allows them to understand why their actions might contribute to desired environmental solutions. Engaging in environmental problem-solving in class is likely to create optimally challenging situations in which students are asked to use such understanding to devise environmental solutions, thereby satisfying students' need for competence (Ryan & Deci, 2002). Socio-cultural theory highlights how important it is for problems to be meaningful to students (del Rio & Álvarez, 2002; Dalton & Tharp, 2002). Similarly, SDT posits that offering students an element of choice supports their need for autonomy (Ryan, 1995). Therefore, students should be given options as they engage in problem-solving (Ryan & Deci, 2002), assuming they will make choices that make problems more meaningful to them. Meaningfulness can be further supported by the integration of local environmental problems and cultural resources (Bourdieu, 1986), such as familial knowledge and appropriate role models, into the curriculum. These instructional practices are also supported



by SDT because they are likely to support students' need for relatedness. Finally, such integration also increases the likelihood that students' cultural resources will be valued in the classroom, and therefore, they will be able to exchange their cultural capital (Bourdieu, 1986) for academic and environmental success.

### *Research Questions Revisited*

#### *Research Question 1*

In the first question, I ask to what extent does an SDT-guided environmental biology course differ from a non-SDT-guided course in the degree to which it fosters self-determined motivation toward the environment. Different instructors taught the two sections. The instructor of the comparison group was the usual instructor of the course at San Diego City College and taught the course using the approach he always uses. I taught the experimental group using an approach that was informed by self-determination theory and was intended to support students' basic psychological needs in ways that lead to increased self-determined motivation toward pro-environmental behaviors. This goal, however, did not take the place of other course content; both instructors covered the same general topics. The major difference between the approaches under study was not the absolute presence and absence of factors thought to support students' basic psychological needs. The real difference lied in the instructors' explicit goals. The comparison group's instructor indeed valued motivation toward pro-environmental behavior but did not explicitly attempting to supports students' basic psychological needs, as defined by SDT. I, however, attempted to support

those needs while teaching the same course. It is quite likely that the instructor of the comparison group supported students' basic psychological needs while not explicitly meaning to do so. I considered it unethical, however, to expose the students in the comparison group to an impoverished learning environment by attempting to remove all factors we hypothesize support students basic psychological need fulfillment. It was assumed that an approach informed by SDT and explicitly attempting to support students' needs contained more of these factors than one not informed by SDT but was still effective. The answer to this research question, along with the following research questions, allowed me to determine whether or not the hypothesized supportive factors are indeed supportive of students' basic psychological need fulfillment and whether or not these supports yield any difference compared to how the course was currently being taught. It was hypothesized that the experimental approach would be more effective in increasing self-determined motivation toward pro-environmental behaviors, as measured by the Motivation Toward the Environment Scale (MTES; Pelletier, et al., 1998; Villacorta, Loestner, & Lekes, 2003).

The contribution of this question is more than simply documenting an effective treatment. It documents an effect on pro-environmental behaviors when an EE instructor is defining as an explicit instructional goal to support students' basic psychological needs. It provides empirical support for the notion that EE instructors should consider what may support the basic psychological needs of

their own students, but it also validates the description of the approach used to develop instruction in this study. An approach to developing instruction (rather than a specific, pre-determined curriculum) is better than curriculum because it gives practitioners freedom to adapt instruction to be appropriate for the specific students in their classes and the particular communities in which the students live. Yet, such an approach provides sufficient structure that it can still guide practitioners in the development of instruction by outlining the parameters of instruction and providing theoretical explanations of why those parameters lead to desired outcomes.

#### *Research Question 2*

In the second question, I asked what the multiple influences are on fostering self-determined motivation toward the environment in an SDT-informed EE course. According to SDT, one's perceptions of support for basic psychological needs determine the degree to which one's needs are satisfied. Degree of need satisfaction, in turn, affects one's self-determined motivation. This question allows me to determine whether or not students' perceptions of need support in the classroom affect students' self-determined motivation toward pro-environmental behavior by fulfilling their basic psychological needs. It was hypothesized that students' perceptions of basic psychological need supports in their environmental biology classroom would positively correlate with their need satisfaction, which would in turn, correlate positively with their self-determined

motivation toward pro-environmental behaviors. In other words, I hypothesized a path of causality (Figure 4) in which students' perceptions of need supports are mediated by need satisfaction to give rise to their self-determined motivation toward pro-environmental behaviors.

This question sought to define effective predictors of motivation of pro-environmental behaviors. The path of causality that results from this question is a major accomplishment for two reasons. First, the path demonstrates the appropriateness of SDT to informing EE research that attempts to bring about behavior change. Second, such a path provides a new theoretical conceptualization of how pro-environmental behaviors can be motivated in the EE classroom. Although these are important, the strength of this question lies in its union with the other questions involved in this study. This path will provide a statistical model that, in combination with the remaining research questions, is theoretically grounded and recognizes the socio-contextual influences on learning and the development of self-determined motivation toward pro-environmental behaviors.

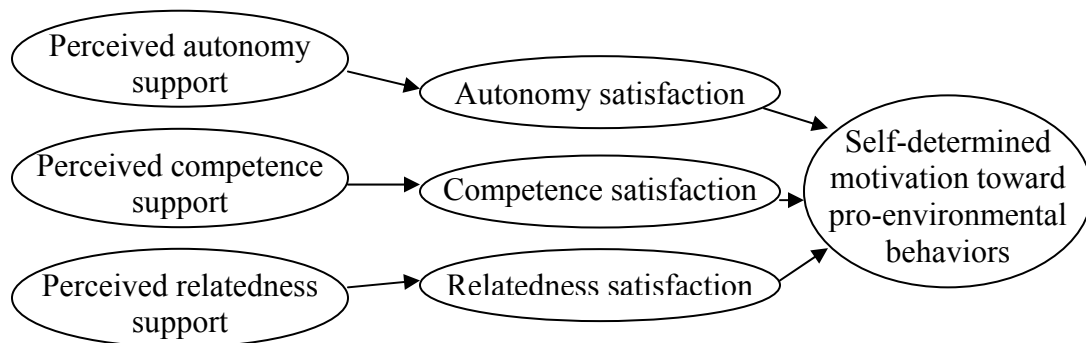


Figure 4. Hypothesized path of causality describing how perceptions of basic psychological need support are mediated by need satisfaction to lead to self-determined motivation toward pro-environmental behaviors.

### *Research Question 3*

Researchers applying SDT to pro-environmental behaviors claim that a person's need for competence is supported by being noncoercively told what behaviors are pro-environmental, how to engage in them, and why they are successful in bringing about desired environmental outcomes (Pelletier, 2002). In this study, I am claiming that this characterization of competence is problematic for two reasons. First, simply being told why a behavior is likely to be successful does not necessarily foster understanding. Second, the typical characterization of competence support does not recognize the importance of optimally challenging situations in supporting one's sense of competence.

I argue that knowing why a behavior is "pro-environmental" requires a particular type of scientific knowledge. Throughout this dissertation, I distinguish between the terms concept, understanding, and conceptualization. An idea that a student has in his mind is termed a concept, and the collection of concepts and the relations between them is referred to as the students' understanding. When a

student's understanding is put into action during problem-solving, the student's understanding is conceptualized. Thus, a student's conceptualization is how his/her understanding is mobilized in a particular problem-solving context. I claim that, in order for satisfaction of students' need for competence to lead to self-determined environmental motivation, students' scientific understanding needs to allow them to carry out three related accomplishments during problem-solving. First, their understanding should allow them to conceptualize human participation in Earth systems. Second, their understanding should allow them to recognize what aspects of the system lead to environmental problems. Finally, their understanding should allow students to reason about what pro-environmental behaviors can be performed to remedy those environmental problems. To summarize, their scientific knowledge needs to be human-inclusive as they solve environmental problems.

I also argue that when studying students' sense of competence, the importance of optimally challenging situations (Deci & Ryan, 1990) cannot be ignored. In other words, students' scientific understandings, or the scientific concepts and the relations between concepts in a students' mind, is not sufficient for us to comprehend how students become motivated to engage in environmental problems. Rather, students' conceptualizations, or how their scientific concepts and the relations between them are realized while engaging in optimally challenging situations, are more likely to offer insight into how students can become self-determined toward pro-environmental behaviors. Therefore, for this

research question, I ask what characterizes students' scientific conceptualizations as they solve environmental problems intended to be optimally challenging and to what extent do their conceptualizations relate to the satisfaction of their need for competence. These analyses are then synthesized to characterize competence support in an environmental biology course.

#### *Research Question 4*

In the final question, I ask what classroom features exist when students report that their basic psychological needs are being highly fulfilled or thwarted. This question seeks to describe relevant socio-contextual features that students cite when they indicate that the satisfaction of their basic psychological needs was being supported or thwarted. Throughout this literature review, I have alluded to several a priori hypotheses about what I think is likely to support or undermine students' basic psychological need satisfaction. They will be finally described here because this research question seeks evidence to support these hypotheses.

I hypothesized that the need for competence is partially fulfilled by a rich, scientific understanding of Earth systems in which humans are understood as an organism participating in ecosystems in interdependence with other organisms and abiotic components of the ecosystem. To understand further why such an understanding would support students' competence, consider Deci and Ryan's (1990, p. 243) definition of the need for competence: "The need for competence encompasses people's strivings to control outcomes and to experience effectance; in other words to understand the instrumentalities that lead to desired outcomes

and to be able to reliably affect those instrumentalities.” If one understands ecological as human-inclusive, one is better able to place him/herself in the system, determine the consequences of one’s actions within the system, and reason about what actions would bring about desired environmental changes. This differs from the typical characterization of what defines competence relative to pro-environmental behaviors. It has been proposed that non-coercively providing “information about specific actions to solve a problem” (Pelletier, 2002, p. 221) can foster a learner’s sense of competence. I argue that telling students about actions probably does not help learners understand why actions may be beneficial, and they are therefore unlikely to “understand the instrumentalities that lead to desired outcomes” (Deci & Ryan, 1991, p. 243). Furthermore, simply providing information to learners without fostering understanding compels learners to rely on the providers of information (e.g., teachers) for telling them what actions should be taken. In this scenario, the learner may perceive the source of the action as external (i.e., from the teacher), rather originating from oneself. Thus, such an approach could potentially undermining two basic psychological needs, competence and autonomy. Such a scenario is highly unlikely to lead to self-determined motivation for pro-environmental behaviors.

Alternatively, students may feel more competent if they deeply understand the functioning of ecosystems as they include humans, and explanations for why pro-environmental behaviors are beneficial can emerge from that deep ecological understanding. Consider the two learners in the following example. The first



learner has attended an educational program in which they were non-coercively told what pro-environmental actions they could take to solve the problem of global warming; the other learner has taken a course in which she developed a deep ecological understanding and students were instructed to devise pro-environmental action plans relating to global warming. When asked why driving a fuel-efficient car would be beneficial, the first learner's explanation would likely be because fuel-efficient cars create less pollution or emit fewer greenhouse gases. When asked the same question, the second learner, however, would likely explain that global warming is being caused by an imbalance in the carbon cycle; humans, through their activities, are emitting carbon-based molecules, which trap heat, into the atmosphere at a higher rate than the rate at which organisms are sequestering carbon. Therefore, fuel-efficient cars are better because they emit fewer carbon-based molecules into the air. The difference between these two students becomes more dramatic when they are asked what additional actions may be taken to slow global warming. The first student must rely on his or her memory of what information was given in the educational program. The second student, however, can use his or her human-inclusive, energy-and-matter-focused, ecological understanding as a psychological tool to conclude that slowing global warming can be accomplished by any action that either slows the rate at which carbon-based molecules are emitted into the atmosphere (e.g., reduce the burning of fossil fuels, scale down factory farms, etc.) or increases the rate at which carbon is sequestered (e.g., plant and preserve trees, conserve soil, etc.). This is a

hypothetical depiction of how this type of ecological understanding could support one's competence regarding pro-environmental behaviors by allowing them to reason about how humans can be effective within matter cycling systems to bring about desired outcomes. Such understanding may provide a better explanation of why actions are effective and/or a means for articulating new actions that can be taken for old and arising environmental problems. This study investigated the times when students feel high and low competence to determine the extent to which they correspond to times when students are developing and/or using such deep ecological understanding during problem-solving.

I hypothesized that the need for relatedness would be fulfilled in this environmental biology classroom in two ways. First, I expected that students would feel their need for relatedness will be particularly fulfilled on the days when teacher and students are participating in classroom discussions in which they share their concerns, ideas, plausible solutions, and frustrations regarding the environment and humans' impact on it. It was thought that this will offer opportunities for students to bring their cultural ways of understanding to bear in the classroom so that their culture capital is valued, which will in turn foster a sense of community in which students can be free to be themselves while caring for the environment. Second, I expected students' need for relatedness will be highly satisfied on the days in which we connect classroom activities with the larger community involving their school, families, and local activist groups by investigating local environmental problems that involve the larger community. It

was thought that this would support students' need for relatedness by highlighting the environmental aspects of the connections they already have with their larger community. This was done with the intention that once the course was finished, students would still have environment-valuing supports for their sense of relatedness outside of the classroom in their community.

Finally, I hypothesized that students would report feeling highly autonomous during the days in which they are offered choice about how to investigate, present their findings, and/or solve an environmental problem being addressed in class. It is thought that environmental problem-solving would require students to conceptualize their scientific understanding and would thereby support autonomy because students would become less reliant on an authority (e.g., teacher, textbook) for scientific knowledge and come to consult their own knowledge base. Therefore, it was expected that when students reported high feelings of autonomy, they also cited their participation in activities that asked them to use their own scientific understanding in solving environmental problems.

Throughout this literature review, I have posed several hypotheses about what these features are, but I have no empirical evidence to support my claims. This research question will allow me to gather such evidence, which will allow me to make evidence-based claims about what kind of instruction, activities, and classroom community features support or undermine students' basic psychological needs in an environmental biology classroom. Because this question was investigated qualitatively and required the development of emergent

codes when my hypotheses did not fully describe the data, this question also allows me to posit alternative classroom features that support students' basic psychological needs.

The sum of the results from all four research questions allows me to piece together a picture of what an environmental biology course looks like if it is successful in motivating pro-environmental behaviors. This picture not only includes a theoretically grounded statistical model, but it is supported by thick descriptions of what socio-contextual features of an EE classroom support the relations observed in the model. This study provides support for an approach that other practitioners can adopt in constructing EE courses and classroom communities that support students' basic psychological needs so that they become self-determined toward pro-environmental behaviors.

## CHAPTER 3: METHODOLOGY

In this chapter, I will first describe the research setting in which this study took place by sharing demographic information about the school and participants, and overviews of the environmental biology course and curricula in both sections of the course. Then, I will describe for each research question the methods used to collect data.

### *Research setting*

#### *School*

This study took place at San Diego City College (SDCC), a community college located in downtown San Diego, California that serves approximately 15,000 students (SDCC, 2004). Within SDCC's service area, 36.2% of the residents have earned a college degree, compared to 42.6% in the city as a whole (SDCC, 2004) and 36% compared to the state as a whole (NCHEMS, 2005). Sixty-six percent of SDCC's students qualify for financial aid (SDCC, 2004). The ethnic breakdown of SDCC's student population is 33.2% White, 28.0% Latino, 14.4% African-American, 6.8% Asian/Pacific Islander, 4.1% Filipino, 1.2% Native American, and 12.3% other or unknown (SDCC, 2004). The majority (44.9%) of enrolled students are 18-24 years old, although the percentage of students over 24 years has been increasing since 1996 (SDCC, 2004). Slightly more females (52.5%) attend SDCC than males (47.5%) (SDCC, 2004). Only 17.2% of students attend SDCC full-time ( $\geq 12$  semester hours) (SDCC, 2004). Forty-five percent of SDCC's students intend to transfer to a four-year institution,

and this number is rising due to state budget cuts that have increased tuition costs and decreased enrollment at four-year schools, causing university-bound students to enroll in community colleges, including SDCC (SDCC, 2004). There is concern that this trend will permit the displacement of first-generation college students by university-bound students who have more enrollment expertise (SDCC, 2004).

### *Participants*

This study took place in two sections of *Biology 101: Issues in Environmental Biology*. One section served as the comparison group for the first research question and will be referred to as the comparison section. The other section was taught from an approach informed by self-determination theory (SDT) and was the context in which the second, third, and fourth research questions were investigated; this section will be called the experimental section.

The experimental section contained 20 students, 15 of whom participated in the study. The comparison section contained 17 students, twelve of whom participated in the study. In the experimental section, there were seven males and eight females, while the twelve participants in the comparison section were evenly split according to gender. Participants were asked the question, “How do you describe your ethnicity?” Participants who self-identified as Latino, Latina, Latin, Hispanic, Mexican, or Mexican-American are described here as Latino/a. Participants who self-identified as White, Caucasian, or Caucasian-American are described here as White. Participants who self-identified as Asian, Filipino, or

Laotian are described here as Asian. Participants who self-identified as Black or African-American are described here as Black. Participants who self-identified as “mix,” “diverse,” or “mestizo” are described here as Multiracial. Gender and ethnicity statistics are detailed in Table 1.

Table 1. Demographic information for participants in the experimental (E) and comparison (C) sections.

<b>Section</b>	<b>Total</b>	<b>Males</b>	<b>Females</b>	<b>Latino/a</b>	<b>Asian</b>	<b>White</b>	<b>Black</b>	<b>Multi-racial</b>
E	15	7	8	6	3	3	1	3
C	12	6	6	5	0	5	1	1

In the experimental section, two students were in the 30-39 age range, and all others were in the 18-29 age range. In the comparison section, two students were in the 30-39 age range; one student was in the 40-49 age range, and all others were in the 18-29 age range. Ten of the 15 participants in the experimental section were first-generation college students. Eight of the twelve participants in the comparison section were first-generation college students.

#### *Course*

Biology 101 is an introductory course for non-majors and is transferable to four-year institutions as a laboratory science credit. The course has both classroom and laboratory components. In both sections of the course, students met twice a week for 75 minutes for the classroom portion and once a week for 185 minutes for the laboratory portion. There are no science prerequisites for the course, although students must pass two English courses with a C or better or

obtain a satisfactory score on a writing skills placement exam. The course does not serve as a prerequisite for any other course. The course catalog states that this course addresses “contemporary issues in environmental biology” including “basic ecological principles, biodiversity, human population dynamics, human resource management, and pollution” (SDCC, 2005-2006, p. 120). The course emphasizes southern California’s environmental issues and involves field trips. In order to be successful in the course, students are expected to spend 3-7 hours per week outside of class completing assignments, reading, and reviewing course material.

#### *Curricular Overview*

Both sections covered the same topics and spent approximately the same amount of time on each topic (*Appendix II: Syllabi*). Both sections used the seventh edition of the text, *Environmental Science: A Systems Approach to Sustainable Development* by Daniel Chiras (2001), which was supplemented by a department-written guide entitled *Biology 101 Laboratory and Lecture Guide* (Singer et al., 2005). Both sections involved five exams. Each instructor completed a questionnaire (*Appendix III: Instruments*) describing what they perceived their instruction to be (Table 2). While the comparison section was not explicitly guided by SDT, it did contain elements, such as a service learning assignment, that were likely to support students’ basic psychological needs. Therefore, it was not a true control in that it lacked all supportive elements the



experimental section was attempting to provide. Significant differences between the sections are detailed in Table 2 and explored next.

Table 2. Experimental and comparison instructors' responses describing their instruction.

Instructional Feature	Experimental Instructor	Comparison Instructor
Purpose of lecture	Give important science content to students in response to specific student inquiries; address students' misconceptions about important science content.	Give important science content to students; address students' misconceptions about important science content; give important science content to students in response to formative assessment errors.
Use of outside resources	Field trips to locations in the community that are relevant to the topics being addressed in class; guest speakers who hold expertise that is relevant to the topics being addressed in class; newspaper articles from the local community that address relevant topics; interviews of students' family members/friends/acquaintances who hold expertise that is relevant to the topics being addressed class.	Field trips to locations in the community that are relevant to the topics being addressed in class; newspaper articles from the local community that address relevant topics; outside projects such as the "vacant lot study" and service learning.
Student choice	Offer students choice regarding how they complete assignments and how they solve scientific/environmental problems.	Offer students choice regarding how they complete assignments and the type of outside projects they complete.

Table 2 continued.

Instructional Feature	Experimental Instructor	Comparison Instructor
Emphasis of pro-environmental behaviors	Ask students to brainstorm behaviors that may be beneficial toward a particular environmental problem; ask students to give explanations for why certain behaviors may be beneficial toward a particular environmental problem.	Tell students behaviors and the evidence for the consequences of those behaviors.
Environmental problem-solving	Introduce the problem to students and prompt them to devise plausible scientific explanation/remedies to the problem with their classmates, after which the class discusses students' explanations/remedies.	Introduce the problem to students and describe the scientific explanation/remedy to the problem.

The comparison section was taught by the usual instructor of Biology 101 at SDCC who has been teaching the course for several years and consistently receives praise from his students on instructor/course evaluations. This section was taught primarily through lecture and whole class discussion and followed a sequence of predetermined laboratory activities that demonstrated the phenomena addressed in lectures. There were five exams in the comparison section and included short answer, matching, and multiple-choice questions, concept-mapping, and 5-part-analysis problems. This section also involved 15-minute quizzes given each week, except for weeks involving exams, in the classroom

portion of the course. Other quizzes were given at the end of each laboratory period with the exception of those laboratory periods that are field trips guided by someone other than the instructor, in which case students were asked to write a thank-you letter to the guide explaining what was learned. Extra-credit was offered in the comparison section.

The lecture portion of the experimental section involved problem-solving activities, whole class and small group discussions, and limited lecture. In this section, three general phases comprised each unit. In the first phase, the scientific and social aspects of a new issue was introduced by looking at the environmental issue through an everyday resource, such as the local newspaper, interviews of community members, guest speakers from the community, or field trip. The introduction concluded with a summarizing whole class discussion. The introduction was followed by engaging in a problem set (*Appendix V: Conceptualization Problem Sets*). For each problem, student groups were given a prompt asking them to consider and discuss a situation and devise a solution or explanation for the phenomenon being addressed by the problem. Student groups would then share their explanations with the class in a whole class discussion. This process was repeated several times, depending on the particular problem set. Each problem set concluded with a general conclusion that was integrated into the final phase of the unit. To conclude each unit, both scientific and social aspects of the problem were addressed in a student-guided lecture in which students were

encouraged to reflect on the problem-solving activity, ask related questions, and use their everyday knowledge.

Assessment in the experimental section was accomplished through five exams, laboratory worksheets/homework, reflection writing, a group project, and participation in class discussions. Exams were composed of short-answer, multiple choice, multiple-choice with explanation, and essay questions. Students performed both classroom and laboratory activities in the same groups which were determined at the beginning of the semester through the use of the 15-item New Ecological Paradigm (NEP; Dunlap et al., 2000; *Appendix III: Instruments*), which measures a person's pro-environmental orientation (or lack thereof). Heterogeneous groups of 3-4 students were formed according to responses on the NEP. This was done to attempt to avoid having a group(s) that only contained students who do not care about the environment and the issues addressed in the course.

Student groups were required to do a project in which they investigated both the social and scientific aspects of an environmental issue of their choosing, construct an environmental action plan (EAP), share their findings and EAP with the class, and lead a classroom activity. At the beginning of the course, after student groups had been established, student groups were given time to review the syllabus and decide which topic they wanted to investigate. Their presentation/activity was worked into the course when the content was being addressed according to the syllabus.

*Research Question 1*

In the first question, I ask to what extent does an SDT-informed environmental biology course differ from a non-SDT-informed course in the degree to which it fosters self-determined motivation toward the environment. This question was answered by administering the Motivation Toward the Environment Scale (MTES; Pelletier, et al., 1998; Villacorta, Koestner, & Lekes, 2003) to participants in the experimental and comparison sections at the beginning, end, and six months following the course. For the first two administrations of the MTES, a fellow science educator distributed the questionnaires, read the instructions aloud, gave students an opportunity to ask questions, and collected the questionnaires when they were finished. Participants' addresses and email addresses were collected at the end of the course so that the final MTES questionnaire could be mailed to the participants. A pre-stamped, addressed envelope was included with the questionnaire so that participants could mail the questionnaire back. Emails were used if mailed questionnaires were returned in the mail. For all three questionnaire administrations, the MTES was combined with the General Need Satisfaction Scale (GNSS; Illardi, et al., 1993). The second administration (at the end of the course) also included basic demographic items. The version of the MTES/GNSS questionnaire administered at the beginning of the course and six months following the course will subsequently be referred to as Questionnaire A, and the version administered at the end of the course will subsequently be referred to as Questionnaire D

(*Appendix III: Instruments*). All questionnaires were coded with students' birth dates to add a layer of confidentiality protection. Students took no more than fifteen minutes of class time to complete Questionnaires A and D.

The MTES is a 26-item questionnaire that measures an individual's motivation toward pro-environmental behaviors. The MTES consists of six subscales that correspond to the motivation types posited by SDT: intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, and amotivation (Pelletier, et al., 1998). This measure was validated through a series of four studies conducted by Pelletier et al. (1998) that demonstrated the scale's validity in inferring individuals' self-determination toward pro-environmental behaviors. The first study consisted of interviews and the development of a preliminary 60-item questionnaire; exploratory factor analysis was used to reduce the number of items to four per subscale (Pelletier, et al., 1998). A second study verified the factorial structure of the 24-item questionnaire resulting from the first study, measured correlations between the subscales, and retested the internal consistency of the subscales through confirmatory factor analysis (Pelletier, et al., 1998). The third study assessed relationships between the MTES and other environmental and psychological constructs (e.g., self-reported pro-environmental behaviors, self-esteem) and evaluated its susceptibility to a social desirability bias factor (Pelletier, et al., 1998). This study determined that self-determined motivation, as measured by the MTES, positively correlates with internal locus of control and self-esteem,

thereby supporting the autonomy and competence constructs posited by SDT (Pelletier, et al., 1998). Undesirable factors, such as the social desirability factor, were either unrelated or negatively related to self-determined motivation, as measured by the MTES (Pelletier, et al., 1998). The final study confirmed acceptable test-retest reliability of the MTES across a 5-week period (Pelletier, et al., 1998). Villacorta, Koestner, and Lokes (2003) further validated the MTES by showing that one's MTES scores (i.e., self-reported) correspond to reports from peers regarding environmental self-determination and that environmental self-determination is a construct separate from other types of self-determination, namely academic and political self-determination. Given the extensive validation of the MTES, I consider it an adequate measure for helping to answer the first research question.

At the end of the course, there were twelve participants from the comparison section and fifteen participants from the experimental section ( $n = 27$ ). However, only six participants from the comparison section and eleven participants from the experimental section ( $n = 17$ ) returned the questionnaires that were mailed to them six months following the end of the course. Due to the low response, and resulting small sample size, repeated-measures analyses of variance (RM-ANOVA) are performed on each subscale of the MTES for the actual data set ( $n = 17$ ) and an estimated data set with imputed values for the missing data ( $n = 27$ ). Because the effect of the interaction between time and section indicates how the sections differed over time, only the interaction will be

considered in the analyses. This data imputation assumes that those participants who failed to return the third questionnaire are not significantly different from those participants who returned it. In order to insure this was the case, pre- and post-course scores on all subscales of the MTES from these two groups were compared using RM-ANOVA. No significant differences were observed between these groups. The additional analyses of imputed data indicate significance levels if the sample size were to be larger and the same trends were observed.

### *Research Question 2*

In the second research question, I ask what are the multiple influences on fostering self-determined motivation toward the environment in an SDT-guided environmental biology course. Three measures of students' perceptions of basic psychological need supports were administered to the experimental section. The first measure, the Learning Climate Questionnaire (LCQ; Black & Deci, 2000), contains six items and measures students' perceptions of how well the students feel the instructor supported their autonomy. The second measure, the Connectedness Subscale of the Classroom Community Scale (CCS; Rovai, 2002), contains ten items and measures students' perceptions of how well their classroom community supports their need for relatedness. While the final measure was intended to involve an adaptation of the "understanding systems as the context for decision-making" dimension of the Whole Systems Rubric (Jaime Cloud, November 8, 2005, personal communication; *Appendix III: Instruments*) by assessing students' perceptions of how well they believe they understand



systems as they include humans while they collaboratively constructed their EAPs, this measure was deemed unusable because all students ranked themselves exactly the same (i.e., the highest score possible). The resulting lack of variability prohibited any quantitative comparison of data. Therefore, students' perceptions of competence support were approximated using Morrone, Mancl, and Carr's (2001; *Appendix III: Instruments*) ecological knowledge questionnaire, which was administered simultaneously with the final exam for the course.

The LCQ and CCS were combined into a questionnaire called Questionnaire C (*Appendix III: Instruments*) and were administered during the twelfth week of the course. GNSS data from Questionnaires A and D were used to measure students' basic psychological need satisfaction. GNSS data from Questionnaire D, Questionnaire C, and the environmental knowledge questionnaire were used to analyze the hypothesized path of causation (Figure 4, *Chapter 2: Literature Review*) through path analysis (Loehlin, 2004).

### *Research Question 3*

For this third question, I ask what scientific conceptualizations do students use as they engage in environmental problems and how do they relate to their competence satisfaction. In other words, I seek to offer an alternative characterization of competence support in an environmental biology classroom that incorporates students' scientific knowledge. I claim that, in order for satisfaction of students' need for competence to lead to self-determined

environmental motivation, students' scientific understanding should allow them to:

- i. conceptualize human participation in Earth systems;
- ii. recognize what aspects of the system lead to environmental problems;
- iii. reason about what pro-environmental behaviors can be performed to remedy those environmental problems.

I also argue that when studying students' sense of competence, the importance of optimally challenging situations (Deci & Ryan, 1990; *Chapter 2: Literature Review*) cannot be ignored. In other words, how their scientific concepts and the relations between them are realized while engaging in optimally challenging situations are likely to offer insight into how students can become self-determined toward pro-environmental behaviors. Therefore, for this research question, I investigate students' conceptualizations while solving problems intended to be optimally challenging and their competence satisfaction while engaging in these problems.

Throughout the remainder of this section, I will briefly describe the problem sets in which students' scientific conceptualizations will be examined; problem sets are fully detailed in *Appendix IV: Conceptualization Problem Sets*. I will then describe the sources of data that were used to address this question, and explanations of how classroom and interview data were analyzed will follow. This section will conclude with an explanation of how the resulting analyses were

synthesized to generate hypotheses about the role that scientific conceptualization plays in supporting competence in an environmental biology course.

*Problem Sets*

*Problem #1: American Robins* addresses global warming and was designed to further students' understanding of natural history (e.g., migration patterns, importance of seasons) and how organisms might be affected by climate change. It asked students to consider data collected at the Rocky Mountain Biological Field Station over the past four decades. These data indicate that spring is coming earlier at lower altitudes in the Rocky Mountains while snow at higher altitudes is melting at the same time of year as it has historically, even though temperatures are increasing sooner in the season. American robins spend the winters at lower altitudes and migrate to higher altitudes during the summer where they breed and eat plants whose growth is stimulated by snowmelt. Students were asked to hypothesize about how the earlier spring at the lower altitudes coupled with normal timing of snowmelt would affect the robins. Following this prompt, students were then asked how yellow-bellied marmots, who hibernate at the higher altitudes and do not migrate, would be affected by these same environmental phenomena.

*Problem #2: Colorado River Water Pollution* addresses the effects of water pollution on San Diego's drinking water. I wanted this problem to induce students to reason about where their water originates and how human actions in distant places affect us through the environment. It also was intended to

necessitate practice of useful skills such as map-reading and spatial orienteering. It begins by asking students to familiarize themselves with a series of maps that depict the route of the Colorado River, various facilities (e.g., factories) along its banks, and other human-made developments (e.g., Colorado River Aqueduct, Parker Dam). Students were then asked to speculate which facilities likely affect San Diego's drinking water supply. This activity took place after a presentation from a guest speaker who informed them that the majority of San Diego's drinking water comes from the Colorado River via the Colorado River Aqueduct.

*Problem #3: Channel Island Foxes* was designed to help students develop scientific understanding of how habitat destruction via urbanization and introduction of non-native species affects endangered species. The problem first asked students to consider how an introduced species, the feral pig, affects the native and endangered island foxes and the native ecosystem on the Channel Islands. Next, it asked students whether or not they think the pigs should be eradicated from the Islands. A prompt then informed students that another endangered species, golden eagles, have colonized (i.e., were not introduced by humans) the islands and prey on both the pigs and foxes. Finally, students were asked to pretend they are natural resource managers on the Islands, to decide whether or not eradication of the pigs is a good idea given the added eagle dimension, and to try to devise a sensible plan to protect both endangered species.

*Problem #4: Western and Arroyo Toads* addresses evolution and differs from the previous problem sets in that humans are not directly involved in this

environmental issue. This problem was included in the course because it was designed to help students better understand evolution. Throughout the course, students' ideas about evolution came into play more than I expected while discussing environmental problems. Therefore, a pedagogical decision was made to address evolution more thoroughly; I attempted to use this problem and the following problem, *Problem #5: Baja Rodents*, to help students develop scientific understanding of the concepts of fitness, gene flow, and speciation. Because humans are not causal agents or potential participants in an environmental solution in these problems, analyses of students' reasoning while engaging with these problems did not include a discussion of the human-inclusiveness. Nevertheless, data from these problems are still analyzed according to the nature of the students' scientific conceptualizations, competence satisfaction, and what constitutes an optimally challenging situation.

The *Western and Arroyo Toads* problem begins by letting the students know that males of one species, the Western toads, do advertisement calls to attract females, while the males of the Arroyo toads do not. Furthermore, females of both species are attracted to the advertisement calls. The students were asked who is likely to attract the most females and which males are likely to be more fit (i.e., as in "the survival of the fittest," which had been mentioned repeatedly throughout the course in whole class discussions). They were then told that when a hybrid is formed between the species as a result of a female Arroyo toad mating with a male Western toad, the hybrid is sterile; students are asked if this affects

their fitness and why or why not. In the next prompt, the students were asked to imagine a rare case in which, by chance, a hybrid is fertile and asked to hypothesize about whether or not the Arroyo and Western toads would be considered the same species 200 years from now.

In the *Baja Rodents* problem, students were informed that about five million years ago, the Baja Peninsula was attached to mainland Mexico, and there was one species of rodent across all of the land that is now separated by the Sea of Cortez. However, now the rodents on mainland Mexico are considered a different species from those on the Baja Peninsula. Students were asked to hypothesize about how this could have happened.

The final two problem sets, *Problem #6: A Day in the Life of an Average Joe* and *Problem #7: Environmental Careers*, also served different purposes than the first four problems. The *Average Joe* problem put students into everyday decision-making contexts and asked them to make the choice that is most environmentally friendly. They were also asked to explain to their groups and then to the class why their choice is most environmentally friendly. The purpose of this activity was to encourage students' to think about the many behavioral modifications that one could make in one's lifestyle to be more environmentally friendly and to see if and how students integrated their scientific knowledge into everyday decision-making.

The *Environmental Careers* task asked students to match a description of a person's likes and dislikes with an appropriate collegiate program of study and

an appropriate career path. A tangential purpose of this activity was to help students understand how one chooses a major that will allow one to pursue his/her career of interest, which is knowledge that many students like those in this course are lacking (Pascarella et al., 2004). Another purpose was to inform them of various environment-related careers that are available. The purpose most relevant to the research question was to observe students' discussing environmental career paths and infer whether or not they felt they were capable of pursuing such a career. Their perspective on whether or not they feel capable of pursuing an environmentally related career path gives insight into the satisfaction of their need for competence regarding the global environmental dilemma.

#### *Data Sources*

This research question will be answered using three sources of data: (a) video recordings of a focus group as they engaged in problem-solving during class, (b) video recordings of stimulated-recall interviews of the focus group members, and (c) scores from a basic psychological need instrument. Meg, Carol, and Juan (pseudonyms) comprised the focus group. This group was chosen based on their willingness to participate during the first week of class, high attendance and minimal tardiness during the first two weeks of the course, and availability to participate in interviews immediately after class.

During every class session, beginning on the fourth session, a video camera was set up to record the focus group, while an additional camera recorded the entire class. All three students in the focus group were interviewed three times

throughout the semester; each interview occurred following a class period in which one of the above problem sets was addressed. Two trained science education colleagues conducted the interviews. Because I was the instructor in the course, it would have been inappropriate for me to conduct the interviews before submitting their grades.

The one-hour interviewer training session focused on informing the interviewers about the research goals, important elements of self-determination theory, and the specific research questions. As I described each item of the interview protocol (*Appendix IV: Interview Protocol*), I explained to the interviewers what information I was intending to decipher from the item. They were free to ask questions throughout the meeting, and we negotiated meaning until we felt we had reached intersubjectivity regarding their role in the research. I also provided logistical information, such as how to get to our classroom, where to park, and how to work the cameras. After training the interviewers, I gave the interviewers a course schedule, hard and electronic copies of the interview protocol, and contact information for the students and each other. The interviews were arranged separately between the participants and the interviewers. While the intention was that I be blind to the interview days, I was able to predict which days an interview would take place by considering the number of remaining interviews and the number of remaining days in the semester. Before each interview, I noted the time during which the problem-solving activity took place and located it on the videotape after class so the recording was ready for the



interview. On the days that the interviewer and participant arranged, the interviewer arrived near the end of class, met with the participant, and conducted a 20- to 45-minute interview using the recording I had queued up. The interview itself was also video recorded.

There was one interview following each of the problem sets described earlier, with three exceptions. First, since the *Western and Arroyo Toads* problem occurred across three class periods, all three students were interviewed about this problem. Second, on the day that the focus group was scheduled to do their group presentation on human population growth, the projector that they intended to use was not working; Juan, who was interviewed that day, was unable to engage in the scheduled problem set because he was trouble-shooting the projector problem. Therefore, he was instead interviewed about his project on human population growth. The third and final exception is in the case of *Baja Rodents*. This problem took place on the same day that the *Western and Arroyo Toads* was wrapped up, so the interview addressed the conclusion of that problem. Nevertheless, in-class data from *Baja Rodents* is still analyzed for students' scientific conceptualizations.

After each class period, students completed the nine-item Daily Need Satisfaction Scale DNSS, which is a version of the General Need Satisfaction Scale for relationships (LaGuardia, et al., 2000) that had been modified to be appropriate for the classroom. This instrument, coupled with students' comments

during interviews and in-class discussions, is used to infer the satisfaction of students' need for competence.

### *Data Analyses*

Analyses were informed by Strauss and Corbin's (1994) grounded theory methodology, which was used in combination with a coding scheme developed by Engle (2006). While conducting analyses, my goal was to mentally set aside my a priori hypotheses of what I thought is likely to support students' need for competence so that I could concentrate on what transpired in the data. Analyses occurred in three general phases. First, students' scientific conceptualizations as they engaged in the problem sets were analyzed. Then the stimulated-recall interviews were examined. Finally, these two data sets were linked to generate grounded hypotheses about what seemed to support students' sense of competence as they engaged in the problem sets. Each of these phases will be fully described in turn.

### *Analysis of Classroom Data: Students' Scientific Conceptualizations*

This analysis began with the creation of transcriptions using Transana 2.12 software of the focus group's discussion on the days on which interviews took place. After recordings were transcribed, I created handwritten field notes on the transcriptions to become more familiar with the data. After creating field notes, I open-coded (Strauss, 1987a) the transcribed data in which I described students' understandings of key scientific phenomena as they engaged in the problem solving situations. By inferring students' scientific concepts and how they seem to

be related to each other from the students' perspectives, I established a context in which their causal reasoning took place. In addition, students' scientific understanding is important to building an explanation of what scientific knowledge might coexist with particular states of competence satisfaction.

Once the concepts that students used during environmental problem solving were identified, students' causal reasoning was examined. Patterns in students' causal reasoning are important because genuine environmental problems are multifaceted and, thus, require coordination of various causal factors and the development of several components to a solution. If students are to feel competent as they develop environmental solutions, their causal reasoning likely plays a role in how effective they believe their solutions to be. The collection of causal reasoning patterns that emerged as students engaged in the problems posed in class and the scientific concepts they used constitute their scientific conceptualizations. Three dimensions of their causal reasoning are examined in this study: multicausality, gradedness, and human-inclusiveness. Each of these code types were put forth by Engle (2006) and will be explained in turn.

First, to infer students' multicausal reasoning, I examined the degree to which participants considered several causal factors (Engle, 2006). For example, one instantiation of multicausality was evidenced in Meg and Juan's explanation of how American robins' migration will be affected by global warming (Figure 5). On one hand, Meg reasons about how an earlier spring will lead to an earlier migration; on the other hand, Meg and Juan reason about how the normal timing

of the melting of snow will lead to less food availability for robins after their migration. They coordinate these two lines of reasoning to yield their prediction of how robins will be affected overall. Meg and Juan's multicausal reasoning can be contrasted with Carol's reasoning about how lack of snow would affect the robins' habitat. Carol claims that no snow would lead to a lack of plants, and thus a desolate habitat (Figure 6). Carol's explanation does not involve the coordination of more than one line of reasoning and is, thus, linear. This method of analysis is an adaptation of Engle's (2006) approach to describing students' causal reasoning and was chosen because it allows for indication of individual students' contributions to the focus group's reasoning while not ignoring the group's cooperatively developed line of reasoning. Macrostructure diagrams will be used in *Chapter 5: Results of Research Question 3* to depict lines of reasoning, both multicausal and linear (Engle, 2006).

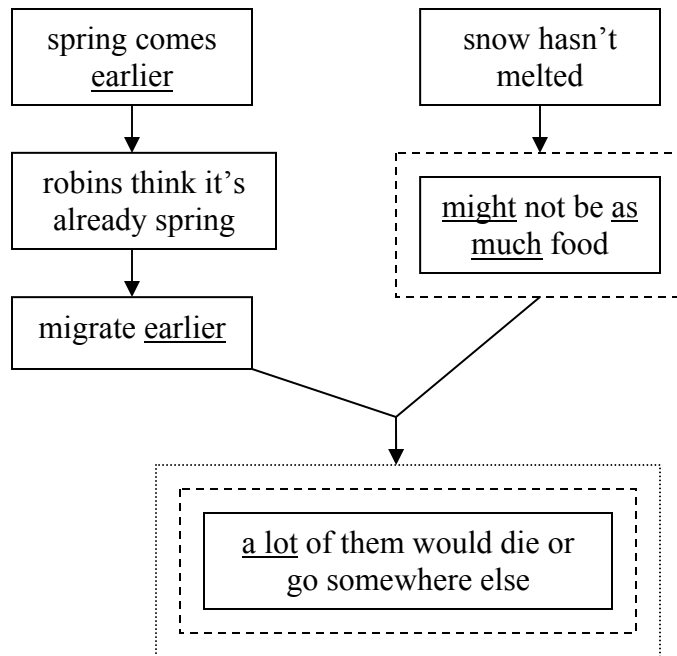


Figure 5. Meg and Juan's argument coordinating numerous factors that might lead to the death of many American robins; Carol eventually agrees with their conclusion.

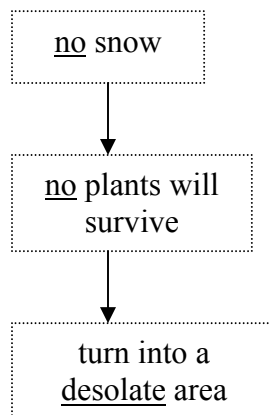


Figure 6. Carol's argument during the *American Robins* problem about how no snow will affect the environment at high altitudes.

Causality was also coded according to the gradedness of student's ideas; this code addresses how well students are able to account for the continual, rather

than categorical, nature of environmental responses (Engle, 2006). Again, graded causal reasoning is observed in Meg's argument about how robins are affected by global warming. She states that if the snow does not melt, "there *might not* be as *much* food." Emphasis is added to indicate the gradedness of her response. Meg could have claimed that there simply would not be any food whatsoever, but her language indicates she does not believe the effect would be that extreme. Again, Meg's graded reasoning contrasts with Carol's argument about lack of snow. She states that "if it *doesn't snow* then that place is going to turn into ... a *desolate* area 'cause *no plants* will be able to survive." Emphasis is added to indicate Carol's categorical, rather than graded, reasoning in which lack of snow will lead to extreme results: lack of plants and desolation. Gradedness is an important aspect of causal reasoning because environmental problems seldom lead to immediate catastrophic effects, which is why human behavior changes are likely to be successful in reducing environmental impact. When students understand the gradedness of environmental impact, they will likely feel more competent when devising environmental solutions because they will not feel as if all hope in solving the environmental problem is lost. Language relevant to the gradedness of students' causality arguments will be underlined in the macrostructure diagrams.

Finally, students' causal reasoning was coded according to whether or not humans are included in the causal factors and/or potential environmental solutions involved in their reasoning. Language indicating human-inclusiveness is italicized in the macrostructure diagrams. In all but two problem sets posed in the course

(i.e., the *Western and Arroyo Toads* and *Baja Rodents* problems), humans are one of the causal agents and can potentially be part of a solution to the environmental issue that serves as the context for the problem. Therefore, students can include humans in their discussions of what caused the problem, what can be done to resolve the problem, or both. The human-inclusiveness of student's reasoning is important because if they do not see humans as part of environmental problems, they will be less likely to feel competent in preventing and solving environmental problems. Likewise, if students see humans as both causal agents and potential solutions to environmental problems, they are likely to feel highly competent in both preventing and solving environmental problems.

Student's causal reasoning will be described in text and in macrostructure diagrams (Engle, 2006) in *Chapter 5: Results of Research Question 3*. These diagrams show the steps in a line of reasoning; a box before an arrow indicates a cause that leads to an effect, which is boxed after the arrow. When there are several boxes and arrows leading to one effect, it is coded as multicausal; when only one cause leads to a single effect throughout the line of reasoning, it is coded as linear. Contributions from different students are shown in different boxes. Meg's contributions are in solid-lined boxes; Juan's contributions are in dashed-lined boxes; and Carol's contributions are in dotted-lined boxes (Figure 7). When possible, students' actual utterances are depicted in the lines of reasoning, although there are exceptions. Namely, pronouns (e.g., them, they) are replaced with the referent for clarification purposes. Also, when the same line of reasoning

is inferred from two or more students, the utterance from the first student who made the claim is used in the diagram. Then the utterance is double- or triple-boxed using the line type that corresponds to the student(s) who either agrees or makes a claim that is inferred to be the same as the first student. Often, a student does not overtly agree with another students' claim but furthers his or her line of reasoning. In this case, the claim is not double-boxed, but the total line of reasoning may include boxes from different students. While initially confusing, this is an advantage of using macrostructure diagrams; the group's collectively constructed line of reasoning can be portrayed while still honoring individual students' contributions to the argument (Engle, 2006).

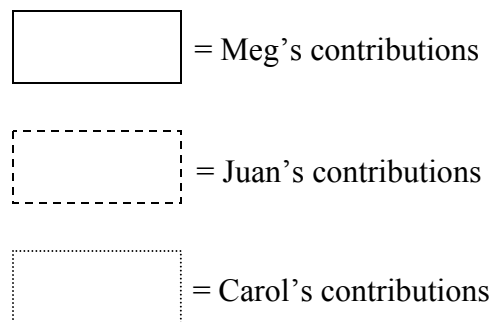


Figure 7. Legend identifying line types for each student contributing to a causal argument depicted in macrostructure diagrams. Meg's contributions are in solid-lined boxes; Juan's contributions are in dashed-lined boxes; and Carol's contributions are in dotted-lined boxes.

*Analysis of Interview Data: Satisfaction of Students' Need for Competence*

After the in-class data were analyzed, analysis of the nine interviews began. The interviews were also transcribed using Transana 2.12, and handwritten field notes were created. I then open-coded (Strauss, 1987a) the interviews in



which I produced conjectural answers to the following questions for each student's interview.

- i. Can the student conceptualize their own role in a process contributing to the environmental problem being studied?
- ii. Can the student reason about which pro-environmental behaviors can be performed to solve the environmental problem?
- iii. What was the students' sense of competence while solving the problem?

The fourth question is augmented by comparing students' DNSS scores on the interview days with their mean DNSS score throughout the course.

#### *Hypothesis Generation*

Analysis concluded with axial coding (Strauss, 1987a) in which I constructed an organizing table that summarized in-class and interview data for each student and each problem about which s/he was interviewed. I then used these tables to decipher patterns in scientific concepts and patterns of causal reasoning, on one hand, and responses to the three guiding questions, on the other hand. Throughout this process, I used the constant comparative method (Strauss, 1987a) in which grounded hypotheses generated from a subset of the data were used to explain more data until all the data were fully explained by the grounded hypotheses. This resulted in a collection of classroom conditions and associated consequences of competence satisfaction from which I was able to construct a

substantive theory (Strauss, 1987b) that describes what aspects of scientific conceptualizations support or undermine students' need for competence.

#### *Research Question 4*

For the final question, I ask what classroom features existed when students indicated that their basic psychological needs were being fulfilled or thwarted. This question seeks to describe relevant socio-contextual features that students cite when they indicate that the satisfaction of their basic psychological needs was being supported or thwarted. These results will be considered in light of results from the third research question to hypothesize what constitutes an optimally challenging situation (Deci & Ryan, 2002; *Chapter 2: Literature Review*) in an environmental biology course.

Stimulated-recall interviews conducted to answer the third research question were also used to address this final question; the protocol contained questions addressing both research questions (*Appendix IV: Interview Protocol*). I open-coded (Strauss, 1987a) transcriptions from interviews to identify which classroom features seemed to support or undermine their basic psychological needs. This resulted in a list of classroom features that seemed to support or undermine the satisfaction of students' basic psychological needs. As I analyzed students' interviews, supporting evidence for each item on this list accumulated, as did additional items on the list. Again, the constant comparative method (Strauss, 1987a) was used to continually modify the hypothesized classroom features until they fully accounted for the data.

## CHAPTER 4: QUANTITATIVE RESULTS

In this chapter, I present the results of my first two research questions. The first research question is to what extent does an SDT-guided environmental biology course differ from a non-SDT-guided course in the degree to which it fosters self-determined motivation toward the environment. After administering the MTES to the experimental (i.e., SDT-guided) and comparison sections before, after, and six months following the end of the course, sections were compared using repeated-measures analyses of variance (RM-ANOVA) on each subscale. My second research question, which asks what are the multiple influences on fostering self-determined motivation toward the environment in an SDT-informed EE course, was tested using path analysis (Loehlin, 2004).

### *Research Question 1*

#### *Diagnostic Analyses*

Analyses of variance hold three assumptions: that data are distributed normally, that the sample be randomly selected and distributed among groups, and that variance be homogeneous. Normality was checked by performing Shapiro-Wilk's goodness of fit test and by checking for outliers. In the experimental section, non-normal distributions were observed on the following subscales: pre-course external regulation ( $W = .659, p < .001$ ), pre-course amotivation ( $W = .827, p = .008$ ), post-course identified regulation ( $W = .878, p = .044$ ), post-course external regulation ( $W = .723, p < .001$ ), post-course amotivation ( $W = .745, p < .001$ ), 6-month identified regulation ( $W = .718, p =$

.001), 6-month introjected regulation ( $W = .832, p = .026$ ), 6-month external regulation ( $W = .845, p = .038$ ), and 6-month amotivation ( $W = .747, p = .003$ ). In the comparison section, non-normal distributions were observed on the following subscales: pre-course amotivation ( $W = .741, p = .002$ ), post-course amotivation ( $W = .796, p = .007$ ), 6-month amotivation ( $W = .654, p < .001$ ). Because there were outliers, analyses without outliers will follow analyses of the actual data.

Participants were not randomly assigned to each section because the students themselves had to register for one section or the other. However, they were unaware of the study at the time of registration, and there were no statistically significant differences between groups at the first administration of the MTES. Thus, it is reasonable to assume the groups represent a random distribution of the population.

Finally, Levene's statistic was used to test for homogeneity of variance. All variances were homogenous except the pre-course scores on the integrated regulation subscale ( $F_{(1,15)} = 17.882, p = .001$ ). According to Glass and Hopkins (1996), alpha can be affected by heterogeneous variances. As will be discussed in the next section, I do not claim that the difference between the two sections on the pre-course integrated regulation subscale was statistically significant. Therefore, the heterogeneous variances of the pre-course scores on this subscale do not affect any conclusions I draw from the analysis.

*RM-ANOVA of Actual Data*

According to the RM-ANOVA conducted on the actual data set ( $n = 17$ ), there were no statistically significant interactions among the experimental and comparison sections on the intrinsic motivation (Figure 8) or introjected regulation (Figure 9).

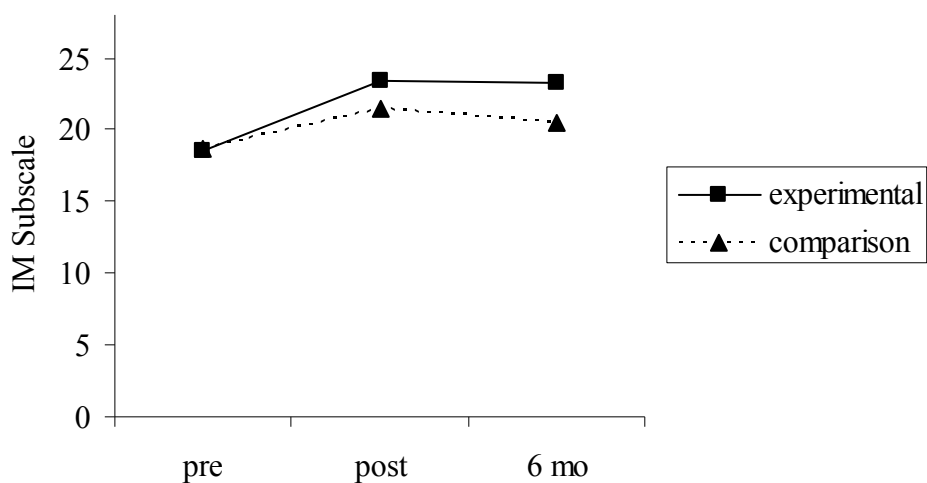


Figure 8. Intrinsic motivation (IM) scores in experimental and comparison sections over three administrations of the MTES.

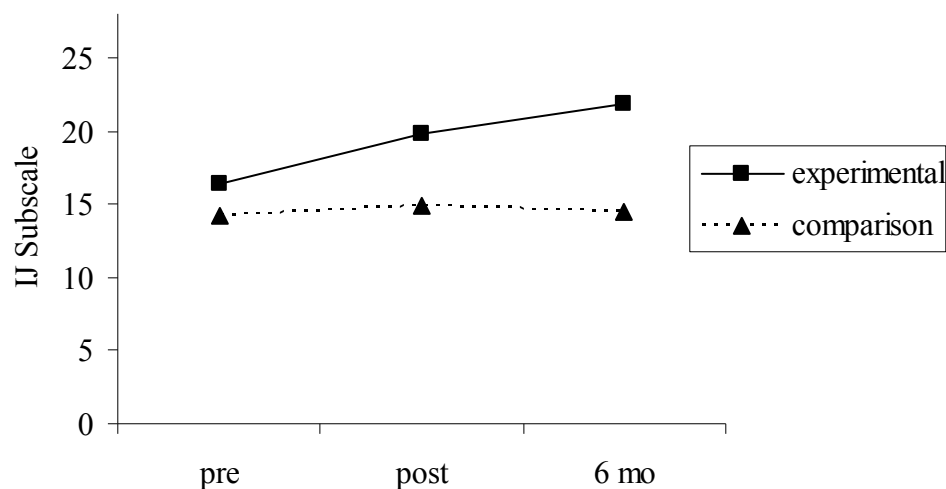


Figure 9. Introjected regulation (IJ) scores in experimental and comparison sections over three administrations of the MTES.

Statistically significant ( $\alpha = .10$ ) interactions were observed on the integrated regulation ( $F_{(1,15)} = 3.532, p = 0.080$ ; Figure 10) and identified regulation ( $F_{(1,15)} = 3.387, p = 0.086$ ; Figure 11) subscales. The integrated regulation subscale in the experimental section increased and remained high six months following the course, while the comparison section's scores increased following the course but returned to their pre-course levels six months following the course. The identified regulation subscale increased after the course in the experimental section and remained high, while the comparison section experienced no differences across the three MTES administrations (Figure 11).

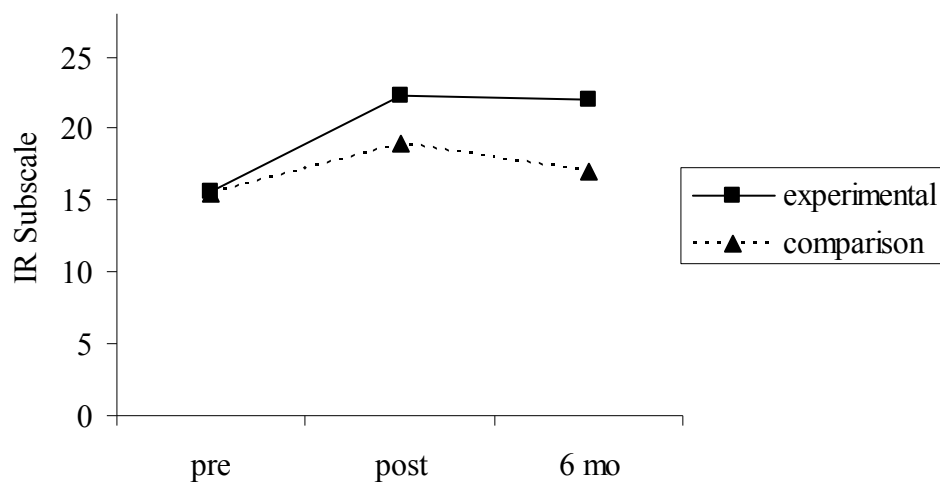


Figure 10. Integrated regulation (IR) scores in experimental and comparison sections over three administrations of the MTES.

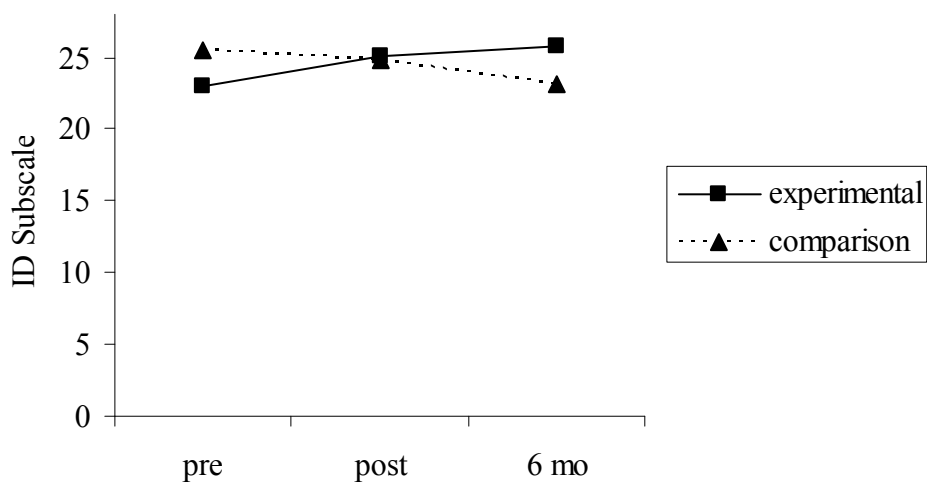


Figure 11. Identified regulation (ID) scores in experimental and comparison sections over three administrations of the MTES.

There were statistically significant quadratic relationships on the external regulation ( $F_{(1,15)} = 4.434, p = .052$ ; Figure 12) and amotivation subscales ( $F_{(1,15)} = 8.177, p = .012$ ; Figure 13). Both of these less desirable types of motivation

decreased in the experimental section but returned to their pre-course level six months following the course.

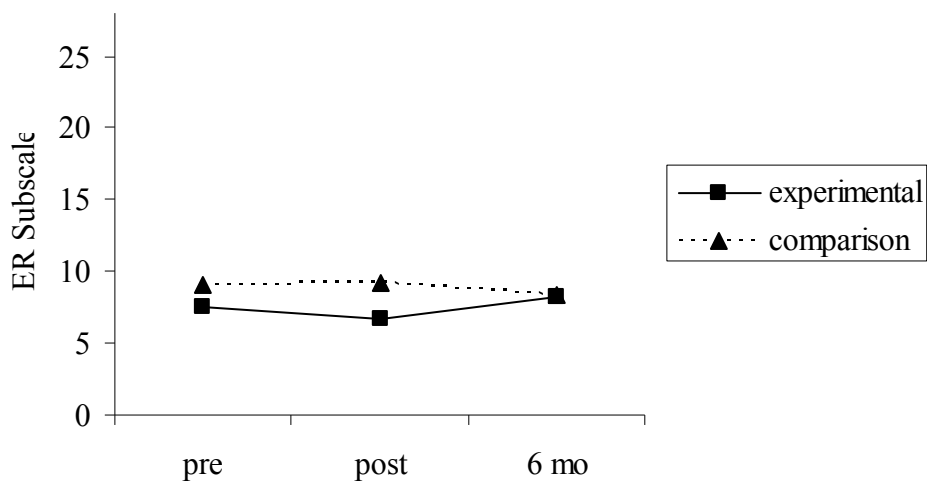


Figure 12. External regulation (ER) scores in experimental and comparison sections over three administrations of the MTES.

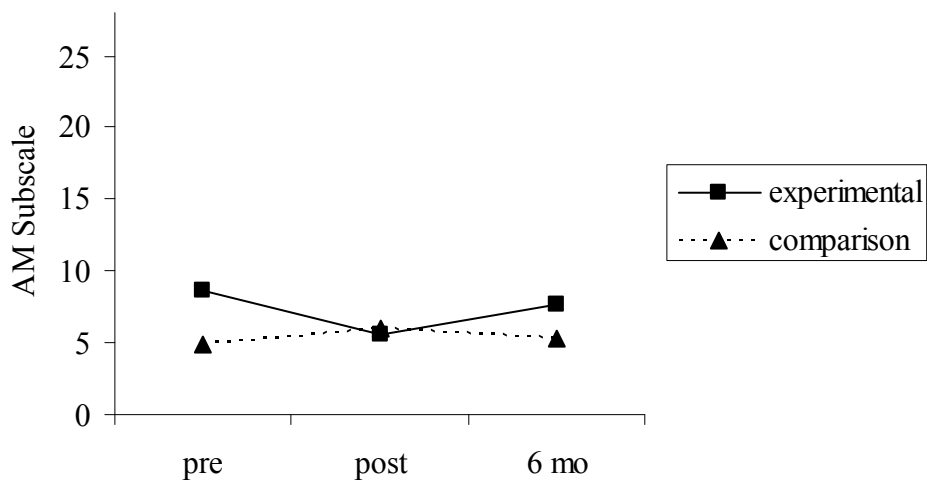


Figure 13. Amotivation (AM) scores in experimental and comparison sections over three administrations of the MTES.



*RM-ANOVA Excluding Outliers*

There were no outliers on the intrinsic motivation, integrated regulation, or introjected regulation subscales during any of the administrations of the MTES. When one outlier was excluded from the introjected regulation data, there was no difference in the significance level of the linear interaction effect ( $F_{(1,14)} = 4.555$ ,  $p = .051$ ). The quadratic interaction effect on the external regulation subscale remained statistically significant without one outlier ( $F_{(1,14)} = 4.788$ ,  $p = .046$ ), as did the quadratic interaction effect on the amotivation subscale when two outliers were excluded ( $F_{(1,13)} = 11.870$ ,  $p = .004$ ).

*RM-ANOVA of Imputed Data*

Due to the low return of the final questionnaire, and resulting small sample size, further analyses were performed on an estimated data set with imputed values for the missing data ( $n = 27$ ). This data imputation assumes that those participants who failed to return the third questionnaire are not different from those participants who returned it. In order to insure this was the case, pre- and post-course scores on all subscales of the MTES from these two groups were compared using RM-ANOVA. No statistically significant differences were observed between these groups. The additional analyses of imputed data indicate significance levels if the sample size were to be larger and the same trends were observed.

According to this RM-ANOVA, there were statistically significant interaction effects on the intrinsic motivation ( $F_{(1,25)} = 3.427$ ,  $p = 0.076$ ),

integrated regulation ( $F_{(1,25)} = 3.785, p = 0.063$ ), identified regulation ( $F_{(1,25)} = 4.738, p = 0.039$ ) and introjected regulation ( $F_{(1,25)} = 6.368, p = 0.018$ ) subscales. The quadratic effect was no longer statistically significant on the external motivation ( $F_{(1,25)} = 1.696, p = .205$ ) subscale. The quadratic effect on the amotivation subscale remained statistically significant ( $F_{(1,25)} = 12.914, p = .001$ ).

### *Research Question 2*

This question asks what are the multiple influences on fostering self-determined motivation toward the environment in an SDT-informed EE course. I devised a theoretically based path of causality in which students' perceptions of psychological need supports are mediated by needs satisfaction to give rise to their self-determined motivation toward pro-environmental behaviors. Self-determined environmental motivation was measured by summing the intrinsic motivation and integrated regulation subscales of the MTES (Pelletier, 2002). The MTES administration at the end of the course was used. Satisfaction of students' psychological needs was measured by General Need Satisfaction Scale (GNSS; Illardi, et al., 1993), which was administered at the same time as the MTES. Student's perceptions of autonomy support in the classroom was measured by the Learning Climate Questionnaire (LCQ; Black & Deci, 2000), while their perceptions of relatedness support was measured by the connectedness subscale of the Classroom Community Scale (CCS; Rovai, 2002). Both the LCQ and the CCS were administered during week 12 of the course. Although student's perceptions of competence support was intended to be measured by an activity in which they

ranked their own understanding of their chosen environmental problem, all students gave themselves the highest score, likely because they believed the rank they assigned themselves contributed to their grade. Therefore, rather than using this measure, Morrone, Mancl, and Carr's (2001) ecological knowledge questionnaire was administered simultaneously with the final exam for the course, and this score will be used to estimate students' perceptions of competence support. The theoretical path was analyzed using path analysis (Loehlin, 2004).

#### *Analysis of Theoretical Path*

Paths from autonomy and relatedness to environmental self-determination were statistically significant (Figure 14). Autonomy negatively predicted environmental self-determination, while relatedness positively predicted environmental self-determination. The path from competence to environmental self-determination was not statistically significant. Statistically significant correlations were observed between all three basic psychological needs. The path from students' perceptions of relatedness support to relatedness was statistically significant. However, paths from competence support and students' perceptions of autonomy support to competence and autonomy, respectively, were not statistically significant. Autonomy support statistically significantly correlated with competence support and relatedness support, but that later two did not significantly correlate with each other.

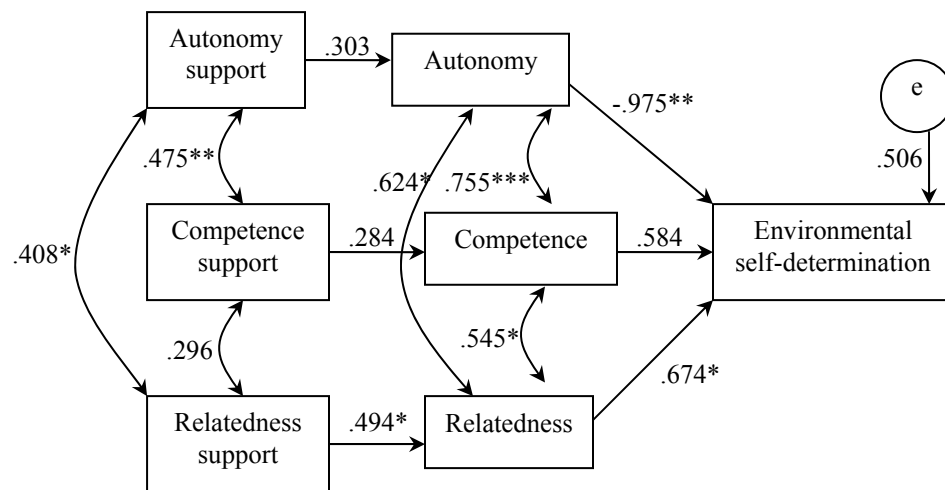


Figure 14. Path analysis results indicating strengths of causal paths to environmental self-determination. \* significant at .10 level; \*\* significant at .05 level; \*\*\* significant at .01 level.

## CHAPTER 5: RESULTS FROM RESEARCH QUESTION 3

In my third research question, I ask what characterizes students' scientific conceptualizations as they solve environmental problems that I intended to be optimally challenging (Deci & Ryan, 1990) and to what extent do their conceptualizations relate to the satisfaction of their need for competence. I approached this question by first inferring students' scientific conceptualizations, which were composed of students' scientific understanding and causal reasoning as they engaged in each problem set (*Chapter 3: Methodology; Appendix V: Conceptualization Problem Sets*). Analysis of the interviews was guided by three questions:

- i. Can the student conceptualize their own role in the process(es) contributing to the environmental problem being discussed?
- ii. Can the student reason about which pro-environmental behaviors can be performed to solve the environmental problem?
- iii. What was the students' sense of competence while solving the problem?

I inferred students' level of competence satisfaction from their stimulated-recall interviews and augmented this analysis with trends seen in the Daily Need Satisfaction Scale (DNSS; *Chapter 3: Methodology*), which was administered after completing the problem sets. Although none of the DNSS scores differed statistically from students' mean scores across the semester, these data will be used to infer general trends in feelings of competence. To complete the analysis, I

searched for patterns across the in-class and interview data, which gave rise to three grounded hypotheses about how competence support can be provided in an environmental biology course.

The first of these grounded hypotheses is that the ability to conceptualize one's role in a social or environmental process contributing to an environmental problem is an influential factor in achieving feelings of high competency regarding solving that environmental problem. When focus group members were able to recognize their own role in a process contributing to the environmental problem discussed during the class period about which they were being interviewed, they seemed to feel highly competent about solving that particular problem, as measured by the DNSS and/or their comments during stimulated-recall interviews. Generally, all students felt highly competent when they were able to conceptualize their own role in a social or environmental process contributing to an environmental problem, recognize what aspects of those process(es) contribute to the problem, and cite pro-environmental behaviors that could be done to solve the problem. When they were only able to achieve the second and/or third of these, however, feelings of high competency were not consistently present. Furthermore, when they were able to conceptualize their role in a social or environmental process contributing to the environmental problem they studied, they felt highly competent, regardless of the accuracy (from a scientific standpoint), gradedness, or multicausality of their scientific conceptualizations. Thus, the first of the criteria I sought while analyzing the

interview data, which is whether or not students can conceptualize their own role in a process(es) contributing to environmental problems, seems to be the most important factor.

The second grounded hypothesis that emerged is that when students experienced feelings of low competency, their in-class participation was generally characterized by less desirable scientific conceptualizations and mostly linear, graded causal arguments. To recap, linear causal arguments are those in which one cause leads to a single effect, while multicausal arguments coordinate several factors to lead to an effect (Engle, 2006). Graded arguments recognize the range of possible effects, while categorical arguments are “all or nothing” (Engle, 2006). Graded, multicausal arguments are preferred because they better represent what actually occurs in nature; a single environmental cause seldom brings about complete disaster. Rather, several environmental conditions cause a range of conditions. Therefore, the presence of graded arguments in less desirable scientific conceptualizations is somewhat unexpected. Nevertheless, this hypothesis also highlights the importance of cultivating desirable scientific understanding and putting it into action through problem-solving, if students are to feel competent toward solving environmental problems.

The final grounded hypothesis is that when students were able to incorporate time into their scientific conceptualizations of the environmental problems, their sense of competence was high. This grounded hypothesis was most often instantiated when a student, usually Juan, approached the problem from an

evolutionary perspective that involved time. Correspondingly, Juan consistently felt highly competent throughout this study, as evidenced by his comments during interviews and high DNSS scores on the days when problem sets were addressed; this was not true for Carol and Meg. Carol and Meg felt statistically significant low competence on two class periods that contained problem sets, and these problems sets were those that specifically addressed evolution. They also approached the problems from an ecological perspective that often did not involve an element of time. Thus, I inferred Juan's tendency to consider time as he engaged in the problems coexisted with his feelings of high competence, while Carol and Meg's tendency to exclude time from their conceptualizations of the problems coexisted with their feelings of low competence.

Throughout the remainder of this chapter, I will present the emergent evidence that supports these three grounded hypotheses. For each problem set, I will share my analysis of each student's scientific understanding, the group's causal reasoning, and students' competence satisfaction. I will then justify how the analysis supports my grounded hypotheses. This format will be repeated for each problem set from which relevant data emerged. Transcripts of in-class discussions and interviews are available in *Appendix VI: Transcripts* for reference. I will conclude this chapter with a brief discussion of the role that scientific knowledge plays in the satisfaction of competence regarding environmental problems, which will be fully revisited in *Chapter 7: Discussion*.



*Problem #1: American Robins*

*Meg's Scientific Understanding*

Two aspects of Meg's scientific understanding are revealed as she conceptualized the *American Robins* problem, and I argue that these lend initial support to my third grounded hypothesis, that an ability to conceptualize a problem using an element of time is a relevant factor regarding one's sense of competence. The first of these aspects is that she seemed to see a connection between environmental conditions and animals' behaviors. Second, she seemed to understand that food replenishes something lost. Evidence for this first claim initially emerges when Meg immediately proposed to the group, "Wouldn't it cause them to migrate earlier ... because spring's coming earlier?" After Carol agreed, Meg completed her thought: "And there might not be as much food." She then further explained that there would not be as much food because of the timing of the snowmelt (*Appendix VI: Transcripts*, line 13). Meg's response to a question Carol proposed further supports my claim that she sees a connection between environmental conditions and animal behavior. When students received the prompt asking them about a slightly different situation involving yellow-bellied marmots, Meg and Juan assumed the situation is exactly the same. Carol, however, was not convinced, and her questioning prompted Meg to reveal her ideas further. Carol, misunderstanding the problem to state that the marmots also migrate to higher altitudes, asked, "I don't understand why they just don't stay at the bottom of the mountain." To this Meg responded, "But if there's nothing

down there why would they stay?” In other words, Meg suggested that migration occurs because environmental conditions do not provide what the animals need at the present time. In this instance, Meg focused on the present environmental conditions and did not conceptualize the problem from a larger time scale. Such a conceptualization would involve the notion that migration is an annual adaptive behavior that occurs regardless of the present environmental conditions.

Evidence for my second claim, that Meg understands that food replenishes something lost, emerges later as the students discussed how the robins would deal with the situation once they migrated up the mountain. Meg proposed that once they arrived and saw no there was no food available (*Appendix VI: Transcripts*, line 30), perhaps they “would die ... [or] go somewhere else.” Initially, her suggestion that the robins might go elsewhere indicates that Meg did not consider why robins need to eat as she reasoned about the situation. However, moments later she stated, “But if they got up there would they have ... enough strength to go back down or go somewhere else?” While it would have been more desirable if she would have referred to the robins’ energy and matter needs, rather than their strength, her statement indicates that she at least recognized that food replenishes something lost. To summarize, Meg’s concepts include a focus on the current environmental conditions, such as amount of food. However, her consideration of the amount of strength that the robins have at the moment they arrive at the higher altitudes indicates that she was at least minimally including time in her conceptualization by considering how much “strength” the robins had lost over

the course of their migration. This distinction is important regarding my third grounded hypothesis, that when students' are able to incorporate time into their conceptualizations of the problem, their sense of competence is supported. As will be thoroughly discussed shortly, Meg experienced feelings of high competence during this problem set.

*Carol's Scientific Understanding*

Carol focused on environmental conditions and how the robins might be affected by them. Carol begins reasoning about this problem by focusing on what "snowmelt" meant. Upon receiving the prompt, she immediately asks her group, "Do you think it snows or does this place primarily depend on snow melting ... because if it doesn't snow then that place is going to turn into ... a desolate area 'cause no plants will be able to survive." It is not clear what her concept of snowmelt is. On one hand, she did not seem to understand that in order to have melting snow, there must first be snow. On the other hand, she may have thought that snow at the highest altitudes melts, and then the water runs down the mountain to provide water to the plants that fulfill the needs of the robins. As the instructor, I inferred this concept from members of other groups as I observed them grappling with this problem. Regardless, her concern about whether or not there would be water or snow indicates that she, like Meg did initially, focused on the present environmental conditions in which the robins are trying to survive. Carol's conceptualization of this problem, however, is different than Meg's in that Meg seemed to minimally reason with time while Carol did not indicate she

included an element of time in her conceptualization. Additionally, Carol's sense of competence was not statistically different than her mean over the course of the semester.

### *Juan's Scientific Understanding*

Little can be said about Juan's understanding while reasoning about this problem because much of what he contributes is in agreement with Meg. However, there is one indication that he may be tending to the robin's energy needs after their migration. The instructor stated in response to Meg's comment about the robins not having enough "strength" to return or go elsewhere, "That's a good question because flying up there, they're expending a whole lot of energy." Juan attempts to finish the instructor's sentence by contributing, "... to recover the energy." Because the last portion of the instructor's statement and Juan's comment were uttered simultaneously, it is unlikely that he was simply using the term "energy" because that is what the instructor used. He seemed to be genuinely attuned to energy needs, rather than "strength," as in Meg's case. When the instructor asks for his input, he reiterated his stance: "Just the same thing. To recover the energy at the end. What will they do next?" Juan's conceptualization involved expending of energy rather than strength, which is more desirable than Meg's idea about strength from a scientific standpoint. His idea about energy, however, is similar to Meg's idea that something was lost during the migration that must be replenished, which indicates he might have been reasoning with time.

*Group's Causality Reasoning*

Meg's initial conceptualization of the *American Robins* problem coordinated two lines of reasoning (Figure 15). The first involves the effects of spring coming earlier, and the second involves the effects of the snow melting at the normal time. Both Juan and Carol agreed with Meg's overall conclusion that many robins would either die or go elsewhere. All three of the students' conceptualizations of the problem as stated in the first prompt are multicausal. Meg's comments indicate that in her conceptualization of the problem, earliness and the amount of food are graded. Because Juan agreed with this statement, his conceptualization is also graded. All three students' conceptualizations receive an additional graded code when Juan and Carol agree with Meg's claim that "a lot" of the robins would die.

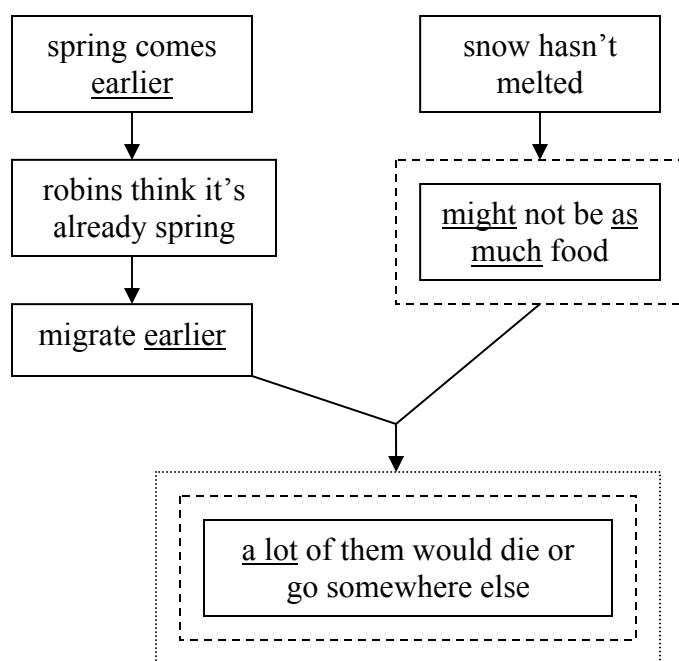


Figure 15. Meg and Juan's argument coordinating numerous factors that might lead to the death of many American robins; Carol eventually agrees with their conclusion. (See legend, Figure 7, *Chapter 3: Methodology*).

Another causal claim occurred when Meg and Juan determine that the robins would not go elsewhere if they were to arrive atop the mountain and find the snow had not yet melted. Because their line of reasoning has a single cause, their argument is coded as linear (Figure 16). The students do not use language that can be coded as graded or categorical. Throughout their entire discussion, human participation in this problem was not discussed, which is why all three students' arguments are coded as non-human-inclusive.

To summarize the group's causality reasoning during the *American Robins* problem, half of Meg's arguments were multicausal, and all of her utterances relevant to gradedness were graded. Carol participated minimally in the causal

arguments constructed in her group. All of the arguments in which Juan participated were multicausal and graded.

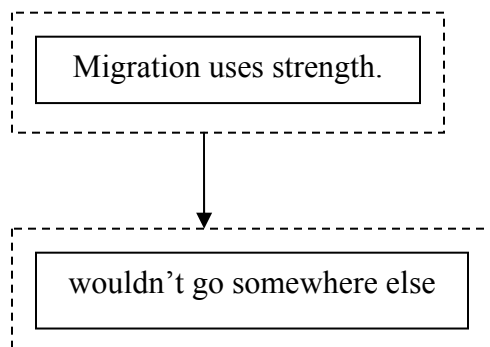


Figure 16. Meg and Juan’s argument about why the American robins would not migrate elsewhere if they were to find no food at the top of the mountain.

#### *Students’ Competence Satisfaction*

Meg was the student interviewed following the *American Robins* problem, so analysis of competence satisfaction will largely be drawn from her scientific conceptualizations and interview data. While explaining to the interviewer why the *American Robins* problem was important to her, Meg provided an account of how she thought the problem fit into the larger scheme of both the class and humans’ role in global warming. She stated, “Like when we did the biomes and stuff we did a lot of the migration and stuff and then also we’re learning about the energy forms. So this kind of relates to it because the migration patterns are all messed up with a lot of *the energy we use* ... and then we’re talking about global warming as an effect of some of the fossil fuels burning, so this kind of went with everything because the global warming is causing the

spring to arrive earlier” (emphasis added). Therefore, regarding the first guiding question used to analyze the interviews (*Chapter 3: Methodology*), which was whether or not Meg can conceptualize her role in the processes contributing to the problem with the American robins, her comment “the energy we use” indicates that she conceptualized her role as a user of energy that relates to the *American Robins* problem via global warming, even though her in-class reasoning was not human-inclusive. This distinction is important because I will argue that conceptualizing human participation in an environmental problem is not equivalent to conceptualizing one’s own participation. In order for one’s feelings of competence to be supported, one must be able to conceptualize his/her personal role in a process contributing to the environmental problem.

When asked if the problem would still be important to her if someone outside of class engaged her in a conversation about it, she said that it would still be important and that she would care about it. She explained, “Because I think it’s important that if someone came up to me and was talking to me about it, then that shows that they’re interested in it too. And if enough people get interested in it then maybe there will be like changes happening, like with oil drilling and the pipelines and everything.” This indicates that Meg recognized the importance of social processes without which change cannot be implemented. Her language “maybe there will be like changes happening” indicated that although she may see herself as part of this social system, she alone cannot bring about systemic change. Further evidence for this was seen later when she stated, “If enough



people know about how the migration things are getting messed up from all of like what we're doing then maybe *something will get changed*" (emphasis added). An alternative explanation is that she knows broader social elements are important, such as with oil companies or the government. Regardless, her consistent inclusion of herself (e.g., use of "we") in social processes that impact global warming is further evidence that she regarded herself as a participating member and that she could conceptualize her role in a process involving the *American Robins* problem. At this point, I draw attention to the notion that the process in which Meg conceptualizes her personal participation is not an environmental process. It seems that one does not need to conceptualize one's role in an environmental process leading to an environmental problem; conceptualizing one's role in a social process seems to suffice regarding feeling highly competent about solving the environmental problem at hand.

During her interview following the *American Robins* problem, Meg commented that she felt like she could effectively contribute to solving it with her group (*Appendix VI: Transcripts*, line 252), and her high sense of competence was reflected in her DNSS score. Although not statistically significant, Meg's score on the day that they engaged in the *American Robins* problem was 19 ( $z = 1.01$ ), while her mean score across the semester was 16.2. This trend and her comments during her interview compelled me to ask what led Meg to feel highly competent while solving the *American Robins* problem. To summarize her conceptualization of the problem, Meg focused on environmental conditions in which the robins are

trying to survive but may have included an element of time. She also was able to conceptualize her role in social processes contributing to the *American Robins* problem. The coexistence of her ability to conceptualize her role in processes contributing to the problem and her high competence lends support to my first grounded hypothesis, that one's ability to conceptualize one's role in processes contributing to an environmental problem is vital to feeling highly competent when attempting to solve that problem. Although her inclusion of time in her conceptualization is tenuous, it could have also contributed to her high sense of competence. This would support my third grounded hypothesis, that incorporating time into one's conceptualization of a problem often coexists with one's feelings of high competence.

Neither Carol (19;  $z = 0.44$ ) nor Juan (19;  $z = 0.27$ ) had DNSS scores that were statistically significant from their mean scores (16.1 and 18.5, respectively). Because Carol participated minimally in her group's causal reasoning, I refrain from making inferences about her feelings of competence. Before moving on the second problem set, however, I would like to highlight again Juan's tendency to incorporate an element of time into his conceptualization of the problem. Just as in Meg's case, this claim about Juan's conceptualization is tenuous in this example, but over the course of several problems, this tendency to incorporate time will emerge in Juan's reasoning. This will become relevant regarding support for my third hypothesis, that an ability to reason with time often coexists with one's sense of high competence while solving environmental problems.

*Problem #2: Colorado River Water Pollution*

*Meg's Scientific Understanding*

Meg's conceptualization of the *Colorado River Water Pollution* problem indicated that she likely held three related concepts about water. The first is a concept of stream flow that does not involve a distinction between upstream and downstream. This is initially supported by her comments immediately following her reading the prompt asking which facilities affect San Diego drinking water quality. She claimed, "They all do, don't they?" She further explained, "If they all run into the Colorado River they're all gonna ... basically [be] coming from over here." She reiterated her point to the instructor: "They *all connect* and it's going into the river there (points along river on map) and it's coming ... to San Diego there (points to San Diego on map)" (emphasis added). These comments indicate that Meg believed that because all the water is connected, pollutants dumped into the water at any location along the river will reach San Diego, regardless of whether they were dumped upstream or downstream of where the Colorado River Aqueduct departs from the river. In other words, a pollutant dumped into the river downstream from where the Aqueduct departs could still reach San Diego by traveling upstream and then via the Aqueduct. A second concept emerged later when Juan stated that only those upstream from where the Aqueduct departs the river will affect San Diego's drinking water. Carol responded, "Don't they run into each other anyway?" Meg attempted to address her confusion by stating, "Maybe the location ... maybe one of them is like closer so it has more of an

effect than the one that's further away." This statement is evidence that Meg also likely believed that proximity of a potential pollutant to a body of water determines the degree to which it is a threat to water quality. In this explanation, she also continued to not use a concept of direction of water flow that would allow her to perceive a difference between facilities that are upstream versus downstream from where the Aqueduct departs the river. Finally, Meg called on her concept of dilution while reasoning with this problem. She referred to the guest speaker's comments when reasoning about contaminants that are released into the river: "Remember how they said the uranium is diluted ... It gets diluted because it's *so far away*" (emphasis added). It seems that Meg's concept of dilution was another instantiation of the second of her concepts discussed here; if the pollutant's source is a long distance away, its effect is lessened. It is important to note that none of Meg's three concepts that emerged from her conceptualization of this problem involved an element of time. She was easily able to reason about the importance of distance of a pollutant's source and its potential effects. She did not, however, reason about how a pollutant must travel from its source to where it might have an effect and what might happen (i.e., it gets diluted, it gets washed downstream rather than upstream) to the pollutant during that time. This claim will become relevant shortly when I discuss evidence for my third grounded hypothesis.

*Carol's Scientific Understanding*

When the group received the prompt, Carol immediately agreed with Meg that all the facilities along the river affect San Diego drinking water. She states, "Yea, they all do, yea ... because they empty into the sea together." Although her explanation is somewhat difficult to decipher, it seems as though she held a concept of water that was similar to Meg's concept in which stream flow did not involve a distinction between upstream and downstream. Thus, pollution in one water region yields pollution in another region. She offered further evidence for my conjecture by stating to Juan, who was claiming only upstream facilities affect the water quality, "I was just wondering, don't they run into each other anyway? Like you [Meg] said, don't they flow into the same area?" In one instance, Carol also indicated that she may have also believed proximity influences the degree of pollution by stating, "It is the closest, so ...". However, she apprehensively made this comment in response to a claim that Meg had made, so it is unclear if she really believed this or was simply following Meg's reasoning. Nevertheless, Carol, like Meg, did not incorporate timing into her reasoning.

*Juan's Scientific Understanding*

Juan, unlike Carol and Meg, held a concept of stream flow through which he could conceptualize this problem using an element of time. When reasoning about which facilities along the Colorado River might affect drinking water quality in San Diego, Juan pointed out to his group mates that two facilities in particular are "pretty close... It goes really close to the Colorado River." Meg

then claimed that a different facility would likely not affect our water quality in San Diego, and Juan offered a reason why: “[Be]cause it goes down, right ... over to another place.” Here “down” seemed to refer to downstream; he was claiming that the facility would not affect San Diego drinking water because it is downstream from where the Colorado River Aqueduct, which supplies San Diego with its drinking water, comes off the river. This was further supported by his contribution to the whole class discussion. When the instructor asked, “Do all of those facilities along the Colorado River affect our drinking water?” Juan answered no. When another student disagreed with his claim, Juan said seemingly to himself while the other student was talking, “It’s downriver” and pointed downward. Two aspects of Juan’s understanding can be inferred from his utterances. First, by mentioning a facility “goes really close” to the river, he seemed to believe that proximity of a potential pollutant to a body of water at least partially determines the degree to which it is a threat to water quality. Second, he held a concept of river flow in which water only flows in one general direction, and that prevents pollutants from traveling in the opposite direction. Juan’s concepts are different than Meg and Carol’s concepts. Juan seems able to reason about what happens to pollutants *after* they are released by the source (e.g., they are swept downstream). Emphasis is added to point out that Juan’s notion involves an element of time. Carol and Meg’s concept is one in which pollution at the pollutant’s source equates to pollution throughout the connected body of water; there is no explanation of what happens between the time that the pollutant

is released (i.e., the cause) and the time that it brings about its effect on San Diego's drinking water. Again, this will be used to support my third grounded hypothesis.

*Group's Causality Reasoning*

My inferences about students' causality reasoning during the *Colorado River Water Pollution* problem will offer support for my second grounded hypothesis, that less desirable scientific conceptions and graded, linear causal arguments generally coexist with feelings of low competence. Upon reading the prompt, Meg and Carol immediately conceptualized the problem so that all the facilities along the Colorado River affect San Diego's drinking water because they are all connected by the river (Figure 17). This argument has a single cause and is thus linear. It is also categorical because their claim did not distinguish the different degrees to which the facilities affect San Diego's drinking water, nor does it take into account direction of stream flow.

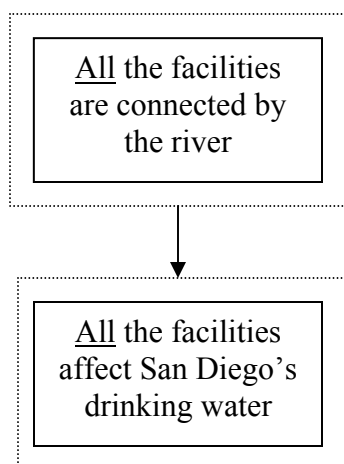


Figure 17. Carol and Meg's initial reasoning in the *Colorado River Water Pollution* problem that all the facilities along the Colorado River will affect San Diego's drinking water because water connects them all.

After further discussion with Juan and Carol, Meg changed her mind and constructs a multicausal argument with Juan in which three lines of reasoning are coordinated (Figure 18). Throughout the discussion, Meg claimed that “some” facilities are “pretty close” to the river, and these would have “more of an effect” on San Diego's drinking water. All of these comments are graded because they indicate a continuum of amount, distance, and degree of effect, respectively. Juan pointed out that a facility is downstream from where the Colorado River Aqueduct departs the river and stated that it “doesn't really” affect San Diego's drinking water. This comment is also graded because it indicates the degree of the effect. After coordination of these three lines of reasoning, Juan and Meg conclude that “not all” of the facilities affect San Diego's drinking water. This final utterance is graded because, unlike Carol and Meg's initial idea, it distinguishes between the facilities along the Colorado River according to



proximity to the river, degree of dilution, and location relative to where the Aqueduct departs the Colorado River. Meg incorporated human's participation in this problem when she pointed out that scientists are unable to find uranium in the water in San Diego even though it is dumped far upstream; thus, her conceptualization of the problem was human-inclusive.

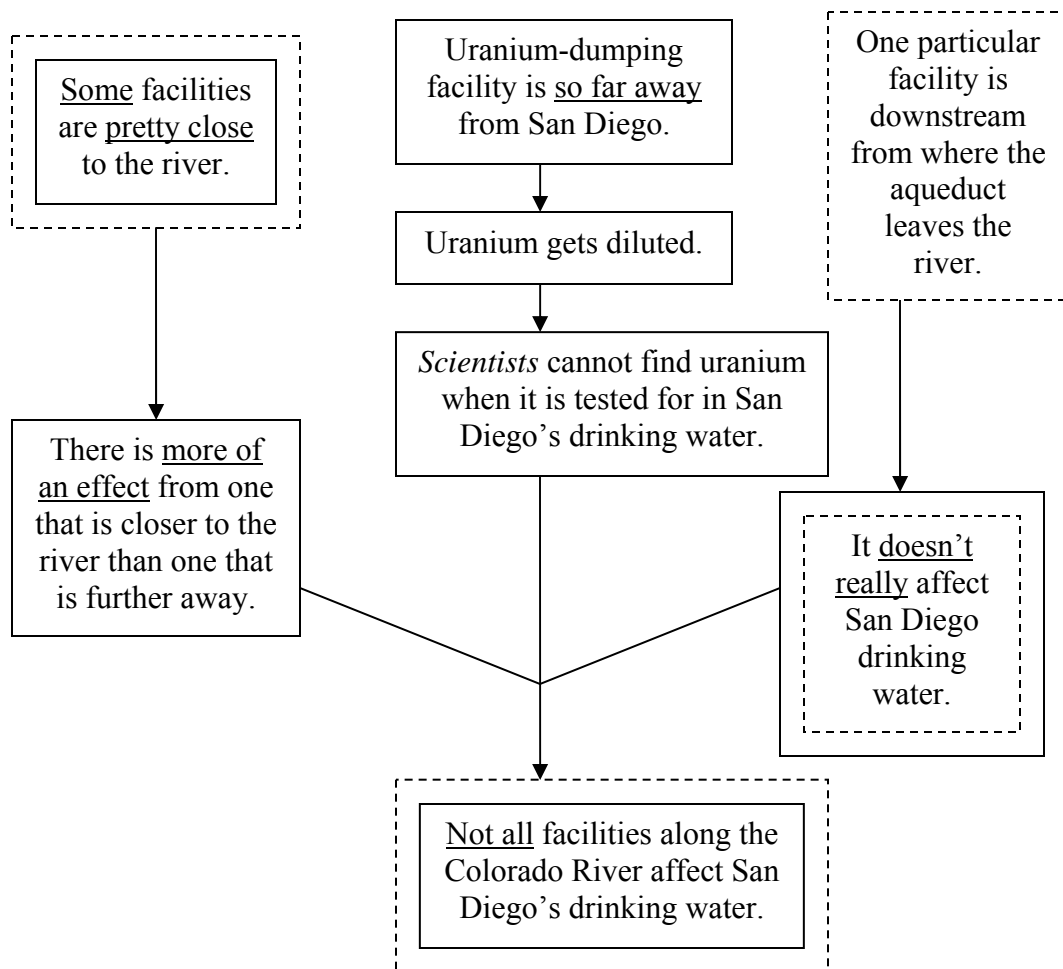


Figure 18. Meg and Juan's reasoning after Meg has decided not all the facilities will affect San Diego's drinking water.

Carol was unconvinced by Meg and Juan's argument regarding why not all of the facilities along the Colorado River affect San Diego's drinking water.

She constructs a linear, categorical argument (Figure 19) that reiterated her original idea that she initially shared with Meg.

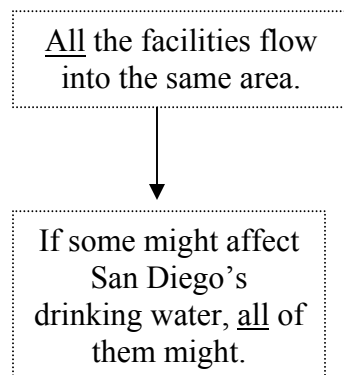


Figure 19. Carol's reasoning after Meg and Juan have decided not all the facilities affect San Diego's drinking water.

To summarize the group's causality reasoning during the *Colorado River Water Pollution* problem, the argument in which Meg took part were multicausal, while most (75%) of her language was graded. Carol's arguments were totally linear and categorical, while Juan's were totally multicausal and graded. Meg is the only student who included humans in her reasoning.

#### *Students' Competence Satisfaction*

Juan was interviewed following the *Colorado River Water Pollution* problem, so the majority of the conclusions drawn from this problem set emerged from his data. His interview began by his explaining to the interviewer that they were attempting figure out which facilities were "going to affect the drinking water ... the *water that we use*" (emphasis added). This is an initial indication that he conceptualized his role in processes involving Colorado River water pollution; he identified himself as a consumer of drinking water that comes from the

Colorado River. He also stated, “We, meaning us humans, have been destroying ... animals, in this case, or vegetation. We are polluting water, we are destroying habitat ... From these facilities we got different chemicals that go into our body and then by having these facilities, destroy different habitats.” Here Juan further evidenced that he can conceptualize his role in processes contributing to Colorado River water pollution.

Juan made no comments regarding his sense of competence during the interview following this problem, but his DNSS score of 20 ( $z = 0.81$ ) was higher than his mean score across the semester, indicating a trend toward higher feelings of competence. Conversely, Carol’s score of 14 ( $z = -1.46$ ) and Meg’s score of 12 ( $z = -1.43$ ) were both lower than their mean scores across the semester. My analysis of this problem set supports all three of my grounded hypotheses. First, it seemed natural for Juan to conceptualize his own role in the processes contributing to water pollution in the Colorado River, which I claim to be highly supportive of students’ sense of competency. Second, Juan’s more desirable concept of stream flow that incorporated direction may implicitly involve an element of time that did not seem present in Carol and Meg’s concepts. Correspondingly, Juan’s competence during this class period was higher than usual for him, while Carol and Meg’s feelings of competence were lower than usual. Meg’s causal reasoning during this class period was highly graded, and all of the causal arguments in which Carol participated were linear. Additionally, neither Meg nor Carol successfully incorporated the desirable concept of stream

flow that I inferred in Juan's case. Therefore, this supports my second grounded hypothesis that when students experience feelings of low competency, their in-class reasoning is characterized by less desirable scientific conceptualizations and mostly linear, graded causal arguments. Finally, Juan's concept of stream flow, which implicitly involved time, coexisted with his higher feelings of competence, thereby supporting my third grounded hypothesis that an incorporation of time an influential factor regarding feelings of competence.

*Problem #3: Channel Island Foxes*

*Meg's Scientific Understanding*

Meg's focus on current environmental conditions that I observed during the *American Robins* problem reappeared in the *Channel Island Foxes* problem, which will lend support to my third grounded hypothesis. At the beginning of the problem, Meg stated that the pigs were "just taking away things from the natural need of the plants and animals." She used the term "need" rather than "food," despite her two group mates' focus on food alone. She also stated that the pigs may be taking away things from not only animals, which may share food resources with them, but also plants, which do not consume food. It seems that Meg knew that organisms require other things besides food but was unable to specify what those are and was content using the term "resource" to refer to those things that were amorphous to her. Further evidence for this claim emerged when she commented in the whole-class discussion, "Well, we thought they'd just both be competing for the same resources and food." If she understood food and

resources as synonymous, as her group mates seemed to, she would likely have not been redundant by saying “resources and food.” Meg’s concept of resources and/or food allowed her to pay attention to feeding relationships but also recognize how their depletion may contribute to the endangerment of the foxes through increased competition for those resources. This was demonstrated when she attempted to devise a solution to the eagle problem. She asked her group mates, “What eats the eagles?” and later, “So what’s controlling the eagle population?” Her first comment indicated that she can focus on direct feeding relationships but can also consider other means of population control, such as competition, as indicated by her second question. Although Meg effectively engages with this problem on an ecological level, her focus on present environmental conditions did not involve an element of time.

In her attempt to find a creative solution to this problem, Meg revealed unexpected understanding about how organisms avoid predation. She suggested that all the foxes be relocated to one island that is furthest away (*Appendix VI: Transcripts*, line 1276). After Carol commented that that would put them at a greater risk of predation by the eagles, Meg offered the solution to plant more trees to create more cover that would lead to a reduced risk of the foxes being preyed upon. Considering behavioral ecologists conduct detailed studies on how much cover is required for prey organisms to effectively avoid predation (e.g., Dill & Lima, 1990), her comment was quite insightful. Her suggestion also

further highlights her focus on the present environmental conditions in which the foxes are attempting to survive.

*Carol's Scientific Understanding*

Carol's focus during this problem set is also on current environmental conditions, which to her, are composed primarily of predator-prey relationships. After hearing the prompt, Carol's immediate question to her group mates was whether the foxes would eat the pigs or vice versa. Meg and Juan were not able to answer her question but moved on to an alternative idea – the introduced pigs compete with the foxes for resources, which Meg claimed was leading to the further endangerment of the foxes. Carol returned to attempting to figure out a feeding relationship between the foxes and the pigs, even though Meg and Juan further developed their competition for the resources idea. Meg and Juan temporarily abandoned their competition idea to explore the feeding relationship idea with Carol to the point that they asked for the instructor's help. I did not offer a direct answer about who eats who but gave them information on the approximate weight of each organism, their diets (i.e., omnivore, carnivore, etc.), and their teeth. After receiving this information, Carol abandoned her idea that one of the organisms must be eating the other. She then exclaimed, "It's depletion of resources!" While Carol was determined in the exploration of her hypothesis, her reluctance to abandon her idea that focused on feeding relationships in the face of her group mates' convincing reasoning about competition indicates that to Carol, feeding relationships constitute much of what is meant by "organismal

interaction.” Although she used the language (i.e., “resources”) that Meg used to refer to those interactions that do not involve direct feeding relationships, there is no evidence to suggest that Carol’s concept of resources involved much more than food. At one point, Juan claimed that the pigs are changing the environment, including the available resources, to which the foxes are adapted (*Appendix VI: Transcripts*, line 1198). Carol responded by acknowledging that that could be happening, or the pigs are “just going to contribute to them being endangered.” She did not offer a mechanism by which the pigs would contribute to their endangerment, indicating that Carol likely does not conceive of a non-feeding relationship interaction, such as competition, as a plausible cause for endangerment. Furthermore, when Juan put forth an idea that asked her to implicitly incorporate an element of time (i.e., “are changing the environment”) into how she was conceptualizing the situation, she seemed to have trouble assimilating and thus resorted to restating the likely effect in her own terms.

The nature of Carol’s “organismal interactions as feeding relationships” concept becomes clearer when the eagle is introduced into the problem. Initially, she misunderstood the problem, but her proposed solution gives insight into her reasoning. She thought the problem stated that there are two species of eagle – one that eats the foxes and one that eats the pigs. Carol suggested to her group that the eagle species that is eating the foxes be eradicated so that the species eating the pigs would decrease the pig population. If there were indeed two species of eagle, it would be unlikely that the feeding relationships in which they

participate would be so linear. Considering the group had just discussed with the instructor how similar in size and niche the pig and fox are, it would not be reasonable to think that the diets of two eagle species would be so differentiated, unless one's concept of feeding relationships is linear. In other words, Carol seemed to conceptualize feeding relationships as linear (i.e., food chain) rather than as a complex network in this problem (i.e., food web). This highlights her tendency to reason about the current state of conditions as stated in the particular problem rather than taking a broad perspective that would enable her to see the eagle as an organism adapted to eating a collection of prey items that share a set of characteristics, such as items that are easy to detect and catch. In other words, she seems to take an ecological approach, rather than an evolutionary approach that implicitly involves an element of time, to solving environmental problems. As will be discussed shortly, this is relevant regarding her sense of competence while solving this problem.

The final concept that emerged from Carol's conceptualization of this problem involves factors that affect feeding relationships between predators and prey. In an attempt to brainstorm a solution to this problem, Meg suggested that all the foxes be relocated to one island and the eagles be eradicated from that island. Carol immediately rejected this idea, claiming that, "then the freakin' eagles will fly to the island with foxes and murder them all!" This indicates that to Carol, a greater density of prey allows for a greater chance of predation. Again, she focused solely on the feeding relationship and the current environmental



conditions. She did not conceptualize other outcomes from this scenario that are possible over time, such as a greater density of foxes resulting in more reproduction and a subsequent increase in their population. Carol never considered this type of outcome, presumably because it does not involve a direct feeding relationship and necessitates a conceptualization of the problem that incorporates time.

*Juan's Scientific Understanding*

Juan's approach to this problem was quite different than Meg and Carol's approach. When Meg proposed that the pigs affect the Channel Islands ecosystem by "taking things that the native things need," Juan agreed and seemed to put her comment into his own terms: "So the pig would be eating some stuff that the fox ... So they would be probably fighting for food that's native for the fox, not the pig." Although Meg consistently talked about the foxes' "needs", Juan always discussed food, as if it is the only need. Juan's focus on feeding relationships is, however, different than Carol's concept. While Carol attempted to figure out if the fox is eating the pig or vice versa, Juan was not fixed on a direct feeding relationship between the fox and the pig. This allowed him to effectively discuss with Meg the possibility of competition between the pig and the fox. Juan's idea of competition between the fox and the pig persisted, even after the eagle is introduced into the problem, when he agreed with Meg that the only reason to remove the pigs is because "they're changing everything." He then mentioned, "If only the eagles weren't eating the foxes," indicating that he believed the problem

of increased competition for the foxes would be resolved if the eagles were not eating foxes in addition to pigs. Thus far, Juan's comments indicate that his concept of necessary resources for survival is essentially "food," but he was nevertheless able to reason about competition for food with Meg, not only a direct feeding relationship, as was the case with Carol. Furthermore, his mentioning of "food that's native for the fox, not the pig" gives initial support to my claim that he approaches this problem from an evolutionary, rather than an ecological, perspective. While biologists would not use the word "native" like this, this comment is an initial indication that Juan thought there was somehow a match between the foxes and the food resources available on the Channel Islands, and the pigs did not have this match because they are not native to the Channel Islands. It is plausible that Juan had a concept for native in which organisms are adapted to specific environments, and if those environments are altered, once-beneficial adaptations may no longer be useful. More convincing evidence for this claim was offered when he later stated, "Maybe they're taking out resources from an adapted species, which is the fox. They're changing their whole environment or their ways of surviving." While there certainly is not evidence to state that Juan knew the means through which an organism adapts to its environment, Juan seemed to have the understanding that organisms are adapted to their environments and that environmental change may render adaptations useless. Again, Juan's conceptualization of the problem set is different than Meg and Carol's conceptualizations because he incorporated an element of time into his

reasoning by approaching it from an evolutionary perspective. He seemed able to discuss the dynamics of the situation, as in what the environmental conditions were before and after the introduction of the feral pigs. Conversely, Meg and Carol only focus on the current environmental conditions when they attempted to understand who competes with or eats whom.

*Group's Causality Reasoning*

When the students received the first prompt, their initial inclination was to figure out who eats whom. They each devised their own causal arguments for what was happening in the problem (Figures 20-22). Juan stated that pigs are meat and foxes eat anything that is meat. He then coordinates these two conditions to conclude that the foxes could eat the pigs. Because there is coordination of these two conditions, this is a multicausal argument (Figure 20). Juan's claim that foxes eat "anything that is bloody" is categorical because he did not claim there is a degree to which something can be bloody. However, he stated that foxes "could" eat pigs, thus leaving open the possibility that they may not; this conclusion is graded.

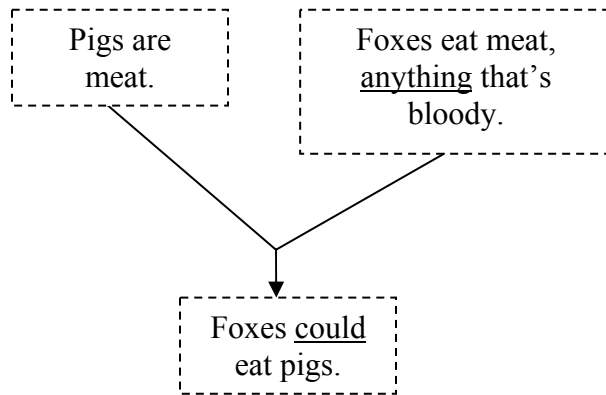


Figure 20. Juan's initial reasoning in response to prompt #1 of the *Channel Island Foxes* problem and Carol's question about whether the foxes eat the pigs or vice versa.

Carol initially responded to the first prompt through two separate arguments (Figure 21). She first proposed that there would be so many pigs that they would gang up on the foxes. Her language "so many," while extreme, is graded because it indicates a continuum in the number of pigs. She then proposed that if foxes eat pigs, then the fox population would increase by the presence of the pigs. Both of these arguments are linear because in each a single condition leads to a single effect.

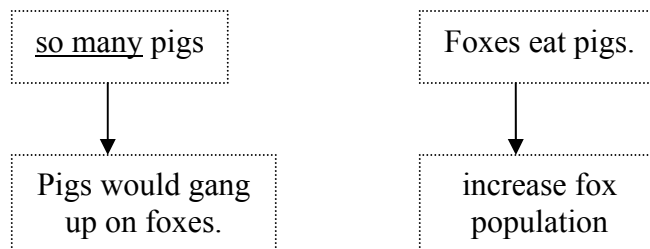


Figure 21. Carol's two initial lines of reasoning in response to prompt #1.

Meg proposed her own argument in reaction to the first prompt (Figure 22). She coordinated three conditions with one line of reasoning, in which she claims that if pigs eat foxes, the fox population would decrease. Thus, her argument is multicausal. Her argument that the fox population would “decrease,” rather simply be eliminated, is graded, and she included humans in her reasoning by proposing they should get rid of the pigs.

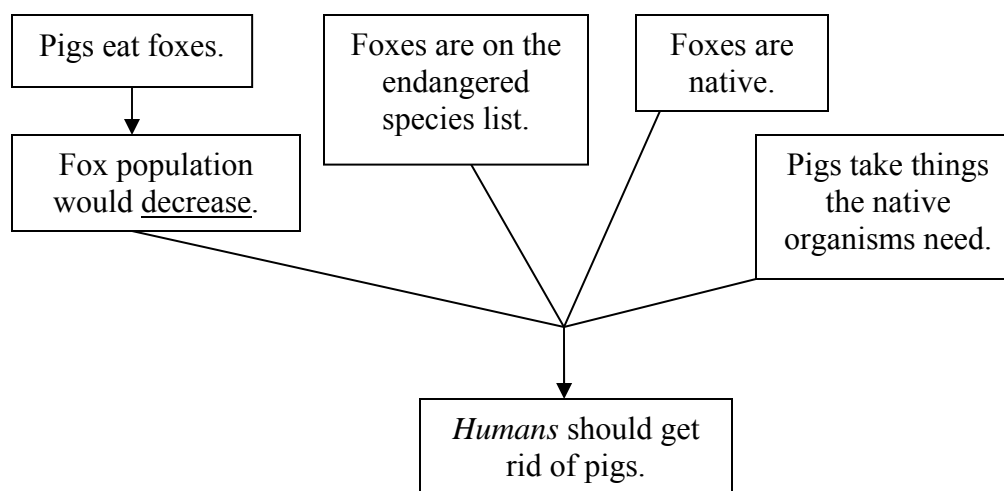


Figure 22. Meg’s initial lines of reasoning in response to prompt #1.

After their initial reactions to the prompt, the focus group members discussed the issue and generated a multicausal argument explaining how the pigs’ presence affects the Channel Island ecosystem (Figure 23). All three students coordinated two conditions, that pigs eat things the foxes would eat and that pigs are non-native, but they arose at three different conclusions. Carol’s idea that the foxes are too fast to be eaten by the pigs is graded because her argument demonstrates a degree of fastness. She also stated that the pigs will “contribute” to

the foxes' endangerment, which is also graded because she did not argue that the pigs cause extinction. Juan's argument that the pigs change the "whole" environment is categorical because his language did not indicate a degree to which the pigs may affect foxes' habitat.

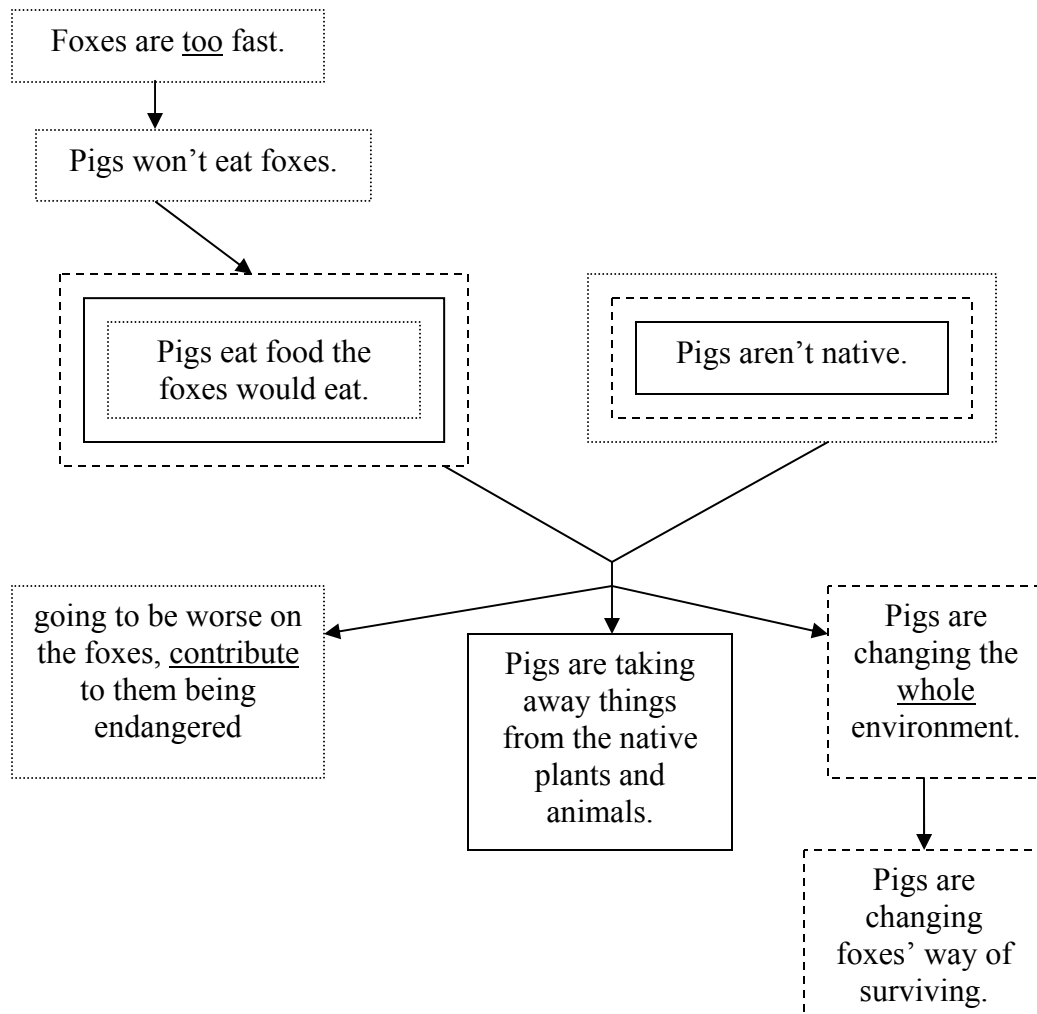


Figure 23. Focus group's causal arguments about how the introduced pigs affect the ecosystem and the foxes on the Channel Islands.

Carol initially misunderstood the second prompt to read that there are two species of eagle, one that preys on foxes and one that preys on pigs. Based on her

misunderstanding, she devised a plan on how to bring the fox and pig populations into balance (Figure 24). She proposed eradicating the species of eagle that eats the foxes, which is human-inclusive. She argued that this would lead to two effects, which makes her argument multicausal. Both effects are graded. “More,” rather than all, of the pigs would be eaten, and the foxes would have “a chance,” rather than a guarantee, to survive.

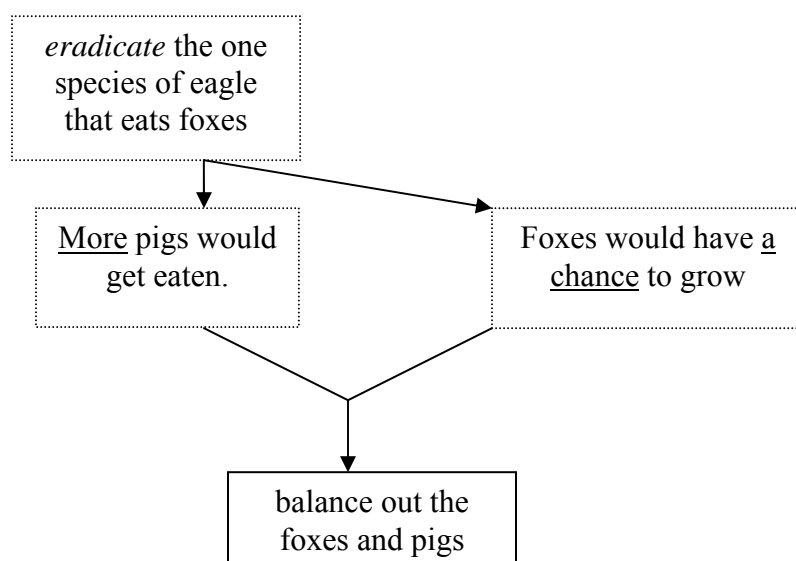


Figure 24. Carol’s initial reasoning in response to prompt #2 when she misunderstood the problem to have two species of eagles.

After Carol had realized her original misunderstanding of the problem, the focus group reasoned multicausally about the situation, mostly under Meg’s direction (Figure 25). Meg included humans in her reasoning three times, one of which was echoed by Carol, when she discussed the pros and cons of eradicating and putting more pigs. She used graded language twice when claiming the pigs

are “only helping” affect the foxes’ endangerment “only ... a little;” this contrasted with a categorical argument in which the pigs would directly causing the foxes’ endangerment. Meg made three categorical claims when she agreed with Juan that the pigs were changing “everything,” and when she independently stated that “all” the eagles would eat are foxes, which would go “completely” extinct.



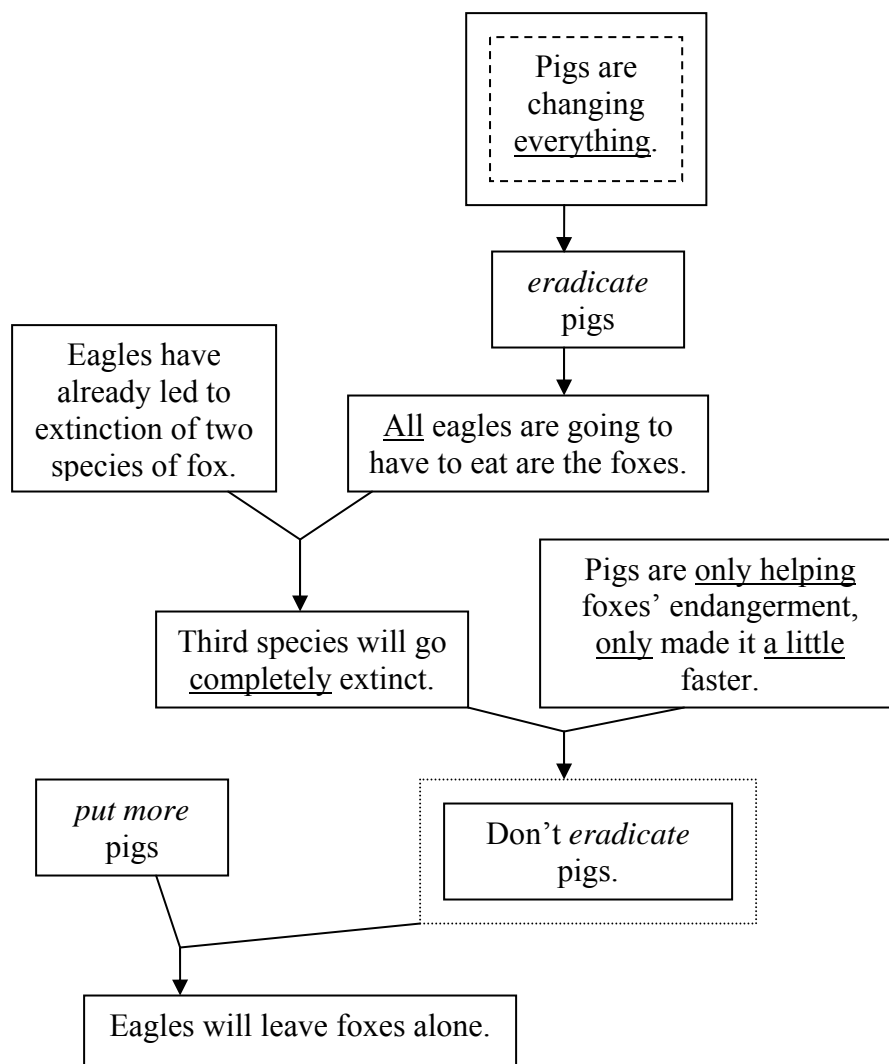


Figure 25. Focus group's reasoning about why the pigs should not be eradicated if the eagles are present.

In an attempt to find a creative solution to the problem, Meg offered three more arguments (Figures 26-28) to which her group mates responded. In the first (Figure 26), she proposed the eagles be eradicated from one island, to which Juan and Carol pointed out that the eagles colonized the islands initially. Thus, they all concluded the eagles would fly back to the one from which they were eradicated.

This conclusion is multicausal because it coordinates both conditions: eradication from one island and the fact that the eagles colonized the islands initially. Meg's conceptualization involved humans in her potential solution, and it is also graded because she proposed the eagle eradication be done on a small scale, not across the entire island chain.

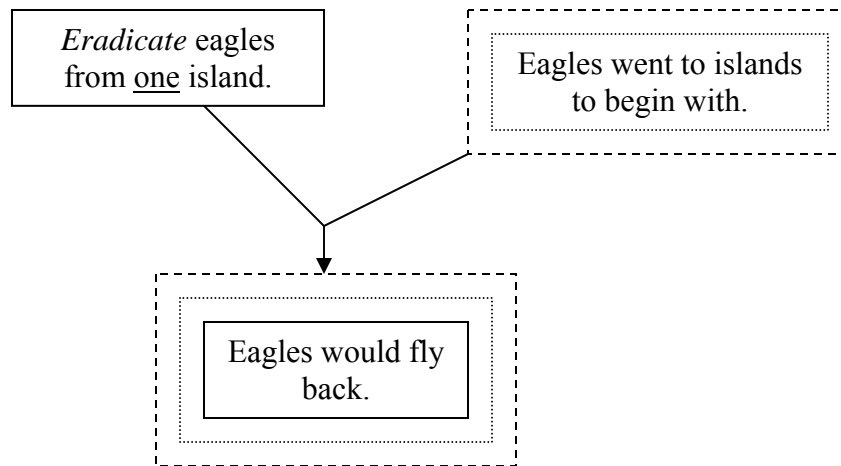


Figure 26. Focus group's response to Meg's idea that eagles be eradicated from one island.

In Meg's second attempt to find a solution, she questioned what could possibly control the eagle population; she included both human and nonhuman controls (Figure 27). Carol disagreed with her proposition that the eagles should be controlled, but her disagreement indicated she too was considering the consequences of human participation in this issue.

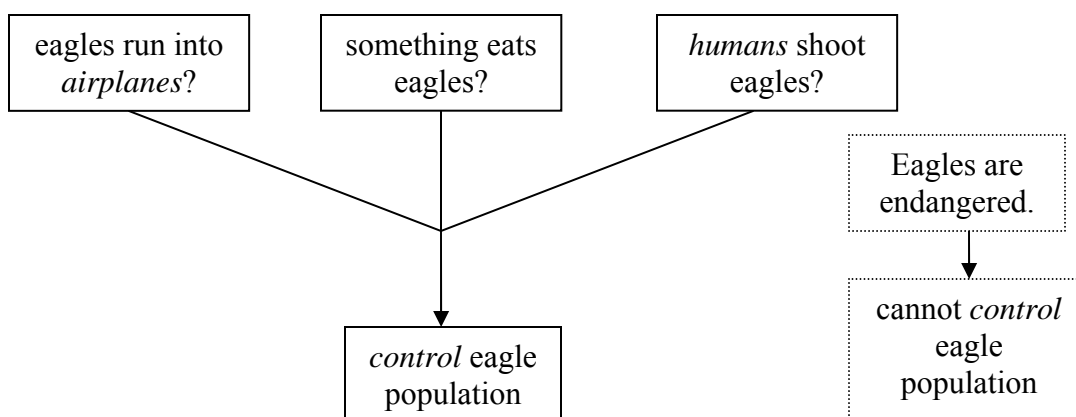


Figure 27. Meg reasoned about what could control the eagle population, while Carol argued their population should not be controlled.

Finally, Meg made three propositions, all of which involved human participation in the problem (Figure 28). She suggested humans sequester all the foxes on one island and hide them by planting more trees. When Carol disagreed with this, she retorted the foxes could be on the “bottom” island, or the southernmost island that is most isolated from the others in the archipelago. Carol's initial response to Meg's suggestion that the foxes all be sequestered to one island is categorical because she argued “all” of the foxes would be “murdered” by the eagles.

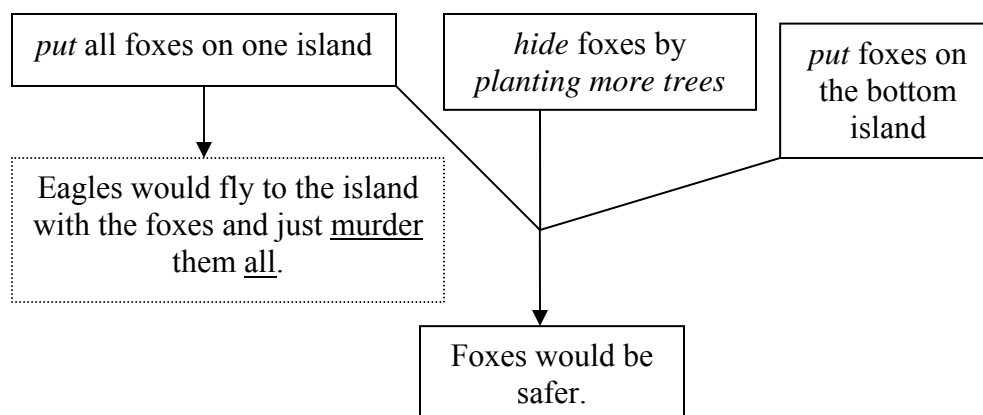


Figure 28. Meg and Carol's reasoning about what would happen if all the foxes were placed on one island.

To summarize the group's causality reasoning, the arguments in which Meg took part were multicausal, although her language was mostly (63%) graded. Meg also attempted to incorporate humans in her solutions several (12) times. Half of Carol's arguments were linear, and most (71%) of her language was graded. However, Carol only included humans in her reasoning when engaged in an argument with Meg. Finally, the arguments in which Juan participated were all multicausal and mostly (80%) categorical. Like Carol, the only human-inclusive arguments in which he participated were the ones that also involved Meg.

#### *Students' Competence Satisfaction*

Carol was the focus group member interviewed following the *Channel Island Foxes* problem. Although Carol was able to explain that urbanization in California is what led to the eagles colonizing the Channels Islands, she did not mention her role in urbanization. Thus, she did not seem able to conceptualize her own role in a process that lead to the environmental problem with the Channel

Island foxes. Regarding her sense of competence while solving this problem, Carol felt that in order to effectively solve it, she needed more information, such as how much each animal eats per day. This indicates that she did not feel especially competent during this class period. Her DNSS score of 19 ( $z = 0.44$ ) was higher, although not statistically significantly different, than her mean score of 17.8. I will discuss in *Chapter 5: Results of Research Question 4* how Carol fulfilled the role of “questioner” in her group; she and her group mates all felt that she contributed to the group by constantly asking questions that allowed them to converge on a solution. So while she cited lack of information as a contributor to her feelings of low competence in the *Channel Island Foxes* problem, it was unlike Carol to passively accept the lack of information without attempting to find the information she felt she needed to solve the problem. It is plausible that because she was unable to conceptualize her role in the processes leading to the problem with the Channels Island foxes, her sense of competence was not supported, and this in turn prevented her from asking questions to find the information she felt she needed to solve the problem. In other words, Carol’s experience with this problem further supports my first grounded hypothesis, that the ability to conceptualize one’s role in the system involving an environmental problem is vital to feeling competent about solving the problem.

My analysis of Carol’s conceptualization of this problem also offers support for my second and third grounded hypotheses. Half of the arguments in which she took part were linear and most of them were also graded. Furthermore,

her conceptualization of the problem involved a limited concept of organismal interactions, focused exclusively on the present environmental conditions, and involved an ecological, rather than an evolutionary, perspective. In other words, Carol's feelings of low competence coexisted with a scientific conceptualization that is less desirable from a scientific standpoint and is characterized by a large number of linear, graded causal arguments, which supports my second grounded hypothesis. Carol also had trouble incorporating an element of time into her reasoning while discussing the problem with Juan. The coexistence of this challenge with her feelings of low competence supports my final grounded hypothesis.

Although not statistically significant, Meg's DNSS score (15,  $z = -0.39$ ) was below her mean, while Juan's score (20,  $z = 0.81$ ) was higher than his mean. Because Meg and Juan were not interviewed following this problem, I can only speculate about what the relevance of these trends. Juan's discussion of how the pigs are changing the environment to which the foxes are adapted highlights Juan's tendency to incorporate an element of time into his conceptualizations of problem sets via an evolutionary approach. Correspondingly, his sense of competence was high as measured by the DNSS. Conversely, Meg effectively engaged with the problem on an ecological level but did not incorporate an element of time, which coexisted with a DNSS score that was lower than her mean. Thus, their data offers token support for my third grounded hypothesis, that

conceptualizing a problem from an evolutionary perspective that involves time is influential regarding feelings of competence.

*Problem #4: Western and Arroyo Toads*

*Meg's Scientific Understanding*

Meg's conceptualization of the *Western and Arroyo Toads* problem revealed her concept of fitness, which when compared to Juan's concept, will offer more support for my third grounded hypothesis, that an ability to reason with time is influential toward feeling competent. Juan and Carol began by discussing the meaning of "fitness," but Meg did not contribute to this discussion until she shares, "I think it's in the literal sense, like their strength." This indicates that at least initially, Meg did not see a connection between how often an organism mates and their biological fitness. Moreover, to Meg, fitness means "strength"; if an organism has high fitness, it is strong. This notion of fitness does not incorporate an element of time because it focuses on an organism's strength at a particular time, which can change only over an individual's lifetime. A concept of fitness that involves reproduction, however, would allow for conceptualization of how fitness affects future generations, which occurs over a much broader time scale.

Unfortunately, Meg had to miss the second class period in which this problem was discussed due to a death in her family. Therefore, she was not present during the whole class discussion in which biological fitness was determined to mean one's ability to pass one's genes to future generations. On the

third day in which this problem was discussed, they were asked if Western and Arroyo toads would be considered the same species in 200 years if a fertile hybrid were to occur. It was in this discussion when Meg's concept of a hybrid emerges. Meg stated, "It wouldn't really change the population, would it? There would just be more of these hybrids running around." This indicates that she did not see how a hybrid could be the beginning of gene flow between species. She also asked her group, "But I don't know if they'd be considered the same species." She also seemed to regard the hybrid as an inherently different from both the Arroyo and Western toads, not as simply a new combination of pre-existing genes. This is further evidenced by her explanation to the instructor of why she thinks the Arroyo toad population would decrease over time: "Because they're not as good. Because they don't have that advertisement call, so they're not gonna be as good." On one hand, this is encouraging because she seemed to use the collectively constructed notion of fitness that emphasized ability to reproduce (i.e., "They don't have that advertisement call [which enables reproduction], so they're not gonna be as good"). However, she seemed unable to imagine what happens *after* the creation of the first hybrid. She seems unable to see that the hybrid would produce offspring, and some of them would likely be fertile and will thus mate with Arroyo and Western toads, which would repeat indefinitely. In other words, her conceptualization of the problem lacks an element of time, even though the problem set includes language relevant to time (i.e., "200 years from now"). Her understanding that the hybrids are separate from both the Arroyo and



Western toads and the lack of the time element in her conceptualization combined to prevent her from seeing potential gene flow in this situation. Meg's conceptualization of this problem will be contrasted with Juan's to offer more support for my third grounded hypothesis.

*Carol's Scientific Understanding*

Carol seemed to have a concept of fitness that is similar to Meg's, although she referred to "physical features" rather than "strength." Upon receiving the prompt, Carol seemed to immediately consider the notion of reproductive competition between the male Western and Arroyo toads. She asked her group mates, "Do they fight? Do toads fight?" It is unclear if she was asking if they literally fight or if they do so figuratively, as in competing for the same female toads. After Juan stated that he thinks they would "fight," she took her idea further by stating that if the female toads are attracted to the Western toads, then the Arroyo males "would have to go find the females." This is the first utterance that allows inference of Carol's concept of biological fitness. The group's conversation turned toward this issue. After Meg and Juan discussed what fitness is, Carol concluded, "I think it's the Arroyo toads [that have greater fitness]." She explained that if fitness refers to "physical features," then the Western toads are "not going to be searching for females if they're going to be in one area ... calling." In other words, Carol believed that because the male Arroyo toads do not call, they have to actively search for females, which would involve exercise that results in greater fitness. She reiterated her idea to the instructor:

“The male Arroyo toads are having to chase the females ... and the Western toads are just calling and staying in one place ... so the Arroyo might be more fit.” At the beginning of this problem, it seems Carol’s concept of biological fitness is essentially physical fitness; when an organism is biological fit, it is in shape.

The prompt distributed the following day revealed that the hybrid was most likely sterile, and it asked the students to decide whether or not sterility would affect the hybrid’s fitness. Juan stated that he does not think the sterility would affect fitness because “the offspring is going to be the same, strong and everything but it’s not going to be able to reproduce, that’s all.” Carol agreed with him: “I think it’ll be the same too.” This is further evidence that her concept of biological fitness does not involve the necessity to reproduce, as the desirable concept does. Like Meg’s idea, this does not allow for a consideration of how one’s fitness affects future generations and thus does not incorporate an element of time at the appropriate scale.

By the third day of working with this problem, the class had collectively decided that biological fitness is different than physical fitness and refers instead to one’s ability to pass one’s genes to future generations. They were given the prompt that asked them to consider whether or not the Western and Arroyo toads would be considered the same species 200 years from now if, by a lucky fluke, a hybrid were to be fertile. After listening to Meg and Juan toss ideas back and forth, Carol contributed, “I think that it would like evolve somehow ... because since the hybrids are gonna be more powerful they’ll be able to multiply ... better,

I guess, 'cause they'll be more fit. Then I think that the other frogs will have to evolve in order to catch up to them or else they're just gonna ...” It seemed that her concept of fitness had changed, or at least she was attempting to use the concept constructed in the whole class discussion, albeit apprehensively. This statement also evidences that she believed evolution occurs out of necessity rather than by chance (as in mutation) or introduction of new genes (as in emigration or immigration); this is a well documented alternative concept in the literature (Bishop & Anderson, 1990). Finally, she, like Meg, did not seem to consider the hybrid as the medium through which genes could flow between species because she regarded the hybrids as a separate type of toad than the Western and Arroyo toads. Unlike Meg, however, Carol incorporated an element of time into her conceptualization when she claimed that the “other frogs” (i.e., Western and Arroyo toads) would have to evolve to “catch up.” Despite the undesirable concept of evolution, it seems she was attempting to conceptualize how the toads would have to change due to the new condition, the presence of the fertile hybrids. In other words, this incorporation of time into her conceptualization seemed to allow her to reason about the problem as conditions changed, rather than focus on present environmental conditions.

Later in this discussion, Carol claimed that the hybrids are “kinda different ... but it's not introducing anything different.” This seems to indicate a change in her understanding in two respects. First, she seemed to realize that the hybrid was simply a new combination of genes that already existed in the Western and

Arroyo toads. This realization could serve as a foundation for the development of the scientific concept of gene flow. Second, Carol seemed to also recognize, perhaps tacitly, that change had occurred in the toad populations even though it was not out of necessity. This is critical if she is to develop a desirable concept of evolution in which new species can be new combinations of previously existing species, rather than phenomena that simply happen due to the necessity to survive. Another one of Carol's comments indicates that she was not there yet; she stated, "From homework, I've found out that in order ... for another species to catch up ... they have to sometimes do things differently, and that's how they evolve. Like, the ones that are doing things differently, and the ones that are able to reproduce, are the ones that are gonna survive." This indicates that Carol still believed that "doing things differently" is done out of necessity and most likely consciously. However, this statement also indicates that she was reasoning more fluently with the collectively constructed concept of fitness, which involved the importance of reproduction. It also provides further evidence that her reasoning was becoming more dynamic as it incorporated an element of time.

#### *Juan's Scientific Understanding*

Juan's concept of biological fitness will be contrasted with Meg and Carol's to offer support for my third grounded hypothesis. His concept seemed to be in flux throughout this problem set. Upon receiving the first prompt, Juan immediately agreed with Meg that the Arroyo males would be most likely to mate with female toads. He then moved on to the next question: which would have

greater fitness? He asked his group mates, “What do they mean by fitness? Is it his body?” This suggestion was what spurred the rest of the discussion that led the group to conclude (for the day) that biological fitness is the same as physical fitness. However, after he posed this question to Meg and Carol, he asked, “Maybe ... the greater opportunity to procreate?” After they did not respond to his comment, he stated again, “The greater fitness ... I guess the more opportunity to reproduce.” Both of these comments were virtually ignored and the discussion continued toward the “biological fitness is physical fitness” concept. Juan’s concept of what biological fitness vacillated between physical fitness and opportunity to reproduce. He first asked, “Is it his body?” which would correspond to the idea that the group constructed. However, he also suggested twice that biological fitness might involve an opportunity to reproduce. The latter concept is not totally desirable from a scientific standpoint; fitness involves one’s actual success in reproduction, not only the number of opportunities to reproduce. Yet, his concept was quite sophisticated because it focuses on reproduction rather than physical fitness, which is why it is unfortunate that it was not integrated into the group’s discussion. Later in this same discussion, Juan went along with the group’s concept that biological fitness is physical fitness. It is unclear if his group mates convinced him or if he was just being polite. Either of these are plausible, given that his concept originally seemed to be in flux regarding biological fitness.

Not much more can be said about Juan’s scientific understanding because he often agreed with his group mates’ claims. However, his proposals about

reproduction being involved with biological fitness indicate that he may have been incorporating an element of time in his conceptualization of the problem. When a student sees reproduction as important, there is some indication that s/he is at least tacitly attending to what happens in the next generation. There is not enough evidence to make this claim about Juan's conceptualization of this particular problem, but in light of data from the other problem sets, Juan seemed to have a tendency to approach problems from an evolutionary perspective that involved an element of time.

#### *Group's Causality Reasoning*

Although Juan proposed to his group mates that more opportunity to reproduce leads to more fitness, Carol and Meg devised an alternate explanation to the first prompt. They coordinated two conditions and one line of reasoning to conclude that Arroyo toads are more fit (Figure 29). Meg argued that the male Arroyo toads are stronger; the use of the comparative inflection "er" indicates that amount of strength is graded. The two other conditions proposed by Carol also included language that indicates gradedness. Her use of the words "just" and "one" in "They're just calling and staying in one place," indicate there was not a continuum in the amount of calling and movement and are therefore categorical claims. She also equated fitness with physical fitness by stating fitness "is really" physical features. This statement is also categorical because she posited no difference between the two definitions. Meg and Carol's conclusion, that Arroyo

toads were “more” fit, is graded, as it indicated a possible range in fitness.

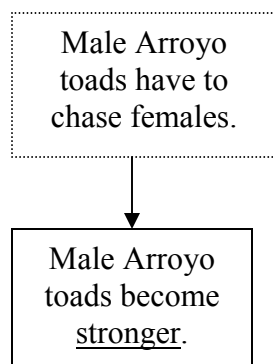


Figure 29. Carol and Meg’s explanation of why Arroyo toads were more fit, to which Juan eventually agreed.

When students were asked to consider a situation in which a hybrid is fertile, Meg devised a multicausal argument about why the Arroyo and Western toad populations would not be affected (Figure 30). Her argument did not include language relevant to gradedness.

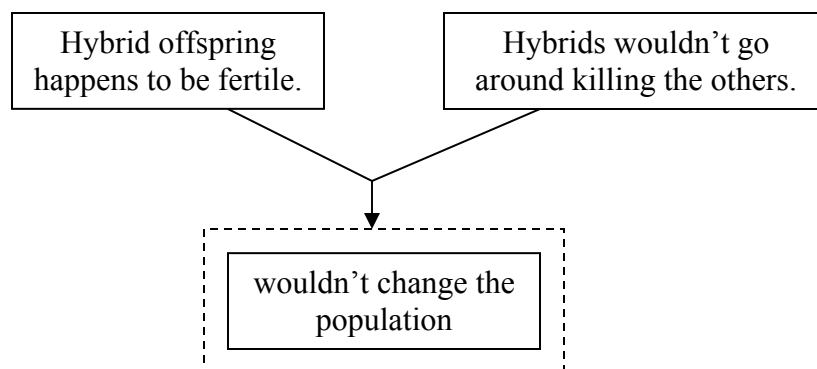


Figure 30. Meg’s explanation of why Arroyo and Western toad populations would not be affected by a fertile Arroyo-Western toad hybrid.

Meg finalized the discussion by offering two multicausal arguments that explained how the Arroyo and Western toads would be affected by a fertile hybrid (Figure 31). She argued that the Arroyo toads “aren’t as good,” which is a graded

claim, because they cannot call while the hybrids can. This led her to conclude that the Arroyo population would “decrease;” this is another graded claim because she was not positing complete extinction. Because Western toads can call, she argued that they will not be affected. This conclusion is categorical because she claimed no degree of effect that the hybrids could have on the Western toads.

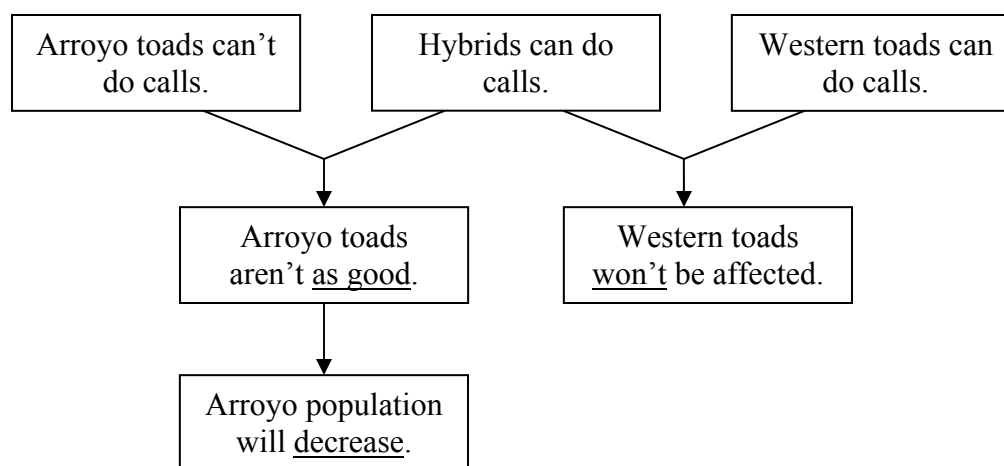


Figure 31. Meg’s modified explanation of how a fertile hybrid will affect Western and Arroyo toads 200 years from now.

To summarize the group’s causality reasoning, all of the causal arguments in which Meg participated were multicausal, while the majority (57%) of her language was graded. Most (60%) of Carol’s arguments were multicausal, and her language was graded half of the time. All of the causal arguments in which Juan took part were multicausal, and he did not use language that indicated gradedness.

#### *Students’ Competence Satisfaction*

Because this problem set occurred across three class periods, each student was interviewed following some portion of the problem. Meg was interviewed



following the first day this problem was addressed. Her DNSS score for the day (14;  $z = -0.73$ ) was lower than her overall mean for the course, and her comments during the interview did not indicate a different conclusion (*Appendix VI: Transcripts*, lines 1445-1458). It was not expected that students would be able to conceptualize their role in the processes that involved the evolution of the toads, and Meg did not give an indication that she could conceptualize her role in this process. She was also unable to conceptualize the problem using an element of time and consistently used concepts that are not desirable. Thus, analysis of Meg's engagement in this problem partially supports my second hypothesis, which is that feelings of low competence coexist with less desirable scientific conceptualizations and mostly linear, graded causal arguments. One exception to this is that Meg's arguments during this problem were exclusively multicausal. It is likely that the presence of multicausal arguments was not sufficient to overcome the feelings of low competence resulting from an inability to conceptualize one's role in the problem, less desirable scientific conceptualizations, and the large number of graded arguments.

Juan was interviewed following the second day this problem set was addressed. He also made comments during his interview that indicated he felt highly competent. He explained, "This class is dedicated to solve problems in the environment. Since the first class we met we started to solve different problems ... so we're kind of getting used to solving different problems. Even though sometimes we might not even get ... a solution because it's not even the scientists

get a solution ... but we sometimes get up to the point that they got, the scientists, the ones that are studying the same thing. We just got to the same level or idea.” His comparison of himself to scientists indicates that he feels competent in the course, although his DNSS score from this particular day (19,  $z = 0.81$ ) was not statistically different from his mean score. An additional comment from this interview also supports the conjecture that he felt highly competent. He explained that he goes “to [his] family and ‘look[s] smart’ (uses quotes gesture).” Because he used the quotes gesture, it is unclear if he really believed himself to be smart or if he only looked smart when discussing what he had learned in class. Regardless, he seemed to feel competent enough to share information with them that he learned in the course. It is also difficult to tell whether or not he feels this high level of competence because of the *Western and Arroyo Toads* problem or because of his overall engagement in the course. Nevertheless, these feelings of high competence seemed to coexist with his consistent tendency to conceptualize the problem sets using an element of time, which thereby supports my third grounded hypothesis that this ability is influential toward feelings of high competence when solving environmental problems.

As stated earlier, I did not expect that students would be able to conceptualize their role in the *Western and Arroyo Toads* problem because humans are not directly involved in toad evolution, at least in how the problem was presented to students. Carol, who was interviewed after the third day of this problem, seemed able to make it meaningful to her. During her interview, Carol

stated that the problem was important to her “because it pertains to us too and our evolution, evolution as human beings.” This indication that she conceptualized her own role in the problem under study may have contributed to her feelings of high competence. Although her DNSS score for the day (19,  $z = 0.44$ ) was not significantly different than her overall mean, data from her interview indicate she felt highly competent. She commented that her group felt “pretty comfortable around each other,” which was why she was not shy about saying wrong answers, even with instructor present. Furthermore, this problem was the first in which I inferred Carol incorporate time into her conceptualization of a problem set. Thus, my analysis of Carol’s engagement with the *Western and Arroyo Toads* problem lends evidence to support my first and third grounded hypotheses. Carol seemed able to conceptualize her role in the system under study, and her conceptualization incorporated an element of time, which I claim combined to influence her feelings of high competence.

*Problem #5: Baja Rodents*

*Meg’s Scientific Understanding*

As seen in previous problem sets, Meg approached the *Baja Rodents* problem from an ecological approach that did not incorporate an element of time even though evolutionary concepts were part of her conceptualization of this problem. Although Meg seemed unable to use a desirable concept of gene flow in the *Arroyo and Western Toads* problem, she immediately used her concept of gene flow to explain how speciation occurred between the rodent species. She

stated, “They probably found a different species over there [on the peninsula] and were like, ‘Oh, okay.’” She clarified by stating, “I think it’s like with the toads, how they just mate with other people and then they just created, like a whole new species. So that’s probably what they did when they separated.” Here, she did not seem use time in her conceptualization of how this separation occurred; it is as if the separation occurred spontaneously or the landmasses were already separated when the speciation occurred spontaneously. It is also unclear if she meant the hybrids would be the new species without further gene flow between the two original species or if the mixing over time would lead to a population that would be considered a different species than on the mainland. Although this time-inclusive possibility remains, her tendency throughout the course has been to reason in the short term. Thus, it is likely she continued to only think in the short term after one hybrid is created rather than what would occur over many generations.

#### *Carol’s Scientific Understanding*

It is unclear if Carol reasons with time during her engagement with the *Baja Rodents* problem, primarily because she contributes minimally to the discussion. Nevertheless, her few utterances indicate growth in her understanding from the *Western and Arroyo Toads* problem. After listening to Meg and Juan pose their ideas, Carol stated, “It could be like with the frogs who where attracted ... differently to different species. Both sides [of the Gulf] aren’t the same right? They’re totally different.” Unlike in the *Western and Arroyo Toads* problem,

Carol considered a new combination (i.e., being “attracted differently to different species”) as a plausible source of speciation. She also asked, “The chemicals and stuff can cause them to change also, right?” While mutations are not always caused by chemicals, seeing mutations as a possible source of variation that could lead to new species is a scientifically desirable concept. On the other hand, her statement about chemicals indicates she thinks humans were present to contaminate the environment. This would be desirable except that the problem stated that the rodent speciation occurred about five million years ago. She could simply not know that humans were not present five million years ago. Alternatively, she could be excluding time from her conceptualization of the problem.

*Juan’s Scientific Understanding*

Like Carol and Meg’s engagement with this problem, I am able to claim very little about Juan’s understanding because their discussion of this problem was so short. Juan’s ideas, however, seem once again different than Meg and Carol’s concepts. After receiving the prompt, Juan asked his group mates, “Isn’t the climate a lot different in Baja from the rest of Mexico?” After Meg agreed, he stated, “That could be one of the causes ... there’s a big different ... and then-”. Juan was then interrupted by Carol. After Meg shared her gene flow idea, Juan tried again to put forth his idea: “What about the fact that Baja is surrounded by water?” His group mates did not seem to pay attention to him, and Juan seemed to go along with Carol and Meg’s ideas for the remainder of the discussion. Juan’s

focus was on the differences in climate between Baja California and mainland Mexico, and indeed these conditions played a role in the evolution of rodents in these two locations. Because his ideas were not integrated into the group's discussion, there was no further exploration of the role that climate plays in the evolution of species. Unfortunately, there is also no more opportunity to fully understand Juan's concepts. On one hand, he could hold a desirable concept in which the two environments exerted different selection pressures on the rodent populations, resulting in differences in genetic diversity over time. Alternatively, he could believe that the different environments directly caused or promoted changes in genetic diversity, which is a common alternative concept (Bishop & Anderson, 1990).

Both of these possibilities, however, are different than Meg's ideas and are likely different than Carol's. Unlike Meg, Juan focused on differences in the environment, rather than what the toads were doing at a particular moment. While Juan's approach could be called ecological because it focused on environmental conditions, I argue he still took an evolutionary approach because in such a problem that asks what may have caused speciation, environmental conditions should be considered because they are what exert selection pressures on organisms. Although Carol considered how chemicals in the environment may have caused mutations in the toads, her conceptualization lacked an element of time, which would have involved some connection between the mutation that she posited and the rodent speciation. I am unable to claim that Juan reasoned with an

element of time because his ideas were never integrated into the discussion, but given his history in the course and focus on broad climatic conditions, it is likely.

#### *Group's Causality Reasoning*

In response to the *Baja Rodents* problem, each member of the focus group devised their own explanation; I will discuss Meg's argument as it is the only one relevant to the claims I make regarding this problem set. Meg (Figure 32) offered a linear explanation in which rodents mate with others on the peninsula after the geologic separation, which somehow led to different species. Her explanation did not contain language that was relevant to gradedness. The students do not discuss the problem sufficiently to converge on a collectively constructed explanation.

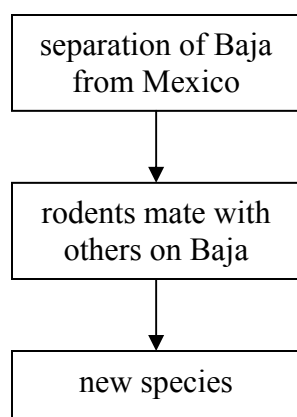


Figure 32. Meg's explanation of what could have led to rodent speciation on mainland Mexico and Baja California.

#### *Students' Competence Satisfaction*

The *Baja Rodents* problem took place on the same day as the third day of the *Western and Arroyo Toads* problem. Therefore, the students' feelings of

competence during this class period have already largely been discussed. To recap, Carol, the student interviewed after this class period, did not have a statistically different DNSS score (19,  $z = 0.44$ ) but made comments during the interview about feeling comfortable enough in her group to say incorrect answers. Meg's DNSS score (12,  $z = -1.43$ ) was lower than her overall mean, although not statistically significantly so. Her apparent feelings of lower competence coexisted with her failure to incorporate time into her conceptualization of the problem, which thereby supports my third ground hypothesis that this ability is relevant regarding feelings of competence. She participated in only one causal argument, which she devised alone, and it was linear. This also lends support to my second grounded hypothesis, that students' in-class participation was generally characterized by less desirable scientific conceptualizations and mostly linear, graded causal arguments when their feelings of competency were low. Juan's DNSS score (20,  $z = 0.81$ ) was higher than his overall mean, and this coexisted with a seemingly desirable, albeit unexplored, scientific conceptualization of the problem. Due to the lack of data about Juan's scientific understanding, his data cannot lend support to any of my grounded hypotheses.

*Problem #6: A Day in the Life of an Average Joe*

*Students' Scientific Understanding*

Unfortunately, students did not draw upon their scientific understanding as they engaged with this problem. This could imply scientific understanding has little to do with the ability to successfully act pro-environmentally. Alternatively,



this activity could have simply failed to elicit their scientific understanding that underlies their reasons for acting pro-environmentally. It could be that no integration of scientific understanding into the justification for certain pro-environmental behaviors may lead to a lack of satisfaction of students' need for competence. The degree to which Carol's need for competence was satisfied during this activity will be discussed because she was the participant interviewed after this activity. Further discussion of the relationship between scientific understanding and feelings of competence toward solving environmental problems will also occur in *Chapter 7: Discussion*.

#### *Students' Competence Satisfaction*

Carol seemed to feel highly competent during the *Average Joe* problem, as evidenced by her high DNSS score (20,  $z = 0.82$ ) and comments during her interview. Her feelings of high competence are evidenced by her explanation of what she feels like when she watches the news: "When I see something or when I read something or when I hear something over the news, I actually think about, whereas before I'd just like turn the channel. (laughs) It was boring ... now that I have the information, I can actually think about it." This comment relates to the *Average Joe* problem because the problem is designed to ask students to put themselves in everyday situations and reason about them from an environmental perspective. The item in the problem that Carol received in the task was to determine what was more environmentally friendly when the bagger in the grocery store asks, "Paper or plastic?" She commented, "It's funny [be]cause the

same question happened to me when I went to Trader Joe's." When the interviewer asked her to share more about her experience at Trader Joe's, she explained that when the bagger asked her, she thought, "What's going to make a bigger impact?" Her comments serve as evidence that Carol conceptualized her role in a larger social process that has environmental implications. She offered further evidence when she described several conversations she had begun with her boyfriend and father. In one instance, she asked her boyfriend, "If you could, would you buy a hydrogen or an ethanol car?" She also recounted another conversation between herself and her boyfriend: "We've even talked about it, like we want to have two kids and then maybe adopt afterward and we were like we're going to teach our kids how to like recycle and all that stuff." Finally, when she referred to a conversation with her father, she stated, "He goes, 'Well why are you worried about it because you're not going to be living long enough to see the destruction.' I was all like, 'Eh, but you could do something about it now, so why just like turn ... your cheek? And what about your children's children?' You know?" Carol's comments indicate that she indeed conceptualized her role in social processes that involve everyday decision relevant to the environment, which is what the *Average Joe* problem touched upon. The primary social element in which conceptualized her role was her family, and she enacted her role by engaging others in that group in discussions about environmental issues. Thus, data from Carol's engagement in the *Average Joe* problem supports my first grounded hypothesis, that the ability to conceptualize one's role in environmental

or social processes contributing to environmental problems supports one's sense of competence.

Juan (19,  $z = 0.81$ ) and Meg (20,  $z = 1.01$ ) also scored higher on the DNSS than their overall means for the course. Because the students' discussion focused primarily on Carol's paper-or-plastic question, I am unable to make claims about what contributed to their feelings of high competence.

### *Scientific Conceptualization and Feelings of Competence*

To sum up this analysis, I have located three general patterns in students' scientific conceptualizations of environmental problem-solving sets and their respective feelings of competence regarding solving environmental problems. I refer to these as the grounded hypotheses that emerged from this research question. The first of these is that the ability to conceptualize one's role in an environmental or social process(es) contributing to an environmental problem is an influential factor in achieving feelings of high competence when attempting to solve that problem. The second is when students experienced feelings of low competence, their in-class participation was generally characterized by less desirable scientific conceptualizations and mostly linear, graded causal arguments. Finally, when students are able incorporate time into their scientific conceptualizations of the environmental problems, which is often instantiated by approaching the problem from an evolutionary perspective, their sense of competence is high.

Regarding my first grounded hypothesis, I emphasize that the ability to conceptualize one's role is not equivalent to including humans in one's scientific conceptualization of the problem. There are several instances, particularly with Meg and Carol during the *Channel Island Foxes* problem, in which a student included humans in their causal reasoning but were unable to conceptualize their own roles in the problem. In the case with Meg and Carol, they spoke often of scientists playing a role in the problem, but Carol was unable to conceptualize herself as a scientist participating in the problem in her interview following that class period. Meg and Carol's inability to identify with the scientists in the problem is evidenced by their consistent reference to scientists as separate from themselves. Meg offered further evidence during her final interview. In that interview she commented, "I had this picture that if you're majoring in some sort of science, you're going to be stuck in a lab, like dissecting animals or doing something boring ... like with a bunch of old people with glasses." This indicates she did not identify with scientists, at least early in the semester when she was participating in the *Channel Island Foxes* problem. My point is that when students conceptualize their role in an environmental problem, it must be personal. Being able to see how a human can play a role is not the same as being able to see how the self participates in the problem.

Regarding my second grounded hypothesis, feelings of low competence coexisted with graded, linear scientific conceptualizations that incorporate less desirable scientific concepts. This is justification for continuing to value the

quality of students' scientific understanding when concerned about environmental motivation. Students might feel as if graded language is inexact and therefore unscientific, which makes them feel less competent while problem-solving. A restructuring of problem sets so that they include and favor graded arguments might simultaneously help students construct their own graded arguments and feel more competent in doing so. Such problem restructuring could also include more pointed questions so that students are compelled to consider more than one cause and effect in their causal arguments. These and similar teaching implications will be explored further in the next chapter. Finally, Pelletier's (2003) claim that non-coercively providing information about pro-environmental behaviors supports competence does not correspond to my finding that less desirable understanding coexisted with feelings of low competence. Scientific understanding, not only information about pro-environmental behaviors, seems to be related to one's feelings of competence regarding environmental problem-solving.

My third grounded hypothesis provides a basis for speculation about how scientific understanding might be related to one's feelings of competence regarding environmental problems. When students incorporated timing into their conceptualizations of the problem sets, they consistently felt more competent. In Juan's case, this was most often instantiated by his taking an evolutionary approach to solving environmental problems, which necessitates considering change over a large period of time. The data suggest at least two possibilities of what could have contributed to his feelings of high competence. Perhaps his

evolutionary understanding provides a foundation to his ecological understanding so that he is able to better conceptualize environmental problems, thereby leaving Juan feeling highly competent. Alternatively, his evolutionary approach could simply be an instantiation of his general ability to conceptualize problems dynamically – to consider how relevant factors change over time. In this case, this general ability might be what supports his sense of competence while solving environmental problems. Clearly, this hypothesis has the potential to lead to fruitful avenues of research. These ideas will be explored further in *Chapter 7: Discussion* through an integration with current literature.

## CHAPTER 6: RESULTS OF RESEARCH QUESTION 4

In this chapter, I will present the results of the final research question in which I asked what socio-contextual features supported or undermined students' basic psychological needs as they related to solving environmental problems. These findings arose from focus group members' reports of feelings of competence, relatedness, and autonomy and the classroom features to which they attributed those feelings during their stimulated-recall interviews. Six features of the instructional environment emerged from the data which I inferred to be supportive of students' basic psychological needs. I refer to these as *curricular interconnectivity*, *conceptualization problem sets*, *instructional guidance*, *socio-scientific integration* throughout the curriculum, *student-guided lecture*, and *cohesive group dynamics*. I inferred one feature of the instructional environment that seemed to undermine students' basic psychological needs; it will be referred to as *the "anything-goes" norm*. Each of these features will be explained in turn with supporting evidence and consequences toward students' feelings of competence, autonomy, and relatedness.

### *Curricular Interconnectivity*

A type of curricular design emerged from students' comments about what was supportive of their basic psychological needs. I call this type of design *curricular interconnectivity*, which is when there are consistent themes throughout a unit so as to provide students multiple experiences to draw upon as they engage in environmental problem-solving. This feature first emerged from Meg's first

interview following the *American Robins* problem. Meg provided an account of how she thought the problem fit into the larger scheme of both the class and humans' role in global warming by stating, "When we did the biomes and stuff we did a lot of the migration and stuff and then also we're learning about the energy forms. So this kind of relates to it because the migration patterns are all messed up with a lot of the energy we use ... and then we're talking about global warming as an effect of some of the fossil fuels burning, so this kind of went with everything because the global warming is causing the spring to arrive earlier." Although this utterance does not seem to offer much in the way of explanation, Meg cited several important aspects of the curriculum. Prior to the day on which this interview took place, each student group was asked to briefly describe to the class a threat to a biome. Meg and her group discussed how oil drilling threatens the Arctic tundra. In their presentation, they cited how oil pipelines impede animal migrations, causing reproductive cycles to be disrupted. During the class period in which the *American Robins* problem occurred, we also constructed energy chains that portrayed how humans use energy from the sun. Given this history, Meg's comment begins to make sense. The problem seemed to be important to her because it fit within the context of how global warming was being addressed in the course (Figure 33). When asked what helped her group devise a solution to the *American Robins* problem, she cited instructional guidance, to be discussed later, and "just like prior knowledge of the global warming and then knowing what we had already learned about what could be like



the bad effects of screwing up someone’s migration.” In other words, the *American Robins* problem included several other elements in the course, such as global warming and migration disruptions, and Meg was able to draw on each of these, which likely allowed her to effectively solve and feel competent about the problem. Meg’s account of the *American Robins* problem exemplifies curricular interconnectivity.

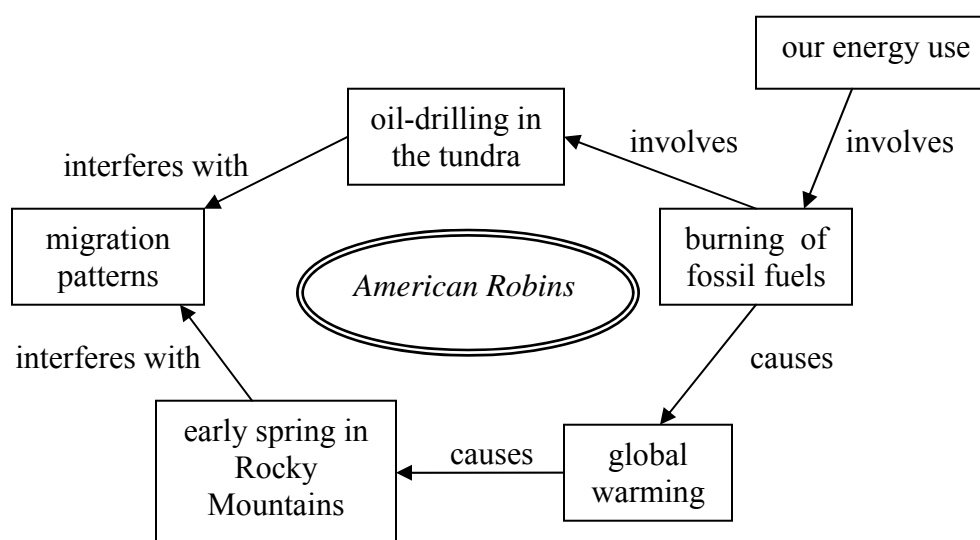


Figure 33. A depiction of how the *American Robins* problem was situated in the interconnected curriculum, which Meg cited in explaining why the problem was important to her.

After I established curricular interconnectivity as a classroom feature that is likely to be supportive of students’ basic psychological needs, more evidence to support this feature arose from the data. For example, Meg’s comments during her second interview about what she did not like about the *Western and Arroyo Toads* problem give insight into the importance of curricular interconnectivity regarding her need for competence. When asked why the problem was important to her,

Meg stated that she “couldn’t really relate it to what we were doing in class.” She further explains, “With most of the problem sets, I can relate it to what our discussion was, but with this one I had a little bit of trouble relating.” These comments further highlight the importance of multiple relations to other curricular activities.

Similarly, in his first interview, Juan offered a similar account of how curricular interconnectivity supported his sense of competence regarding the *Colorado River Water Pollution* problem. When asked what his favorite part of the class period was, he commented that it was the presentation given by the guest speaker from the City of San Diego’s Water Department. He also commented, “Last Tuesday, we went to this Padre thing, which we saw the process of recycling the water and then the presentation from today, it was kind of interesting, adding to the stuff learned-.” At that moment the interviewer interrupted with “on your field trip,” to which Juan agreed. In his comment, “the Padre thing” refers to the Padre Dam facility, which we visited on a field trip the previous week; it is where wastewater from the town of Santee, California is recycled for use throughout San Diego County for irrigation. Later in the interview, these elements come together as he explained, “Well this (puts hands on problem set) was kind of related to the presentation because the presentation showed some of these different parts actually, these different pictures of these places ... so this related to it. It’s not that there was a different solving of a problem but it was related to the presentation of today’s-.” The interviewer again

interrupted with “which was related to Tuesday’s so it was all kind of ...” Juan concluded, “Yea, it was all connected.” Like Meg’s account of the *American Robins* problem, it becomes clearer how the *Colorado River Water Pollution* problem was woven into the curriculum (Figure 34) so that Juan was able to draw upon multiple aspects in order to solve and feel competent about the problem set.

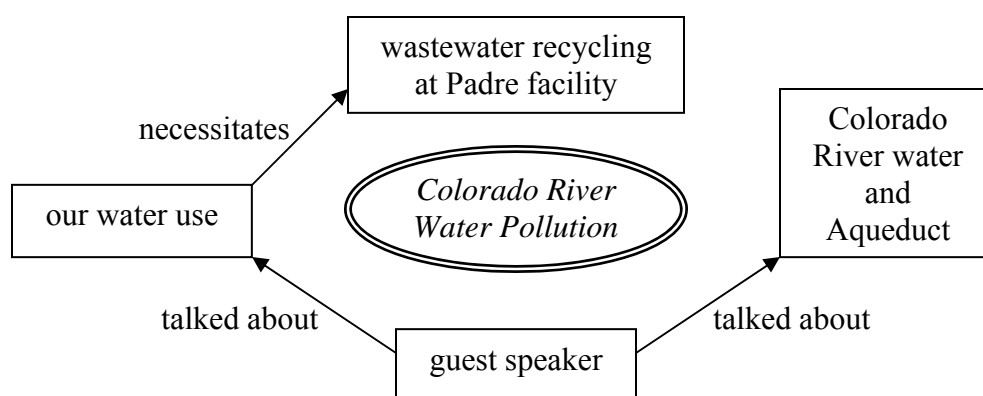


Figure 34. A depiction of how the Colorado River Water Pollution problem was situated in the interconnected curriculum, which Juan cited in explaining why the presentation was his favorite part of the class period.

In her comments supporting the importance of an interconnected curriculum, Carol’s explained of the importance of field trips. In her third interview, Carol stated, “[Be]cause when you talk about biology, it’s like learning about your surroundings, I guess, your natural surroundings, and that’s what we’re doing. You can’t just really learn everything from a book or copying the board or something like that. You have to actually go out and explore.” It seems that Carol valued the field trips because they helped her learn better, which likely supports her competence while solving the related problem sets in class. Field trips are a simple way to incorporate the out-of-school context on which students

can draw as they solve environmental problems imbedded in an interconnected curriculum.

### *Conceptualization Problem Sets*

Woven into the curriculum for this course was what I have come to refer to as conceptualization problem sets. These are problems that have a specific structure and are intended to activate students' scientific understanding. As stated in previous chapters, students have scientific concepts in their minds. I have termed the collection of concepts and the relations between concepts their scientific understanding, but when this understanding is used to solve environmental problems, their understanding is conceptualized in the particular context of the problem. In other words, conceptualization is when their understanding is put into action in the context of the problem. In this study, I claim that this mobilization of their scientific understanding helps to satisfy students' basic psychological needs. This claim is supported by several of the focus group members' comments. For example, when the interviewer asked Juan during his second interview if there was anything else he would like to say about the problem or the discussion he and his group had, he stated, "Well ... it was really interesting to me, basically because the learning, the learning is really interesting in this lab, basically ... solving problems and I think I'm learning about different species and I'm being able to many times explain other people." His references to educating other people and solving problems indicate that the act of solving problems likely supports Juan's need for competence. In their

interviews, focus group members cited two aspects of the conceptualization problem sets that likely supported their basic psychological needs. I have named these aspects the collective construction of ideas and optimal complexity. Each of these will be discussed in turn.

### *Collective Construction of Ideas*

In his first interview, the interviewer asked Juan how he and his group went about solving the *Colorado River Water Pollution* problem, and he stated, “We kind of come up with a different answer and then compare and then maybe get to one, just single solution.” After the interviewer misunderstood his explanation as they choose the best solution from those that are put forth from each student, he clarified, “We actually ... we kind of like mix it together to just make one single idea.” In other words, Juan describes the collective construction of ideas, rather than simply choosing the best idea from individual students, and he cited this type of knowledge construction (i.e., “mix[ing] it together to make one single idea”) as a factor allowing his group to devise a solution to the problem. Once this feature was established based on data from Juan’s first interview, I returned to Carol and Meg’s interviews in search of further evidence. In her second interview, Carol pointed to how Meg was able to remind her of which toad species made the call so that she could continue to engage in the problem. In her first interview, Meg stated that their group comes to an agreement by “pull[ing] pieces from everybody’s idea,” and in her final interview, she described how each individual is able to contribute to the collective construction

of ideas when she stated, “When you read it you don’t necessarily soak up all the information so the three of us each reading the problem, and then we each had a different intake like in one problem.” I interpret these statements to mean that individual students are attuned to different aspects of the problem, so by working together, they can collectively construct solutions that draw upon each student’s perspective. Collective construction of ideas, however, does not occur in all problem sets. In order for ideas to be collectively constructed during group discussion, the problems have to be of optimal complexity, which will be discussed next.

#### *Optimal Complexity*

When Meg was interviewed about the *Western and Arroyo Toads* problem, she commented that because she and her group mates had little prior knowledge regarding the problem, they “had a consensus from the beginning.” She felt like she had more to contribute when the problems were more complicated because she and her group mates “all have different opinions and ... have to share information to back up [their] individual opinion[s].” This depiction of conceptualization problem sets, when they are sufficiently complicated to generate discussion but still draw upon prior knowledge constructed while engaged in an interconnected curriculum, highlights what it means for a problem to be optimally complex. I also found evidence supporting the need for optimal complexity in Juan’s second interview when he describes how he and Carol approached the *Western and Arroyo Toads* problem on the day when Meg was

absent: “We kind of didn’t discuss it that much, this answer, we just came up to the same idea.” Alternatively, Juan tried to describe during his first interview what he experienced when the problem was of optimal complexity. He said, “I think that just the fact that by solving these kind of problems, I kind of use more my ... I don’t know ... my thinking or my ... what can be the word for it ... critical thinking, I guess ... Sometimes it’s kind of hard, the problems, but sometimes they’re just good enough.” In this comment, Juan seems to agree with my claim that learning is different when scientific understanding is conceptualized (i.e., “by solving these kind of problems”), and a problem’s level of difficulty is of optimal complexity (i.e., “just good enough”).

#### *Instructional Guidance*

Every instructor helps his/her students in some way, but focus group members referred to the help that I offered students while problem-solving as supportive of their basic psychological needs. This first emerged in the data during Meg’s interview following the *American Robins* problem. She stated, “She came over and kind of pointed us in the right direction,” and later in the same interview, she used the word “encouragement” to describe the help I gave her. It is important to note that as a general rule I did not simply give students answers to problems. I consider this different than what is offered in traditionally taught courses (Lord, 1999; Travis & Lord, 2004) in that I attempted to guide students as they constructed their own solutions, rather than giving the actual solutions. It is plausible that Meg cited the type of help I offered because it supported her needs

for competence and autonomy. This is because if students construct their own environmental solutions, they would come to feel competent about constructing their ability to do so, and they would not feel coerced into solving environmental problems.

There was one instance, however, in which I did give an answer, and Juan found that to be especially satisfying. The *Western and Arroyo Toads* problem was addressed for three consecutive class periods during which several discussions took place about the meaning of biological fitness, the importance of fertility and sterility, and the consequences of hybridization. Juan's second interview took place following the second day of the *Western and Arroyo Toads* problem, at the end of which I resolved a lively discussion between two camps of students who were discussing whether biological fitness referred to physical fitness or something involved with reproduction. When asked what his favorite part of the class period was, he commented it was, "at the very end, when she gave us the answer and then we kind of understand it better and then well, we basically understand the idea or the whole problem that we started last week in coming to the conclusion." He later commented that my "giving them the answer" was when I told them that fitness, in biology, is one's ability to pass on one's genes to future generations, which resolved the dispute between the two camps of students. It seems that this provided Juan closure that he had been seeking for several days, which is why it was satisfying to him. It is unclear which basic psychological need this supported, but his reference to understanding "the idea or



the whole problem” indicated that it likely supported his sense of competence. In most cases, simply giving students answers would likely undermine their sense of autonomy and competence (Reeve, 2002). This situation was different in that Juan seemed to feel like he had been involved in the knowledge construction up until the point that I provided the definition to them (i.e., “we understand the idea or the whole problem that we started last week”). From a pedagogical standpoint, my goal for waiting so long to give them the biological definition of fitness was to give the students an opportunity to distinguish the “biological fitness is physical fitness” concept from the scientific concept, only after which I would provide the definition. Juan’s comments indicate that this not only helped him construct a more desirable concept of biological fitness, but it also supported his basic psychological needs.

#### *Socio-scientific Integration*

As I was analyzing the interview transcripts, I encountered numerous instances when students referenced social elements in the importance of their learning. For example, all three students at one time mentioned the importance of “real-life” connections. As these references accumulated, I decided I needed a way to encapsulate the social elements to which students were referring, which is why I devised the term socio-scientific integration. Socio-scientific integration is the inclusion of social elements of environmental problems in the environmental biology curriculum so that problem situations addressed in the course are more authentic to the environmental issues students are likely to encounter outside of

the course. Initial evidence supporting the importance of socio-scientific integration was offered in Meg's first interview. Meg explained that if someone outside of the course were to approach her to discuss an environmental problem, she would be interested in the problem because "that shows that they're interested in it too, and if enough people get interested ... then maybe there will be like changes." This indicates that in order for the environmental problem to be meaningful to Meg, it must be solvable given the larger social context. While addressing the problem in class, the social context is school, in which the norm is to solve a problem if it is assigned by an instructor, regardless if a student is interested in the problem. Meg, however, distinguished the school context from the out-of-school context when she said that, "if someone came up to me and was talking to me about it, then that shows that they're *interested*" (emphasis added). In other words, in order for Meg to feel that she can effectively solve environmental problems, others outside of school need to be interested in solving it as well. This indicates that in order for her to feel competent in solving environmental problems, her need for relatedness must first be satisfied in an out-of-school context that values environmental solutions. Theoretically, this could be accomplished by simultaneously integrating social groups that value pro-environmental behaviors and social groups to which students already belong, such as family, into the coursework through field trips, guest speakers, newspaper articles, and interviews of community members. This would help to connect Meg

to social groups who are interested in solving environmental problems outside of the school context.

Further evidence supporting socio-scientific integration is given in Meg's interview following the *Western and Arroyo Toads* problem. She commented that her favorite part of this class period was when the pet trade was discussed, which gives insight into what satisfies Meg's need for relatedness. The pet trade is a social system that has ecological implications. Thus, more socio-scientific integration in the *Western and Arroyo Toads* problem would likely have been satisfying regarding Meg's need for relatedness, in addition to her need for competence. The importance of socio-scientific integration regarding satisfaction of students' need for relatedness is further evidenced by Meg's comments at the end of her second interview when she states that generally, the problems help "because [they] connect it to real life." She elaborated that this is also accomplished via our field trips, and this sentiment was echoed in her third interview when she stated, "The problems and stuff that we did and the field trips also helped because it showed you in real life." Similarly, Carol indicated a connection between the problems and everyday situations was important to her in her interview following the *Average Joe* problem. The item she received during that problem was to decide between paper or plastic bags at the grocery store. She explained to the interviewer, "It's funny [be]cause the same question happened to me when I went to Trader Joe's ... So I'm thinking about it, 'So okay what would be better for the environment.'" Although she does not explicitly reference how

receiving this item made her feel, the fact that she asked herself at the store what would be better for the environment indicates that she likely felt self-determined toward a pro-environmental behavior, which would necessitate satisfaction of basic psychological needs.

Carol's comments from her third interview further support the importance of social groups such as family. Carol mentioned her boyfriend and how "he already knows" how to recycle because "his family is into recycling and stuff." She explained why she did not know: "When I was growing up, we were never told to recycle anything. We threw everything away ... We were never taught about the environment in school, at least I don't remember. We were taught about car pollution and stuff like that but nothing about recycling." Carol's comments indicate that recycling is likely a cultural behavior in which only certain groups participate, and the school culture of which she was a part did not value this behavior, even though they learned about environmental issues such as pollution. Her discussion with the interviewer throughout her third interview indicates that she is becoming acculturated into a social group, which includes her boyfriend, that values pro-environmental behaviors. She explains how this has supported her sense of competence regarding environmental problems: "When I see something or when I read something or when I hear something over the news, I actually think about it, whereas before I'd just like turn the channel. (laughs) It was boring ... No, now that I have the information, I can actually think about it." Becoming a

part of social group that values pro-environmental behaviors, such as recycling, also likely supports Carol's sense of relatedness.

A final piece of evidence supporting socio-scientific integration arose from Meg's final interview following the *Environmental Careers* task, after which she was particularly excited about looking into Sonoma State University's Environment and Education program. She stated, "I just basically liked the careers part of it because I always had this picture that if you're majoring in some sort of science, you're going to be stuck in a lab, like dissection animals or doing something boring ... like with a bunch of old people with glasses. I had this typical stereotype, so this kind of opened your eyes to all the different things you could do. When we had guest speakers come in and when we were like interested in their jobs, she told us like what kind of degrees you want to get." Here Meg offers evidence that her social perception of scientists had prevented her from engaging in science before this course. By integrating social elements into the course, her perception was changed, and she left this class period with the intention of exploring a science-related degree program, thereby indicating her sense of competence had been supported. Furthermore, she cited the integration of guest speakers into the curriculum as a factor in changing her perception. So while field trips, guest speakers, and family interviews were incorporated into the curriculum of this course for theoretical reasons, the focus group members' comments provide empirical evidence that these socio-scientific features indeed

supported their basic psychological needs so that they became more self-determined toward pro-environmental behaviors.

### *Student-guided Lecture*

Importance of the student-guided lecture initially emerged from Meg's first interview. Although it has numerous definitions in the literature, student-guided lecture, as I define it in this study, is a whole-class discussion in which pertinent information comes from the students, rather than the instructor, and students are granted the opportunity to direct the discussion within parameters set by the instructor. In the student-guided lecture that Meg references in her first interview, the material addressed was the various ways that humans use energy from the sun. From a previous activity, the students knew of the various ways, but my goal of this discussion was to construct energy chains for each use and follow the energy from the sun to how it is used by humans. In her interview following this class period, Meg explained that her favorite part of class was this lecture about how humans use energy from the sun. When asked why this was her favorite part, Meg stated, "[Be]cause I like feeling like I am knowing what she is talking about." Later she also states, "It's cool when she gives notes ... and stuff in my head is clicking," and "I like when I know something and I'm not just sitting here like confused ... trying to figure out what's going on." These comments indicate that this discussion was her favorite part because it likely satisfied her need for competence. She then described how I led the discussion: "She'll say 'Okay, which one do you guys want to talk about?' and so the first

one we picked was fossil fuels, so then we tell her like what to write.” In other words, the students were allowed to take some level of ownership over the direction of the lecture within the parameters that I had set. As they provided what to include in the energy chains, I constructed them on the board and asked directed questions of the students when they omitted information. I provided the information myself only as a last resort when students were unable to provide important elements to the discussion. I also allowed them to choose which energy chains would be constructed in which order, although I had determined which chains would be constructed. Meg’s comments indicated that this style supported her need for competence. Student-led lectures, however, likely support their need for autonomy as well because most of the important information arises from the students, not the instructor as an authority.

Juan’s comments from his second interview, following the *Western and Arroyo Toads* problem, also support the importance of the student-guided lecture. When he was asked what helped him to solve the problem, he twice referenced other groups’ ideas as influential on his thinking. For example, while watching the video with the interviewer, he explained, “We started to listen to the different ideas that got-”; the interviewer interrupted with, “From the other group?” Juan responded, “Yea, exactly.” In the same interview, he explained that learning from another student about how a sterile mule comes about through the mating of a horse and donkey helped him to think about the *Western and Arroyo Toads* problem. Although Juan did not describe the student-led lecture like Meg did,

such sharing of ideas between students would be much less likely if students were not explicitly invited to contribute to the collective construction of the lecture.

### *Cohesive Group Dynamics*

The socio-contextual feature that I have labeled cohesive group dynamics actually refers to a collection of characteristics describing what members of the focus group referenced that seemed to support their basic psychological needs throughout the course. Meg described the first characteristic in her last interview when she explained why she is open to sharing her ideas in her group: “I think it’s gotten better over the semester where we can each kind of say whatever we think and not worry about like ‘Are these people going to think I’m a weirdo?’ or ‘Am I going to be taken seriously?’” Later she clarified the importance of staying with the same group throughout the whole course: “I also think that ... it was good that Juan and Carol were my partners everyday, that we didn’t rotate around, because we got more comfortable with each other.” Therefore, the first characteristic of the focus group that seemed to support their basic psychological needs was a consistent student group. Specifically, this feature likely supported their sense of relatedness because they came to feel a sense of belonging within their student group. Moreover, it also likely supported their sense of competence, as such ease with their group members allowed them to put forth ideas for solving problems that they would not have shared if they were to feel hindered by a lack of relatedness. It should be noted that I assembled heterogeneous groups according to their responses on an environmental attitudes questionnaire, so while Meg cited



consistent groups as a supporting factor, the instructor should take the initiative to assemble the groups based on some theoretical grounds.

Meg also explained that she did not feel afraid to offer her ideas because she knew they would be taken seriously, which likely supported her basic psychological needs. Similarly, Carol and Juan both commented in all of their interviews that they felt their group mates took their contributions seriously. For example, in her final interview, Carol commented, “We listen to each other’s ideas and stuff without just disregarding right away.” While compelling students to take each others’ ideas seriously may be considered out of the instructor’s control, the instructor can assemble groups so that each group is composed of students of relatively equal status. Indeed, Meg’s comments indicated that she perceived her group mates having equal status. For example, in her final interview, Meg explained, “I think that each of us take each other’s opinions like equally. It’s not like my opinion is better than Carol or Juan’s but if my opinion is treated the same, it’s like as if it was their own opinion so it’s just equal.” Later she reiterated, “It’s not like one of us is smarter than the other.” Upon my return to Meg’s earlier interviews, I inferred further evidence for this characteristic of their group. She commented, “It’s different with every problem. One of us could be like knowing it all and then another one of us on the next day might know a bunch of other stuff.” This comment not only highlights an added benefit of the conceptualization problem sets, but it also gives insight into what she meant when she stated that none of her group members are smarter than any of the others. The

notion of equal status also arose in Meg's first interview when she explained that everyone's ideas get "a fair shot."

A final characteristic of this group is that it contained one member whom all members perceived as the questioner. Carol described her role in her second interview: "I'm usually the type that ... just throws things out there, even if it's wrong or right or even if someone thinks something is right, I'm always the one to be looking at it like, 'Wait a minute, you know what if, what if this, what if that?'" Carol agreed with the interviewer when she asked if Carol felt if the questions she posed helped her group to come to consensus, indicating that playing this role likely supports her sense of competence. Similarly, in her interview following the *Channel Island Foxes* problem, she explained the video to the interviewer by stating, "So I'm just trying to throw something out there so we can just start talking about it." Meg described Carol's tendency to "throw things out there" when she stated in her final interview, "Some of us are more shy than other so like if Juan knew the answer in his head, he might not necessarily spit it out, but if Carol knows it, she's just going to blurt it out right away." In his first interview, Juan described Carol's tendency to question their claims when he said, "She's the kind of girl that we say something and she starts thinking 'What if? What if?'" Juan explained that in the case of the *Colorado River Water Pollution* problem, Carol's persistence led them to seek help from the instructor. It seems that having a questioner in the group helped them for two reasons. First, Carol's tendency to "throw stuff out there" generates discussion in the group, a vital

factor in supporting students' basic psychological needs, as discussed in the section on *Conceptualization Problem Sets*. Juan evidenced this in his first interview when he described how he contributes to the group. He stated, "I kind of listen to them when they start with the conversation and then I ... start thinking about their opinions and then agree or disagree or say something or add to it."

Second, the discussion that is generated by Carol's questions led students to feel more competent in solving problems. Juan also supported this notion in his first interview when the interviewer asked, "Do you think they ever change their opinions because of what you say?" He responded, "A little bit ... When I ... add to it, maybe they will ask another question just to make sure their idea is right or wrong ... They try to make sure that their thoughts are right, maybe having more people agreeing with the idea." In other words, by Carol and Meg's continuing to ask questions, Juan seemed to think they approached a more correct answer, which likely supported how competent he felt in solving the problem.

Additionally, Juan implies that each member of his group has a role to play. Carol is the questioner; Meg responds; and Juan agrees or disagrees to provide a level of confidence to their solutions. By having a specific role to play in the group, the students' need for relatedness is also likely satisfied.

#### *The "Anything-goes" Norm*

The "anything-goes" norm describes the collective belief that developed in this course that any comment or question, no matter how tangential or unrelated to the problem at hand, could be asked during the discussion. I believe this norm

developed because of my openness to student participation in during lectures and encouragement to their asking questions. Initial evidence for the development of this norm came from Meg's data. In her first interview, she stated, "When we're talking in lecture I always get these random questions like don't really pertain to anything ... but I don't usually ask them just like I don't want to get off on a tangent and direct the class in a whole different direction." Later she added, "That would take the class in a whole different direction [be]cause when one person says something random, ... it's fun, be we get off from where we're trying to go." She seemed to find this norm annoying because she wanted to stay on task. This issue arose in this interview because during the discussion about humans' energy uses, she wanted to ask about windmills she had seen in the area, but she refrained from doing so for the reason explained above. Meg also commented that she and Carol were wondering if the robins that survived the period without food one year would remember the following year to wait longer to migrate to higher altitudes. Yet, she did not ask this question because "It didn't really pertain to anything. It didn't really matter. It was just completely off the subject." Given her and others' anthropomorphization of the robins and other animals throughout the course, I would have welcomed this question, and an answer to it would have likely supported her feelings of competence in solving the problem. The development of the "anything-goes" norm, however, prevented her from asking these questions, the answers to which would have likely supported her basic psychological needs.

Therefore, the development of this norm seemed to undermine satisfaction of students' basic psychological needs.

In this chapter, I have presented evidence for seven classroom features that students cited as important regarding the satisfaction of their basic psychological needs. In the next and final chapter, I will compare these findings with that presented in peer-reviewed literature to provide further explanation about why these features supported students as they learned in their environmental biology course. I will also synthesize these findings with that of the other research questions and discuss specific teaching implications arising from these data.

## CHAPTER 7: DISCUSSION

A common goal shared among science educators is a genuine interest in improving the scientific literacy of our citizenry. A generally agreed upon definition of a scientifically literate person is one who understands the nature of science, its processes and products, and the appropriate application of those processes and products to decision-making contexts outside of the science classroom (Laughksch, 1999). This final element, the appropriate application of science to decision-making contexts outside the science classroom, is a major component of what it means to be scientifically literate. In order for this to occur, citizens must possess the motivation to make informed decisions regarding the environment. The global environmental dilemma is the most pressing socio-scientific issue about which everyone makes decisions on a daily basis. Therefore, finding ways to foster environmental motivation is a key contemporary challenge to developing a scientifically literate citizenry. The results of this dissertation indicate that the application of self-determination theory (SDT; Deci & Ryan, 1990) to formal environmental education (EE) settings is a step in this direction.

In this final chapter, I synthesize my research findings by relating them to each other, comparing them to what is known in the field, and discussing instructional implications. For each research question, I will review the results, discuss relevant literature, and highlight prospects for future research. I will conclude with a discussion of teaching implications in which I will suggest one

way that the various factors found to foster students' environmental motivation can be integrated into a single environmental biology course.

### *Implications of Quantitative Results*

#### *Research Question 1*

There were two important trends in the results from the first research question in which I asked to what extent does a SDT-guided environmental biology course differ from a non-SDT-guided course in the degree to which it fosters self-determined motivation toward the environment. First, students in both sections experienced higher integrated and identified regulation after the course, but this trend only remained six months later in the experimental section. This indicates that SDT could indeed be a beneficial tool in guiding instruction so that it fosters self-determined environmental motivation. Due to the small sample size and my inability to directly observe the instruction that occurred in the experimental and comparison sections, I refrain from concluding that SDT-guided instruction in an environmental biology course is superior to non-SDT-guided instruction. Nevertheless, this study indicates that SDT is a potentially fruitful avenue of further research if environmental educators aim to foster environmental motivation in their classrooms. The second trend that I observed was that the experimental section experienced a significant decrease in the least desirable forms of motivation, external regulation and amotivation, but these scores subsequently rebounded six months after the course, indicating that this positive

effect was not sustained. This reminds us that more research is needed to elucidate how the positive effects of instruction can be made more sustainable.

These results indicate several possibilities for future research. First, a similar study that involves a larger sample size would provide more definitive evidence about the usefulness of SDT in guiding environmental biology instruction. Additionally, a more thorough examination of the instruction that is implemented in an SDT-guided classroom and a non-SDT-guided classroom would clarify what instructors can specifically do and avoid doing in their classrooms to foster self-determined environmental motivation. Although the third and fourth research questions in this study attempt to identify specific aspects of students' scientific knowledge and the instructional environment that support self-determined environmental motivation, these findings are not sufficient to make definitive conclusions. This is because these questions are hypothesis-generating research questions, and they did not involve a direct comparison of the instruction that occurred in the two sections. Finally, long-term studies that use both qualitative and quantitative data to track participants beyond the course would help us better understand how desirable effects of EE, such as decreased amotivation toward the environment, can be sustained.

#### *Research Question 2*

For my second research question, I asked what are the multiple influences on fostering self-determined motivation toward the environment in an SDT-



guided environmental biology course. This resulted in a theoretically grounded causal path that describes important factors in fostering self-determined environmental motivation (Figure 14). Given the extensive research supporting SDT (Ryan & Deci, 2002), it is no surprise that in the present research study the three basic psychological needs all correlated positively with each other. The causal path best supported by the observed data is the one from relatedness support, measured by the Classroom Community Scale (Rovai, 2002), through relatedness fulfillment, to environmental self-determination. This indicates that fostering self-determination toward pro-environmental behaviors can be partially accomplished in an environmental biology course by conveying to students that they are cared for, are connected to others, and can trust others while solving environmental problems. This could be because the social group formed in the environmental biology course is a subset of a larger social group to which students belong. Thus, when relatedness is supported in the subset of the social group, overall relatedness in the larger social group is supported. The statistically significant relatedness path also preliminarily supports socio-scientific integration in formal EE courses. Socio-scientific integration will be discussed thoroughly in relation to the fourth research question.

An unexpected finding was that autonomy fulfillment inversely predicted environmental self-determination. Furthermore, autonomy positively correlated with the other two basic psychological needs, which positively predicted

environmental self-determination. While interpreting these puzzling findings, it is important to remember that path analysis utilizes partial correlations along the non-causal paths and regression coefficients along the causal paths. In other words, the regression coefficients in the model indicate relationships between two variables while variance due to all other variables is held constant. Therefore, the path between autonomy and environmental self-determination, once variation due to competence and relatedness are accounted for, is negative and highly statistically significant, although the zero-order correlation (Table 3) is close to zero and not statistically significant. Three observations are important in making sense of the autonomy path. First, autonomy negatively predicts environmental self-determination and second, positively correlates with relatedness. Third, relatedness positively predicts environmental self-determination. This pattern indicates that there is likely some aspect of autonomy that is polar to relatedness so that once variation due to relatedness is removed, autonomy negatively predicts environmental self-determination. These results call for a focused study that elucidates the relationship among the three basic psychological needs and environmental self-determination.

Table 3. Zero-order correlations between students' environmental self-determination (SD) and fulfillment of the three basic psychological needs: autonomy (A), competence (C), and relatedness (R).

	<b>SD</b>	<b>A</b>	<b>C</b>	<b>R</b>
<b>SD</b>	1.00	-.1133, p = .712	.2145, p = .482	.3837, p = .196
<b>A</b>		1.00	.7554, p = .003	.6239, p = .023
<b>C</b>			1.00	.5446, p = .054
<b>R</b>				1.00

No statistically significant relationships were observed along the competence path. From this finding I infer several conclusions. First, general competence in one's daily life, as measured by the General Need Satisfaction Scale (Illardi, et al., 1993), does not predict one's environmental self-determination. Given the statistically significant increase on the integrated regulation (i.e., a type of self-determination) subscale of the Motivation Toward the Environment Scale (MTES; Pelletier, et al., 1998) observed in the first research question, some type of competence likely increased over the course of the semester. A second conclusion that I draw from this finding is that one's ecological knowledge, as measured by Morrone, Mancl, and Carr's (2001) instrument, may not be an accurate measure of students' perceptions of competence support. In other words, students do not see their ecological knowledge as supportive of their feelings of competence. Pelletier (2002) would argue that knowledge of ecosystems is unrelated to competence fulfillment and that knowledge about how to perform pro-environmental behaviors better supports environmental competence. These data at least partially support Pelletier's (2002) claim that knowledge of ecosystems is extraneous to environmental competence support. The results of my third research question, however, indicate that specific qualities of one's scientific knowledge, such as the ability to conceptualize one's role in a process contributing to an environmental problem and the ability to reason about environmental problems using an element of time, influence one's feelings of competence. The sum of these findings is that

environmental competence support is not as simple as having sound ecological knowledge or knowledge about pro-environmental behaviors. My emergent hypotheses about the intricacies of environmental competence support will be discussed next in relation to my third research question.

### *Implications of Qualitative Results*

#### *Research Question 3*

In my third research question, I asked what characterizes students' scientific conceptualizations as they solve environmental problems and to what extent do their conceptualizations relate to the satisfaction of their need for competence. My analysis resulted in three grounded hypotheses. The first of these is that the ability to conceptualize one's own role in a process contributing to an environmental problem is paramount to feeling competent in solving that problem. The process in which students were able to identify their role was not necessarily an environmental process. For example, Meg explained that if she knew others were motivated to solve a problem, she would also be more motivated to solve it. This, in addition to the statistically significant relatedness path (Figure 14) from the second research question, provides more justification for including the social aspects of environmental problems in environmental biology instruction. This issue will resurface again shortly in relation to the fourth research question.

The second grounded hypothesis that emerged from my third research question was that when students felt a sense of low competence when solving an environmental problem, their reasoning was characterized by linear, graded arguments and less desirable scientific conceptualizations. The coexistence of less desirable scientific conceptualizations and linear arguments is somewhat expected, but the presence of graded arguments in less desirable scientific conceptualizations is the reverse of what is preferred from a scientific point of view (Engle, 2006). Because environmental effects are seldom catastrophic (i.e., large effect in a short time), being able to recognize the range of an effect over a long period of time is more scientifically realistic when reasoning about what causes, prevents, and/or solves environmental problems. Students' feelings of low competency, however, coexisted with language that indicated gradedness in their conceptualization of the problem. This could be because graded reasoning makes students feel uneasy, as if the inexactness is not "scientific," although I was unable to corroborate this speculation in the literature base. Nevertheless, it seems reasonable that instruction in an environmental biology course should work to support graded, multicausal arguments. One way this could be accomplished is by incorporating graded language into problem sets and asking more pointed questions that compel students to consider several causal factors rather than only one. Later in this chapter, I will restructure the *American Robins* problem set to demonstrate how this could be done.

This grounded hypothesis also highlights the importance of cultivating desirable scientific understanding and mobilizing it through problem-solving, if students are to feel competent toward solving environmental problems. Simply possessing scientific understanding, as it is defined in this dissertation (*Chapter 2: Literature Review*), does not give students opportunities to practice skills, such as multicausal argumentation, that educators have deemed an important aspect of ecological knowledge (e.g., Eliam, 2002; Engle, 2006). Furthermore, participants in this study consistently cited problem-solving as supportive to their sense of competence regarding solving environmental problems.

The final grounded hypothesis that emerged from my third research question is that when students are able incorporate time into their scientific conceptualizations of environmental problems, their sense of competence is high. This grounded hypothesis was most often instantiated when a student, usually Juan, approached the problem from an evolutionary perspective. Juan's conceptualizations of the problem sets consistently differed from that of Carol and Meg. Correspondingly, Juan consistently felt highly competent throughout this study. His evolutionary understanding did not always involve desirable concepts from a scientific standpoint, but his perspective and feelings of high competence remained consistent.

There are at least two possibilities about why an ability to reason with time coexisted with Juan's high sense of competence. Most ecologists and ecology educators would agree that desirable evolutionary understanding is

foundational to desirable ecological understanding; one possibility is that his evolutionary perspective provided a sound foundation to ecological knowledge that was developed as he engaged in the problem sets, which in turn supported his sense of competence. No study that I am aware of has explicitly investigates the relationship between evolutionary and ecological understanding. Juan's experience in this course provides justification for such research. Another possibility for why an ability to reason with time coexisted with feelings of high competence is that there is a general ability to reason dynamically, or consider factors as they change over time. Juan's evolutionary perspective could be an instantiation of his ability to reason dynamically, and this ability is also useful when solving environmental problems, which thereby supports his sense of competence. Indeed, Eliam (2002) pointed out that ecological reasoning is challenging for students because it requires them to reason across vast space and time. Therefore, it is reasonable to assume that reasoning dynamically would help students reason about both ecology and evolution problems.

Although these speculations provide inspiration for future research, these questions do not need to be answered in order for this grounded hypothesis to contribute to improved instruction. By teaching ecology through an evolutionary lens, instructors could attune students to the importance of factors that change over time and are relevant to solving environmental problems. This approach could help students develop desirable ecological and evolutionary understanding. The end result would be students' feelings of high competence regarding the

environment, in addition to desirable scientific understanding. I discuss specific ways to accomplish this in the *Instructional Implications* section of this chapter.

Originally, I had expected students who had deep scientific understanding, such as an understanding based on energy flow and matter cycling on Earth, would feel more competent regarding solving environmental problems (*Chapter 2: Literature Review*). This was not observed in this study. Students' scientific understanding that incorporated energy flow and/or matter cycling was only observed twice in the data. The first instance occurred when Meg discussed her favorite part of the class period in which the *American Robins* problem was addressed. She stated that it was her favorite part because she enjoyed feeling knowledgeable about what was being discussed in the lecture. While this instance supports my original expectation, there were several other times throughout the course when she felt competent, although in those instances I did not observe understanding about energy flow and matter cycling. The second instance in which a student's scientific understanding seemed to focus on energy occurred during the same class period; Juan commented that the robins' migration up the mountain depleted their energy. Although he was not interviewed following this class period, his DNSS score was not statistically different from his mean score, indicating that the use of such understanding did not yield significantly higher feelings of competence. Therefore, it seems reasonable to conclude that the data from this study do not support the hypothesis that scientific understanding based on energy flow and matter cycling on Earth gives rise to increased feelings of



competence about resolving environmental issues. This is not to say, however, that scientific understanding does not matter when it comes to feeling competent about environmental problems. Much research has demonstrated that students' knowledge indeed plays a role in determining one's intent to act pro-environmentally (Hines, Hungerford, & Tomera, 1986-1987). Moreover, the coexistence of Juan's high feelings of competence and evolutionary perspective discussed above indicates scientific understanding is important, albeit indirectly.

#### *Research Question 4*

In my final research question, I asked what classroom features do students cite when they indicate that their basic psychological needs are being fulfilled or undermined. Students consistently cited seven features of the instructional environment as relevant to the fulfillment of their basic psychological needs. Because these factors are based on focus group members' comments and were not observed directly, my claims about the benefits of these factors hold hypothesis status. Thus, further research is needed to elucidate how each factor contributes to the fulfillment of one or more of students' basic psychological needs. Nevertheless, many of these features are supported by a literature base, which will be discussed here.

I inferred curricular interconnectivity, which I define as the inclusion of consistent themes throughout a unit so as to provide students multiple experiences to draw upon as they engage in environmental problem-solving, to be supportive of students' sense of competence. The notion of novelty space (Orion & Hofstein,

1994) provides insight into why an interconnected curriculum might support students' learning and basic psychological needs. Orion and Hofstein (1994) define novelty space as the combined effect of cognitive, psychological, and physical aspects of a novel experience that undermines students' ability to learn during that experience. The notion is most often applied to field-based learning, such as during field trips (Hofstein & Kesner, 2006; Kean & Enochs, 2001; Orion & Hofstein, 1994; Riggs, 2004). Nevertheless, the idea that greater familiarity in the learning experience correlates with better learning could apply to any setting, not only learning in the field. In this study, when students' novelty space was reduced through student-guided lecture, field trips, and guest speakers, their learning during in-class problem-solving was supported, which students in turn cited as supportive to their basic psychological needs. Although the novelty space construct has thus far been applied to field-based learning, the importance of curricular interconnectivity in my study indicates that it is also relevant to problem-based learning. Orion (1993) suggests that a pre-field trip orientation can reduce students' novelty space. If an in-class problem set takes the place of a field trip in my fresh application of the novelty space construct, then it would be wise to orient students to the problem set. Therefore, the connected elements of the curriculum, such as a guest speaker, would precede in-class problem-solving. These instructional adaptations are demonstrated later in a learning cycle that I put forth in the *Instructional Implications* of this chapter.

Socio-scientific integration is another feature of the instructional environment that students cited as supportive to their basic psychological needs. I defined this construct as the inclusion of social elements of environmental problems in the environmental biology curriculum so that problem situations addressed in the course are more authentic to the environmental issues students are likely to encounter outside of the course. Social elements of environmental problems can be included in the curriculum in the form of news reports, newspaper articles, field trips, interviews of family or community members, guest speakers, and assignments that ask students to evaluate the claims of a social figure, such as a politician. I will provide further explanation on how elements can be woven into the curriculum in the *Instructional Implications* section of this chapter.

The statistically significant relatedness path in my second research question is likely related to socio-scientific integration of the curriculum because by including those social elements of environmental problems, students' need for relatedness is likely to be better supported in the classroom. Additionally, Meg explained that if someone were to approach her outside of class about an environmental problem, that would indicate to her that there are other people caring about the issue and it would thus be more solvable. These data from Meg indicate that fulfillment of one's sense of relatedness may provide a foundation for one's sense of competence. The positive correlation between competence and relatedness observed in the second research question further supports this

conclusion. Thus, it seems that socio-scientific integration is especially relevant not only to students' sense of relatedness, but also to their sense of competence.

Andrew and Robottom (2001) make a recommendation that is similar to socio-scientific integration when they call for a contextualization of science instruction. Research investigating the relationships between students' conceptual knowledge and conceptions of nature of science on one hand, and their reasoning employed during argumentation and decision-making on the other, support Andrew and Robottom's (2001) and my suggestion. For instance, Sadler (2004a; 2004b) found that students generally do not consider the nature of scientific knowledge when evaluating the accuracy or reliability of information. Furthermore, the quality of their nature of science conceptions do not relate directly to their decision-making regarding socio-scientific issues (Bell & Lederman, 2003; Sadler, 2004a; Sadler, 2004b; Zeidler, et al., 2002). This is likely because students do not only refer to their content knowledge in making a socio-scientific decision and/or argument (Sadler, 2004a; Sadler, 2005; Sadler & Zeidler, 2005), but they also take into account their own emotions, value judgments, and/or personal investment in the socio-scientific issue (Hogan, 2002; Sadler, 2004a; Sadler, 2004b; Sadler & Zeidler, 2005; Zeidler, et al., 2002). Sadler and Zeidler (2005) attribute this observation to three types of reasoning that students use when making decisions about socio-scientific issues: rationalistic, emotive, and intuitive. In making decisions and constructing arguments regarding socio-scientific issues, students use a combination of all

three of these reasoning types (Sadler & Zeidler, 2005). I raise this issue to point out that if we want students to make decisions that are informed by science, which is a well agreed upon component of scientific literacy (Laughksch, 1999), we must consider all of what students use to make decisions. Because a situation that calls for rationalistic reasoning alone is unlike any decision-making context students are likely to encounter in their lives, it is unreasonable to insist that in the science classroom students are only allowed to employ rationalistic reasoning. The alternative that I suggest, which invites authentic decision-making contexts into the classroom, would give instructors the opportunity to teach students to employ rationalistic, emotive, and intuitive reasoning appropriately. Further research is needed to guide instructors on how to do so, but insisting that students check their emotions at the door of the environmental biology classroom would insure failure in accomplishing the decision-making component of scientific literacy.

Another benefit of socio-scientific integration is the necessity for science curricula to evolve as decision-making contexts change. In today's world, environmental issues is the most important of these decision-making contexts, as evidenced by the magnitude of the global environmental dilemma (*Appendix I: The Global Environmental Dilemma*). Hodson (2003) claims that the disconnection between science and society in current science curricula does not allow science education to meet the needs of today's citizenry, including the need to ameliorate the global environmental dilemma. Furthermore, democracy is

increasingly purported to be the key to end a host of international problems such as war and poverty. Citizens who are well equipped to make informed decisions and participate in policy formation support the success of democracies (Hodson, 2003; Roth & Désautels, 2002; Roth & Lee, 2002; Wells & Claxton, 2002). However, if a democracy is going to exist in more than name only, citizens must not only become scientifically literate but politically literate as well (Hodson, 2003; Kolstø, 2001; Roth & Désautels, 2002; Roth & Lee, 2002). Citizen participation in policy-making is the cornerstone of democracies, yet students seldom develop the ability to engage in such participation regarding any issue, including environmental issues (Hodson, 2003). Therefore, several researchers have called for a contextualization of science education that allows students to develop understanding of everyday scientific and technological problems and empower them to work collectively in reaching solutions through socio-political action (Andrew & Robottom, 2001; Hodson, 2003). From my perspective, such a view has already embraced the notion of socio-scientific integration. My study simply puts forth another likely benefit of such an approach, which is fulfillment of students' basic psychological needs so that self-determined environmental motivation is fostered.

A final potential benefit of socio-scientific integration is the valuing of students' cultural capital (Bourdieu, 1986; *Chapter 2: Literature Review*). Perreira, Harris, and Lee's (2006) modern account of cultural capital is of particular relevance to socio-scientific integration as it was realized in my

environmental biology course. They define cultural capital as “family-mediated values and outlooks that facilitate access to education” (Perreira, Harris, & Lee, 2006, p. 515). They draw attention to how families can support students’ academic success by developing close, supportive relationships that facilitate communication (Perreira, Harris, & Lee, 2006). This was observed in the data from all three of the focus group members, each of whom described conversations with family members about the coursework and associated environmental issues. Socio-scientific integration can take advantage of this cultural capital by necessitating such communication with students’ family members through assignments, such as interviewing family members about their ideas regarding an environmental problem. Such an approach would likely support students’ sense of relatedness both in the class and in their family as they solve environmental problems cooperatively.

A final and integral feature of the instructional environment that students indicated were supportive of their basic psychological needs were the conceptualization problem sets (*Appendix V: Conceptualization Problem Sets*). These are so named because they provide students opportunity to mobilize their scientific understanding as they conceptualize environmental problems. These problems follow a specific format in which students receive a description of an environmental problem accompanied by an initial question or task (e.g., “How do you think X affects Y?” or “Construct a diagram ...”). Student groups discuss, collectively construct their solutions, and a whole-class discussion follows. As the

student groups are discussing their solutions, the instructor visits each student group to provide guidance as described in *Chapter 6: Results of Research Question 4*. During this phase, the instructor refrains from simply giving answers, as this robs students of the opportunity to grapple with the problem and devise their own solution. Not only would giving answers at this phase likely undermine students' sense of autonomy, but it would defeat the purpose of giving students the opportunity to conceptualize the problem using their own scientific understanding. During the whole-class discussion, the instructor asks for solutions from student groups and guides the collective construction of ideas toward the learning goal. Then another prompt is given that furthers engagement in the problem, and this process is repeated.

Deci and Ryan (1990) point out that in order for a situation to satisfy all three basic psychological needs, it needs to be an optimally challenging situation. Optimally challenging situations have three components (Deci & Ryan, 1990): the situation must disagree with one's cognitive structure, or their scientific understanding as defined in this dissertation, (b) the student must perceive the situation or problem as solvable, and (c) it must be encountered in a social situation that is supportive of the three basic psychological needs. Ideally, all conceptualization problem sets would constitute an optimally challenging situation for every student, but this is unlikely. This study, however, indicates that there are certain characteristics that make it more likely that a conceptualization problem set will constitute an optimally challenging situation. For example, in



order for it to disagree with one's cognitive structure, it should be of optimal complexity, as defined in *Chapter 6: Results of Research Question 4*, so that it disagrees with students' cognitive structure but still seems solvable to them. Similarly, in order for students to view the conceptualization problem set as solvable, it should be imbedded in an interconnected curriculum that provides multiple resources upon which to draw as they attempt to solve it. Additionally, socio-scientific integration, as discussed above, is likely to provide a social context that is supportive of students' basic psychological needs, and it is within this context that students engage in the conceptualization problem sets. Results from my third research question give more insight into what is likely to support their basic psychological needs – namely desirable scientific understanding, an ability to reason with time, and an ability to conceptualize one's own role in the environmental problem being studied.

The fact that students engage in conceptualization problem sets in a student group also likely supports their basic psychological needs. Group problem-solving allows for the construction of zones of proximal development in which students develop desirable scientific understanding (Lemke, 2002; Vygotsky, 1978), which in turn supports their need for competence when solving environmental problems (*Chapter 5: Results of Research Question 3*). Similarly, group problem-solving involves collaboration through which a learning community is developed (Claxton, 2002; Lemke, 2002; Wells & Claxton, 2002). Such a learning community in an environmental biology course is more likely to

develop shared beliefs, values, and tools through which environmental solutions can be valued and achieved.

### *Instructional Implications*

A host of teaching implications have emerged from this dissertation, many of which have been alluded to already. In this section, I will synthesize these implications to gain perspective on what is likely to constitute an environmental biology course that fosters self-determined environmental motivation.

All three of the focus group members indicated that cohesive group dynamics supported their basic psychological needs, thereby implying that the assembly of student groups cannot be taken lightly. I used the New Ecological Paradigm (NEP; Dunlap et al., 2000; *Appendix III: Instruments*) scale to assemble students of varying environmental attitudes. This seemed to work well, as evidenced by the group members repeated comments about how well they worked together. Due to their comments about how every group member contributed to the group relatively equally, it might also be wise to assemble groups not only according to an attitudinal scale, such as the NEP, but also a scale that measures scientific knowledge, such as Morrone, Mancl, and Carr's (2001; *Appendix III: Instruments*) ecological knowledge questionnaire. Because the group members cited their relative equality as important, this scale could be used to assemble homogeneous student groups. A final recommendation is that student groups be constant throughout the course to help them develop a sense of belonging. It is important to remember, however, that these suggestions are based on students'

ideas about what supported their basic psychological needs and may not reflect what actually helped them. Furthermore, this group was selected as the focus group partially because of their high attendance during the first two weeks of class; it is possible that groups whose members are often absent may not have such a cohesive experience, despite taking the measures described above.

I also have several recommendations for how conceptualization problem sets like the ones I used in this course (*Appendix V: Conceptualization Problem Sets*) can be restructured to reflect what was learned in this study. The following reflects my reformulation of the *American Robins* problem that demonstrates how this could be done:

A population of American robins (see photo) spends their winters at lower altitudes in the Rocky Mountains where there is less snow and warmer temperatures than at higher altitudes. When the temperature begins to rise in the spring, the robins migrate to higher altitudes where they mate, raise their young, and spend the summer before returning to lower altitudes in the fall. As snow at the higher altitudes melts, the water soaks into the soil underneath and stimulates plants to grow from seeds that fell onto the soil the previous year. When the robins arrive at the higher altitudes after their migration, they eat these plants and use them to build their nests. Over the past three decades, spring temperatures have come earlier and earlier at both the lower and higher altitudes. However, the snow melts at about the same time it has historically.

- 1- Generally, how are the American robins in the Rocky Mountains affected by the earlier onset of spring temperatures?
- 2- To what extent would the robins' ability to find food be affected? How might the robins deal with any challenge to obtaining food?

- 3- To what extent would the robins' reproduction be affected? What specific factors would cause changes in their reproduction?
- 4- Some robins would likely be able to find food, successfully mate, and raise their young, despite the earlier onset of spring temperatures. What specific factors would allow some robins to be successful and others not?
- 5- Assume the rise in temperature levels off around the year 2050. In the year 2250, in what condition do you expect this population of American robins to be? How healthy would they be? Would they have trouble finding food and mating? Be prepared to explain your answers.
- 6- This problem is one example of how animals are affected by changing climate. What is your personal role in global climate change? How do you help contribute to it and what can you do to help solve it?

Several changes were made from the original version of this problem (*Appendix V: Conceptualization Problem Sets*) that reflect findings from this study. First, because my findings imply the importance of decreasing students' novelty space by increasing the number of resources they draw upon as they engage with the problem, a photo of an American robin (Figure 35) could be included with the description of the problem situation. Several changes were included in the description of the problem in order to include more graded language. For example, the lower altitudes are described as having "less snow and lower temperatures" during the winter. Similarly, in the original problem, the robins *depended* on the snowmelt for food and nest-building, which encourages categorical reasoning because it implies if there is no snowmelt, the robins will have no food or material for next-building. The revision states that they *use* the plants stimulated by melting snow for food and building nests, which is more

neutral regarding gradedness. In order to suggest an appreciation for graded language, several of the questions ask students “to what extent” something is affected, rather than simply asking them how a factor incurs an effect, as was the case in the original problem. Prompt #4 of the revised version points out that some robins likely survive the change in climate. Therefore, if a student had been arguing until that point that all the robins would die of starvation, which is a categorical argument, this prompt is likely to compel them to conceptualize the problem in a more graded way.



Figure 35. Photo of an American robin (Elliot, 1998) that could be incorporated into the *American Robins* problem.

The restructured *American Robins* problem also includes more pointed questions than the original version to guide students toward multicausal and evolutionary reasoning. For example, prompts #3 and #4 ask students to pinpoint specific factors (i.e., plural) that would incur an effect, rather than just asking them how the robins would be affected by the climate change, which is what the

original version stated. Thus, group members are more likely to ask each other “What else?” while discussing the problem, which is likely to result in a multicausal argument. In order to compel students toward an evolutionary approach to environmental problem solving, prompts #4 and #5 directly ask students about the evolutionary effects of climate change, which were not included in the original version. Finally, the sixth prompt asks students to conceptualize their role in the larger system contributing to climate change, which my findings indicate is crucial to feeling competent about environmental problem-solving.

Another major implication of this study is that helping students to reason dynamically about ecosystems does not only contribute to desirable ecological understanding, but it also may indirectly support students’ feelings of competence regarding solving environmental problems. Juan’s case indicated that approaching environmental problems from an evolutionary perspective may help support the dynamic reasoning skill. Therefore, in a course attempting to cultivate ecological understanding and self-determined environmental motivation, evolution should be part of the content taught in the course. In the following paragraph, I outline a learning cycle through which content could be addressed in such a course. A conceptualization problem set that compels students to mobilize their scientific understanding of evolutionary concepts should be included in the evolution unit because it is through this conceptualization that concepts are likely further developed. In her interview following the *Western and Arroyo Toads* problem,

Carol described her interest in human evolution and her frustration that it was not being covered in the course (*Appendix VI: Transcripts*, line 2363). She stated that she would likely do some research of her own to answer her questions about human evolution. This indicates that a conceptualization problem set involving human evolution would likely be interesting to students and beneficial toward helping them develop desirable evolutionary concepts. Furthermore, the use of pointed questions that compel students to conceptualize ecology from an evolutionary perspective, as demonstrated above in the restructured *American Robins* problem, would further support their conceptual development and the dynamic reasoning skill. Lastly, the inclusion of humans in an evolution problem could also be considered an instance of socio-scientific integration.

I have devised a learning cycle (Figure 36) that integrates the numerous factors that I found to be relevant toward fostering students' self-determined environmental motivation. There are many ways in which these factors could be integrated into an environmental biology course; my suggested learning cycle is just one way this integration could occur.

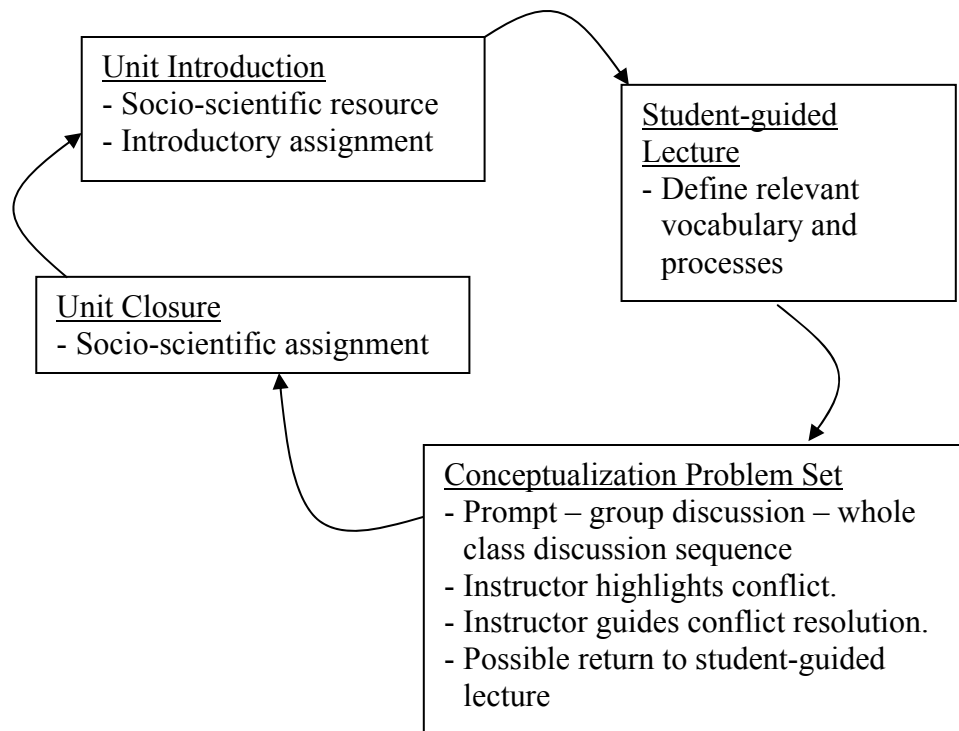


Figure 36. A possible learning cycle based on instructional implications of this study.

According to my suggested learning cycle, the instructor begins a curricular unit by introducing the broad topic through a socio-scientific resource such as a field trip, guest speaker from the community, or news report. An assignment, such as a reflection or online discussion board participation could accompany the introduction. A student-guided lecture follows the introduction in which relevant vocabulary and processes are defined. Engagement in a conceptualization problem set, structured similarly to the *American Robins* problem formulated above, follows the student-guided lecture. The socio-



scientific resource and lecture precede problem-solving in order to provide students numerous resources from which to draw as they engage with the conceptualization problem set. In other words, it better provides an interconnected curriculum that reduces students' novelty space as they conceptualize the environmental problems they are asked to solve. The conceptualization problem set would follow the prompt-group discussion-whole class discussion sequence. During whole class discussions, the instructor highlights conflict that arises between content presented in the student-guided lecture and students' scientific conceptualizations of the problem. The instructor plays an important role during these whole class discussions because s/he is charged with the responsibility of guiding students as they resolve such conflict, which may involve a resurrection of the student-guided lecture. After the problem-solving session, which may take several days of the unit, the unit is closed with a socio-scientifically integrated homework assignment or reflection. Examples of such an activity include participating in an online discussion board or critically analyzing the claims of a political or activist group.

### *Conclusion*

This dissertation has resulted in numerous factors that likely foster self-determined environmental motivation in a formal EE setting. Namely, one's ability to conceptualize one's personal role in systems that contribute to environmental problems is paramount to feeling competent when solving environmental problems. Additionally, one's ability to reason about changing

environments contributes to one's feelings of competence. I also identified several features of the instructional environment that are supportive of students' basic psychological needs so that self-determined environmental motivation is fostered. These features include (a) the use of conceptualization problem sets that allow students to mobilize their scientific understanding in powerful zones of proximal development that become established among group members, (b) an interconnected curriculum that reduces students' novelty space, and (c) socio-scientific integration of the curriculum that supports students sense of relatedness to each other, their communities, and the environmental movement. I have integrated these findings into a learning cycle, the effectiveness of which could serve as a topic of future research. Other research prospects include (a) an explicit comparison of the instruction offered in SDT-guided and non-SDT-guided environmental biology courses, (b) long-term studies that elucidate how desirable effects of instruction can be sustained, and (c) further exploration of the scientific knowledge and instructional features that lead to self-determined pro-environmental behavior. Overall, this dissertation marks the beginning of a new frontier – the application of SDT in formal EE research.

## APPENDIX I: THE GLOBAL ENVIRONMENTAL DILEMMA

This appendix will describe the various facets of the global environmental dilemma, the purpose of which is to help the reader understand the magnitude of the dilemma, how and why environmental solutions must partially arise from science, and why environmental education must be part of the solution.

### *Science and the Global Environmental Dilemma*

Traditionally, the discipline of ecology has studied matter cycling and energy flow through the bodies of organisms (e.g., via photosynthesis, cellular respiration) in addition to abiotic components of an ecosystem (e.g., soil, atmosphere). In this discussion, this type of participation will be called physiological participation in ecosystem processes. Since the rise of behavioral ecology, however, the field of ecology has come to realize that organisms also participate in matter cycles (and thus the flow of energy) through the behaviors (e.g., foraging strategies) they perform to make survival easier. For example, squirrels cache nuts from trees to save food for winter. However, all cached nuts are not retrieved (Smith & Reichman, 1984), thereby altering the processes through which matter cycles through the forest ecosystem in which they live. A nut from a tree could fall directly to the ground and be decomposed; it could be collected, eaten, and digested by a squirrel who produces feces that is eventually decomposed; or it could be essentially planted by a squirrel who caches it and never retrieves it, leading to another tree and thus another player in the ecosystem. In essence, squirrels, through their caching behaviors, mediate matter cycling in

the ecosystems in which they live. All organisms that display behaviors to aid their survival participate in matter cycling in this way, especially humans; this type of participation will be called behavioral participation in ecosystem processes. With the exception of environmental injustice and human population growth, the environmental problems that will be discussed here are the ramifications of humans' behavioral participation of matter cycling and energy flow in the ecosystems in which they live, including the global ecosystem. However, there is one major difference between the behaviors of squirrels and the behaviors of humans. Behavioral ecologists assume that squirrels cache nuts because this behavior is an evolutionary adaptation and therefore has genetic origins. Considering squirrels' behaviors do not harm the local ecosystem and in fact contribute to its functioning, it is likely that these behaviors indeed came about on an evolutionary time scale. The human behaviors discussed here, however, are more a product of culture than biological evolution; we have the ability to make choices about how we affect our environment and more specifically, how we behaviorally participate in the matter cycling and energy flow processes occurring in the ecosystems of which we are a part. Despite our ability to make such choices, the ramifications of our behavioral participation in these processes have led to several problems that will collectively be called the global environmental dilemma.

The global environmental dilemma includes pollution, biodiversity depletion, waste production and management, resource use and allocation,

environmental injustice, and human population growth. Each of these facets will be detailed in this section. While this summary may seem extensive, it is not meant to be all-inclusive. I will simply summarize the global environmental dilemma so that we can understand the extensiveness of the problem, why science is the basis for plausible environmental solutions, and why EE must play a part in changing human behaviors.

### *Pollution*

Pollution is a large-scale effect of numerous human activities that alter the chemical composition of Earth's systems. Changes in atmospheric chemical composition lead to air pollution; issues discussed here will be global warming and gaseous and particulate pollutants. Global warming is essentially<sup>1</sup> caused by an imbalance of the carbon cycle due to humans' release of carbon-containing molecules into the atmosphere (Kump, Kasting, & Crane, 2004). In other words, through behaviors that make our lives easier (e.g., driving to work rather than walking), we participate in the carbon cycle and mediate how carbon is distributed on a global scale. When these carbon-based molecules, namely carbon dioxide, methane, and chlorofluorocarbons (CFCs), trap heat in the Earth's atmosphere, mean temperatures rise. Such changes have either begun or are predicted to cause changes in oceanic currents, glacial retreat, and changes in global climate patterns (Keller, 2000). This last effect indicates that despite its

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<sup>1</sup> Other activities, such as deforestation, exasperate global warming, but the primary cause of global warming is thought to be the excessive burning of fossil fuels (Kump, Kasting, & Crane, 2004; Keller, 2000).

name, global warming does not mean that temperatures everywhere around the globe rise. Instead, climate patterns change because glaciers melt and oceanic currents are altered; both of these play substantial roles in determining climate patterns on landmasses (Keller, 2000). The most obvious way to curtail the effects of global warming is to reduce the burning of fossil fuels (i.e., petroleum, natural gas, coal), the primary source of carbon-based molecule emissions, and/or replace their use with cleaner forms of energy (Keller, 2000). Of course, this reduction would not be likely without alternatives to fossil fuels, which is why “cleaner” (i.e., release fewer carbon-based molecules) fuels must also be part of a solution to global warming. Additionally, activities that increase the sequestration of those carbon-based molecules could also lead the slowing of global warming (Keller, 2000).

Gaseous and particulate pollutants are probably what are most commonly referred to as air pollution. Humans release substances (i.e., matter) into the air through various activities, and these substances can be gaseous or particles of solid or liquid, usually less than 10 $\mu$ m in diameter (Keller, 2000). Gaseous pollutants include sulfur dioxide, nitrogen oxides, carbon monoxide, ozone, volatile organic compounds, hydrogen sulfide, and hydrogen fluoride (Keller, 2000). Particulate pollutants include soot and ash from any burning or incineration process, asbestos, and particulate heavy metals (Keller, 2000). Generally this type of air pollution is responsible for increased soil toxicity; soil leaching; reduction of vegetation growth; increased susceptibility of plants and

animals (including humans) to disease and pests; disruption of plant and animal reproduction cycles; interference with normal physiological development; impairment of respiratory systems, eyes, teeth, and bones; discoloration, erosion, and decomposition of buildings; discoloration of the atmosphere; and reduced visual range due to reduced clarity (Keller, 2000). In essence, these problems are caused by an unusual distribution of matter through ecosystems – a distribution to which organisms are not adapted and therefore leads to health problems. Humans, through their behaviors, mediate the distribution of matter in ecosystems and have the ability to make choices about its distribution. For example, humans can choose to recycle plastics instead of put them with other garbage that is likely to be incinerated and cause air pollution. When a choice such as this is made, matter in a plastic bottle gets reused to make other useful items and remains in a form that is less harmful than the form it would take after being incinerated.

Air and water pollution are not necessarily mutually exclusive. Often, a pollutant that begins as air pollution enters the water cycle by combining with water in the atmosphere and falling to Earth's surface along with precipitation (e.g., acid rain), contaminating aquatic and terrestrial systems in addition to the atmosphere. Therefore, much of the air pollution discussed above leads to water pollution. There are sources of water pollution that do not occur via the atmosphere; the most common is the use of pesticides on agricultural fields, forests, municipal landscapes, and residential properties. Pesticides are examples of chemical combinations that are unlikely to be formed without human

involvement. Humans, through their pesticide-forming activities, alter matter cycling processes to form new compounds (i.e., pesticides) that would be nonexistent without such human interference. Because these compounds do not exist if humans do not manufacture them, organisms are not adapted to their presence in ecosystems and thus, pesticides cause physiological disruptions.

Most pesticides contain chlorinated hydrocarbons, the most infamous being DDT and PCBs (Smith, 1996). When these chemicals are sprayed, the droplets settle onto the surfaces of vegetation and soil and are dispersed into the water system when rain accumulates and runs off vegetation and land into lakes, rivers, and oceans (Smith, 1996). Because chlorinated hydrocarbons are fat-soluble, they accumulate in the fatty tissue of organisms living in or feeding from contaminated aquatic systems (Smith, 1996). These chemicals are typically more concentrated in organisms at high trophic levels, and they are very resistant to degradation (Smith, 1996). When present in the tissue of an animal, they interfere with calcium metabolism, thereby leading to a variety of physiological problems (Smith, 1996). Plausible solutions to this problem include avoiding pesticide use, using “natural” pesticides that do not require manufacturing by humans (and thus are less disruptive to matter cycling processes), and establishing international agreements that restrict the use of pesticides containing chlorinated hydrocarbons.

### *Biodiversity Depletion*

Humans, in order to secure food, shelter, and health, behaviorally alter matter cycling processes to the point that they change the character of ecosystems,



which no longer allows for the survival of other organisms that are adapted to the original ecosystems. For example, in order to extract fossil fuels for heating buildings and transportation, humans deforest tropical jungles, thereby changing rainforest ecosystems into steppe ecosystems (Smith, 1996). The extinction rate of species today rivals that of historical mass extinctions on Earth (Kump, Kastings, & Crane, 2004); at least 75% of modern-day extinctions have been caused by humans (Smith, 1996). The mechanisms for such extinctions include habitat elimination or destruction, introduction of non-native predators and competitors, control of predators and pests to the point of total eradication, hunting, and human competition with threatened organisms for resources (Smith, 1996). Some claim that it is not only species that are going extinct, but also entire ecosystems, particularly equatorial tropical rainforests (Kump, Kastings, & Crane, 2004).

Biodiversity depletion underscores the importance of understanding the environment as a dynamic system with interdependent components. Because of this lack of understanding, it is difficult to convince those lacking scientific understanding of the importance of biodiversity. Besides its recreational and aesthetic value, biodiversity benefits humans in several ways. About 25% of all pharmaceuticals produced in the U.S. are originally derived from native plants (Kump, Kastings, & Crane, 2004). Considering many plants in remote regions have yet to be described, extensive biodiversity depletion could prevent us from discovering potentially life-saving medicines. Destruction of native ecosystems also prevents ecologists from engaging in the pure science needed to better

understand evolution, ecosystems, and other natural systems and processes (Kump, Kastings, & Crane, 2004). Because we do not thoroughly understand complex systems of interdependence in ecosystems, it is probable that humans indirectly depend on organisms and/or ecosystems that we are forcing into extinction. Commerce is becoming increasingly dependent on native ecosystems, especially now that ecotourism has developed into a lucrative industry (Kump, Kastings, & Crane, 2004). Finally, and perhaps most obviously, the existence and maintenance of food supplies is dependent on the health of surrounding ecosystems, which provide crucial pollinators, nutrients, resources for the survival of agricultural workers (Kump, Kastings, & Crane, 2004; Smith, 1996). Habitats are most often destroyed in fossil fuel exploration efforts, for new farming techniques that are immediately profitable but unsustainable, and to create rangeland for grazing animals (Smith, 1996). Therefore, solutions that involve the decreased use of fossil fuels and increased use of sustainable agricultural techniques are thought to alleviate this problem. These solutions are likely to be successful because they involve less interference with ecosystem processes that have evolved over millennia and are thus supportive of organisms' survival mechanisms.

#### *Waste Production & Management*

Every organism creates solid waste as it manages to survive in its environment. For example, squirrels shuck nuts, eat the meaty seed within, and leave the shell to be decomposed. Like squirrels, humans create solid waste, but

few question what happens to waste after it is collected from the curbside. A very basic problem exists regarding waste production; humans, especially those living in urban areas, produce too much waste for which there is not sufficient space for disposal (Keller, 2000). In addition to the massive amount of waste, humans, unlike other animals, create wastes that decomposers are not capable of breaking down; these wastes are not biodegradable (Kemp, 1998; Lincoln, Boxshall, & Clark, 2001). In other words, humans interfere with matter cycling processes to produce compounds (e.g., plastics) that would otherwise not be formed in ecosystems, and then humans dispose of these materials. Because these compounds have never existed in ecosystems, organisms are not adapted to their presence and thus, decomposers are not capable of breaking them down.

The three most common means for disposal are sanitary landfills, incineration, and ocean dumping (Keller, 2000). The first is problematic due to risk of contamination of surface and groundwater (Keller, 2000), the two sources that serve as drinking water for the majority of communities in the United States (USEPA, 2005). Incineration contributes to the particulate air pollution discussed earlier (Keller, 2000). Ocean dumping is also problematic due to damage to marine ecosystems, leading to health hazards to humans depending on those ecosystems for food and reduced aesthetic value (Keller, 2000). Listed in order from greatest to smallest percentage of disposed waste: paper, yard waste, plastics, metals, food waste, glass, and wood comprise most of the solid waste produced by humans (Keller, 2000).

Several behavioral modifications could help to better manage our solid waste problem. Recycling, especially of those materials that are not biodegradable, would not only reduce the amount of waste to be disposed of, but it would also reduce the need for us to further interfere with matter cycling processes to produce more non-biodegradable materials. Paper, plastics, metals, and glass are all recyclable (Keller, 2000). Simply reducing use of materials (e.g., buying products that are minimally packaged) and reusing materials (e.g., repairing broken items rather than replacing them with new ones) would also help reduce the amount of waste we produce (Keller, 2000). Composting of biodegradable materials allows us to take advantage of matter cycling processes to reduce our waste; both yard waste and food waste are generally compostable (Keller, 2000). Finally, avoiding use of hazardous chemicals would reduce our interference in matter cycling processes while reducing risk of water pollution from landfills (Keller, 2000).

#### *Resource Use & Allocation*

The problems surrounding resource use and allocation are closely linked to the issues discussed thus far. The extensive burning of fossil fuels has contributed to global warming. Because nearly all human necessities are dependent on fossil fuels in some way, fossil fuels remain a vital resource for human societies. Likewise, potable water is required for humans to live, as are agricultural and aquacultural products. These obvious statements underscore humans' interdependence with the environment via physiological and behavioral

participation in ecosystem processes. Furthermore, humans are dependent on matter and energy provided by ecosystems in which humans live. Despite humans' need for these resources, they are continually wasted and overburdened, predominantly by developed countries (Oskamp, 2000). For instance, a typical resident in the United States uses about 693 liters of water per day (USEPA, 1995), whereas a typical resident of Gambia, the smallest country in Africa, uses about 4.5 liters per day (Gleick, 1996). Considering Gleick (1996) recommends a per capita use of 50 liters per day as a sustainable and wholesome amount of water, neither the U.S. nor the Gambia rates seem acceptable. Similar patterns occur with the distribution of energy resources (Oskamp, 2000) and food (UNWFP, 2003). Regarding food and water, the general scientific consensus is that there is currently enough for all humans on Earth, but it is not distributed such that all people receive sufficient resources for survival (Pimentel, et al., 1997). Some become malnourished while others have plenty to waste. In the case of fossil fuels, supplies are continuously decreasing; petroleum, for example, cannot be grown and replenished as if it is an agricultural product. In all these cases, distribution is unequal and mandated by financial incentives rather than need. This problem is obviously intertwined with the next facet to be discussed, environmental injustice.

### *Environmental Injustice*

In today's world, resources of all kinds are distributed according to power and prestige (Schwalbe, 2000). Power and prestige, in turn, are often mediated by

factors such as race and wealth (Schwalbe, 2000). In the United States, affluent Whites tend to benefit from public policies and industry practices that affect the environment, while the poor and minorities pay the costs of those policies and practices through unsafe conditions in their homes, neighborhoods, and workplaces (Colquette & Robertson, 1991). Specifically, low-income and/or minority communities have been documented to be:

- Exposed to higher levels of pollution than the national mean (Institute of Medicine, 1999);
- At higher risk of cancer due to air pollution than White communities (Apelberg, Buckley, & White, 2005);
- More likely to have an air-polluting facility in their neighborhood (Mennis, 2005);
- More likely to have a hazardous waste treatment, storage, and disposal facility in their neighborhood (Boer, et al., 1997);
- More likely to not receive information regarding risks from environmental hazards (Figueroa, 2001);
- And more likely to have Superfund<sup>2</sup> sites in their neighborhood (Stretesky & Hogan, 1998).

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<sup>2</sup> Superfund sites are hazardous waste dumping sites that threaten the environment and public health, as designated by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Kemp, 1998).

To make matters worse, some results suggest that areas with relatively high percentages of minorities tend to have weak records of environmental enforcement when compared to White communities (Mennis, 2005; Gaylord & Bell, 2001).

As disturbing as the above injustices are, they are relatively insignificant compared to what occurs on a global scale. Hazardous toxic waste from developed countries is routinely dumped in developing African nations, including Senegal, Nigeria, and Zimbabwe (Gbadegesin, 2001). Residents of these nations, if they are aware of the dumping at all, are seldom told the health risks caused by the contamination of the land on which they work and live (Gbadegesin, 2001). Some attempt to justify this practice by arguing that the “measurement of the costs of health-impairing pollution depends on the forgone earnings from increased morbidity and mortality” (Westra, 1993, p. 216). In other words, because Africans earn less than Westerners, the cost of their lives due to pollution is not as significant as the cost of Westerner’s lives due to pollution, even though Westerners are creating the pollution under discussion. Similar attitudes arise when oil exploration in developed countries is discussed. When multinational corporations drill for oil in developing countries, there is little regard for the local ecosystem or the people who depend on it; spills are common; and companies seldom attempt to restore ecosystems when they are finished (Gbadegesin, 2001).

Environmental injustice is seldom included among the collection of environmental problems caused by humans. Indeed racism and injustice in human

societies predates our destructive effects on the environment. Nevertheless, offloading environmental hazards has become yet another convention through which minority communities are used as means to the majority's ends. The global environmental dilemma and the social disease of racism have become intertwined; efforts to resolve one without addressing the other are sure to be futile. Rather than see this situation as hopeless, it is best to see EE as a means through which both of these problems can be addressed simultaneously. Specifically, scientific understanding can enable us to see how we behaviorally and physiologically participate in ecosystem processes. Such an understanding would allow us to realize how dependent we are on ecosystems and thus have a vested interest in protecting the ecosystem health. Most importantly, scientific understanding would allow us to reason about how we can behaviorally participate in ecosystem processes so that both ecosystems and people are protected from destruction.

### *Human Population Growth*

The rate of human population growth can be regarded as a microscope that magnifies the impact of all of the environmental problems discussed thus far. As the number of humans on Earth increases, so does environmental destruction, demand for more resources, and the number of people who must survive with less than adequate resources (Kump, Kastings, & Crane, 2004; Keller, 2000; Smith, 1996; Pimentel, Giampietro, & Bukkens, 1998; Pimentel, et al., 1997). While developing countries are often viewed as the culprits regarding high birth rates, modest population increases in developed countries actually have greater



environmental impacts (Westra & Lawson, 2001). Lifestyles in developed countries are so environmentally destructive that one person in the United States consumes more resources and produces more pollution than 50 people in some parts of Africa (Westra & Lawson, 2001). Indeed, many Africans do not have sufficient resources to survive, and this illustration is not meant to imply that everyone should adopt the lifestyle of an African. However, it is a common misconception that the environmental impact of rapid population growth is caused by nations with high birth rates, such as those in Africa, but this idea is not supported when the environmental impacts of lifestyles are taken into account. Some countries have recognized the problem of human population growth and enforced laws for controlling population growth that others have labeled draconian and impinging on human rights. There are alternative ways to control human population growth without such heavy-handedness. For example, greater governmental support for adoption is one way through which societies can continue to place a high value on family while slowing human population growth.

The major issues comprising the global environmental dilemma have been summarized here. Throughout this dissertation, the global environmental dilemma will refer to this collection of problems. Regarding this dilemma and EE, some major points of concern are that humans are causing the dilemma through their behavioral participation in matter cycling processes, most humans are unaware of their own behavioral participation in ecosystem processes, and even those humans who are well aware of the causal relationship between human behaviors and

environmental problems do not have the scientific understanding to construct potentially effective environmental solutions. Moreover, scientists do not yet understand many scientific details, which is precisely why natural systems must be preserved so that they can be studied. Scientists alone cannot solve the global environmental dilemma; every human resident on Earth has a role to play. Therefore, EE is needed to help individuals understand their behavioral participation in ecosystems and then define their own role in realizing solutions to the global environmental dilemma.

## APPENDIX II: SYLLABI

### *Comparison Section*

#### **Biology 101 – Issues in Environmental Biology Course Syllabus**

INSTRUCTOR: Gary D. Wisheart

Office: Office: A-227  
Phone: Voice Mail 619-388-3550, e-mail  
gwisehar@sdcdd.net

Course web site: <http://webct.sdcdd.net>. See the attached handout for logging onto the web site.

Required texts: *Environmental Science – A Systems Approach to Sustainable*

*Development*, Seventh Edition by Daniel D. Chiras.  
*Biology 101 Laboratory and Lecture Guide*  
by the Biology Department, San Diego City College.

Attendance: Required.

1. If you have three or more unexcused absences from lectures, you may be dropped from the course. If you have 6 or more, you will be dropped. If you have two or more unexcused absences from laboratory, you may be dropped from the course. If you have 4 or more unexcused absences from laboratory, you will be dropped. EACH LATE ARRIVAL TO AN OFF CAMPUS LABORATORY WILL COUNT AS AN ABSENCE AND YOU WILL RECEIVE A ZERO ON THE LABORATORY ASSIGNMENT(S). Unexcused absences after the drop deadline will result in a 5 point deduction for each absence.
2. District Add-Withdrawal Policy:  
September 10, 2005. Last day to receive an add code, process and pay for add codes and drop without a “W”.  
September 13, 2005. Last day to drop a class and be eligible for refund.  
September 30, 2005. Last day to file a petition for Credit/No Credit option.  
November 5, 2005. Last day to receive a “W”.

3. Attendance after this date will result in assignment of a letter grade.
4. It is your responsibility to add and withdraw by the deadlines posted. A petition of late add or withdrawal will require proof that missing the deadline was beyond your control.
5. If you anticipate difficulty in paying fees before the add deadline, you should check with the Financial Aid Office about sources of funds or other alternatives for which you might be eligible.

Laboratories:

Field trips may have specific dress requirements which will be announced in lecture. Generally you must wear flat, close-toed shoes and must not wear skirts or dresses. These requirements are for safety reasons.

Several field trips require wearing hardhats and safety goggles. These two items will be provided at the field trip site.

For outdoors field trips, you may consider wearing a hat, dark glasses, and sunscreen. For outdoor trips, you may consider bringing water, but no soft drinks or other types of beverages.

All field trips require walking and climbing stairs. The all-day-bus-trip requires getting on and off of a motor coach. If you require an accommodation to meet these requirements you must tell your instructor one week in advance of the field trip. Last minute requests cannot be accommodated. **IF YOU REQUIRE AN ACCOMMODATION FOR THE ALL-DAY-BUYS-TRIP, YOU MUST TELL THE INSTRUCTOR DURING THE FIRST WEEK OF CLASS.**

At the conclusion of each laboratory, a ten minute, 10 point quiz will be given except those which have a guest tour guide. For labs conducted by a guest tour guide, a thank you letter must be prepared, *i.e.*, typewritten or word processed. It must use standard business letter format (If you are not familiar with a standard format, please see your laboratory instructor or go to the English Writing Center in C-226.) and contain

- 1) Date of tour, the fact that you are from San Diego City College and toured with an environmental issues class (use Biology 101 or Environmental Biology or Environmental Issues)
- 2) An expression of your appreciation for the tour
- 3) A *specific, explicit* description of something you learned during the tour
- 4) A *specific, explicit* description of how the tour has changed your behavior or your perception of your environment
- 5) Must be addressed Mr./Ms./Ranger/Dr. followed by a colon (:) not Marya, Mary, Joe, Sam
- 6) If you are asked to make changes and resubmit, you must include the original with your resubmit
- 7) Original is due one week from lab
- 8) Resubmit is due one week from when it was returned to you. The date when it was returned appears on the original.
- 9) If you did not attend the lab, a thank you letter may be written, but no credit will be given. If you are late to an off-campus laboratory, a thank you letter may be written or an end of lab quiz may be taken, but no credit will be given. Late means, when you arrive, the field trip is in progress.

Your letters will be read by the instructor and accepted or returned for corrections and resubmittal. Letters must be resubmitted until accepted for credit.

There will be NO RESUBMITS BEGINNING THE WEEK OF Nov. 21, 2005. During the last four weeks of the semester, letters will be graded acceptable = 10 points, not acceptable = 6 points, below college standards = 3 points, or no credit = 0 points.  
(Total points possible, no more than 160 points).

This class will be conducted in accordance with the college student code of conduct. Field trip attendance is a privilege which may be revoked if unsafe, illegal, or inappropriate

behavior occurs. Tour guides determine specific dress and behavior requirements for each field trip. Failure to adhere to these requirements will result in exclusion from field trip attendance.

- Laboratory Costs** Some lab field trips have a fee. There is no charge to enter the San Diego Zoo unless you arrive late. However, for Sea World there is a \$13.40 admission fee (normal admission is \$50.00!) and a parking fee of \$8.00 per car. The all day bus trip across San Diego County has a \$12.00 to \$15.00 fee per student. Plan for these additional expenses. The San Diego Natural History Museum fossil trip has a \$4.00 entrance fee (regular \$9.00). All field trips are required. The all day bus trip is on a Saturday. Make arrangements well in advance. This is a mandatory trip. **IF YOU ANTICIPATE BEING UNABLE TO PAY THESE FEES, PLEASE SPEAK WITH YOUR INSTRUCTOR DURING THE FIRST WEEK OF CLASS.**
- Quizzes** A 15 minute quiz will be given at the beginning of the periods indicated on the schedule. Each quiz will consist of one short answer question from a list of three questions distributed on Monday/Tuesday of the same week. A quiz will not be given the week of an exam. Quizzes are worth 10 points each (approximately 50 points).
- Exams** Five exams will be given during the semester. They will be worth 100 points and consist of short answer questions, matching questions, multiple-choice questions, concept mapping, 5-part-analysis, and problems similar to those on quizzes. They may consist of any combination of these question types. Your lowest exam score from Exams 1-4 will be dropped. Exam #5 **MUST BE TAKEN** and your results will not be dropped. If you do not take Exam #5, it will count as a zero and your next lowest exam score will be dropped.
- Extra Credit** Extra credit assignments are listed in the attachment. Others will be announced in class. Generally they are worth 10 points. They are due on the dates specified in class and in the extra credit handout. No more than 30 points worth of assignments may be attempted for extra credit.

**Make-ups**                      **No make-up laboratories, laboratory quizzes, thank you letters, lecture quizzes, or exams will be given.** If you miss an exam, it will be assigned a zero and will be dropped as your lowest score except for Exam #5. You **MAY NOT** drop Exam #5. If you miss any other type of assignment, you may complete an extra credit assignment to replace the points you missed.

**Grading**                      Your grade will be based on the total points you accumulate during the semester according to the scale below.

A	=	90-100% of the total points possible
B	=	80-89% of the total points possible
C	=	60-79% of the total points possible
D	=	50-59% of the total points possible
F	=	0-49% of the total points possible

**CHECK THE INTERNET POSTED GRADE SHEET REGULARLY.** Errors or missing grades must be brought to the attention of your instructor within **TWO WEEKS** of their posting (The date is shown in the lower left of the grade sheet.) To correct errors, you must show your instructor the returned item. For this reason, it is important that you save all returned items and make certain you receive your graded items back from the instructor. If you are absent or late when an item is returned, check with your instructor. If you miss an assignment, check the file folder on A-227 marked Bio 101 for the days you are enrolled. When there has been an attempt to distribute an assignment in class, all items left are placed in this folder. Or go the course web site and download the assignment.

**Other information**

1. If you need extra help, come and see an instructor during office hours. Most office hours go unused by students, so take advantage of this opportunity if you need help. And **PLEASE** don't wait!
2. The Science Resource Center (A-207) is open several hours during the week. Materials from some laboratories and supplementary materials are available during these times. A schedule is posted on the door of A-207 and in rooms A-201 and A-230.

3. If you have a disability and need academic accommodations, please inform your instructor during the first two weeks of class to discuss possible options available to you.
4. From time to time this syllabus may need to be modified. Students will be notified of syllabus changes during a regularly scheduled class. It will be the responsibility of the students to ensure they possess the latest version of the class syllabus.
5. This class will be conducted in accordance with the college student code of conduct and basic standards of academic honesty. Cheating, plagiarism or other forms of academic dishonesty are not acceptable and will result in one of the following: a zero for the assignment, an "F" in the class, or forwarding of the matter to the Campus Disciplinary Committee. If the definition of plagiarism is unclear to you, check with your instructor before turning in an assignment, NOT AFTER.
6. EACH ASSIGNMENT INCLUDES POINTS FOR FOLLOWING INSTRUCTIONS.
7. Cell Phone Use. Cell phones may not be set to audibly ring at any time during class. If your cell phone rings during any portion of a class meeting, you will be counted absent for that class. If you answer your cell phone or leave class to answer your cell phone (audible ring or not) without prior permission from your instructor, you will be asked to leave class for the remainder of the period. According to the Student Code of Conduct and Policy 3100 of the San Diego Community College District, if you are asked to leave class, you may not return for the next class meeting. You may return for the second class meeting after the meeting during which you were asked to leave. This policy will be strictly enforced.
8. Assignments will always be accepted early. All assignments must be
  - a. Given directly to your instructor
  - b. Given to a staff person in the Science Resource Center, A-207. Ask them to write the date and time on your assignment.
  - c. Emailed.
  - d. Snail-mailed with a legible date and time stamp.



No other method of turning in assignments is secure. If you do not submit an assignment in one of these manners, the responsibility for your instructor receiving the assignment is yours.

9. Assignments are due when your instructor calls for them in class. YOUR INSTRUCTOR WILL NOT ACCEPT LATE ASSIGNMENTS IF WE HAVE GONE OVER ANY OF THE PROBLEMS IN CLASS WHETHER YOU WERE PRESENT OR NOT, OR ONCE THE ANSWERS HAVE BEEN POSTED ON THE WEBSITE AND/OR ON CAMPUS, WHETHER YOU HAVE SEEN THEM OR NOT.

### Schedule

Week	Lecture Topic	Laboratory
1	Environmental Science (Ch. 1-3)	Reliability & Dichotomous keys
2	Reliability & arguments	Torrey Pines State Reserve
3	Ecology (Ch. 5-6) Quiz	Tijuana River Estuary
4	<b>EXAM #1</b> , Human ecology & evolution (Ch. 7-8)	Fossils of San Diego County
5	Population (Ch. 9)	Populations and evolution
6	Population control (Ch. 10) Quiz	All-day-field-trip on Saturday
7	<b>EXAM #2</b> , Food & agriculture (Ch. 11)	Egg ranch
8	Preserving biological diversity (Ch. 12)	Tropical rainforest/San Diego Zoo
9	Grasslands, forest & wilderness (Ch. 13) Quiz	
10	<b>EXAM #3</b> , Water resources (Ch. 14)	Padre Dam Water Recycling
11	Energy (Ch. 15)	General Atomics Fusion Research
12	Future energy (Ch. 16) Quiz	
13	<b>EXAM #4</b>	
14	Mineral resources (Ch. 17)	Sand and gravel
15	Toxic substances & hazardous materials (Ch. 19, 24) Quiz	UCSD Environmental Management
16	Air pollution (Ch. 20-21) <b>EXAM #5</b>	Marine conservation/Sea World

*Experimental Section***BIOLOGY 101: ISSUES IN ENVIRONMENTAL BIOLOGY**

Instructor's information	Rebekka Darner Office: TBA Office hours: by appointment Phone: 619-594-4696 Email: rdarner@sciences.sdsu.edu
Course meeting  campus in	Lecture sessions: Tuesdays and Thursdays 11:10am-12:35pm in Room TBA Laboratory sessions: Tuesdays 1:00pm-4:05pm or off-Room TBA
Required texts	<i>Environmental Science – A Systems Approach to Sustainable Development</i> , Seventh Edition by Daniel D. Chiras. <i>Biology 101 Laboratory and Lecture Guide</i> by the Biology Department, San Diego City College.
Materials & costs	For this class, you will need paper to take notes, a pencil or pen, a folder to keep returned assignments in, and a composition notebook. One assignment will require you to purchase a disposable, single use camera and pay for the developing of the film. Some field trips have a fee. There is no charge to enter the San Diego Zoo unless you arrive late. However, for Sea World there is a \$13.40 admission fee (normal admission is \$50.00) and a parking fee of \$8.00 per car. I suggest you carpool or use public transportation to reduce or avoid this fee. The all day bus trip across San Diego County has a \$12.00 to \$15.00 fee per student. Please plan for these additional expenses. The San Diego Natural History Museum fossil trip has a \$4.00 entrance fee (regular \$9.00). The all day bus trip is on a Saturday. Please make arrangements well in advance. This is a mandatory trip just like all the other field trips. If you anticipate being unable to pay these fees, please speak with me during the first week of class.
Attendance	In this class, most of what we learn will be from each other.

Therefore, it is necessary that you are here so that you can learn from the instructor and your classmates and so they can learn from you. If you have 6 or more unexcused absences from lecture, you will be dropped from the course. If you have 4 or more unexcused absences from laboratory, you will be dropped from the course. Each unexcused absence will deduct 5 points from your grade.

#### Add/Withdrawal

According to the Districts' Add-Withdrawal Policy, important dates are:

- TBA. Last day to receive an add code, process and pay for add codes and drop without a "W".
- TBA. Last day to drop a class and be eligible for refund. TBA. Last day to file a petition for Credit/No Credit option.
- April 21, 2006. Last day to receive a "W". Attendance after this date will result in assignment of a letter grade.

It is your responsibility to add and withdraw by the deadlines posted. A petition of late add or withdrawal will require proof that missing the deadline was beyond your control. If you anticipate difficulty in paying fees before the add deadline, you should check with the Financial Aid Office about sources of funds or other alternatives for which you might be eligible.

#### Laboratories

An assignment will accompany every laboratory session. Sometimes you will be able to complete your laboratory assignment during the laboratory session, but if not, it is considered homework and is due the following Thursday (i.e., two days following the lab). Each laboratory assignment is worth 10 points.

You are encouraged to hold discussions and ask questions of your lab group while completing your laboratory assignments, but it is never okay for someone else to do your assignment or for you to do someone else's assignment. This means that all answers written on your paper must be your own thinking and written by your own hand. If this is not the case, it is considered to be academic dishonesty and will be taken very seriously in this course. This fine line can be confusing in a class like this that

involves so much collaboration, which is why you should ask questions and clarify to your satisfaction what it means to be academically dishonest in this course. Your questions about what is and is not cheating will never be mocked.

#### Field trips

Field trips are critical to the learning that occurs in this course, so your attendance is required at all of them. Many of the field trips are guided by people donating their time and expertise, and it is considered very rude to arrive late. Please arrive on time to all off-campus field trips. If the field trip has already started by the time you arrive, you will not receive participation credit for that laboratory period, and you will only receive half of the credit you earn on the laboratory assignment. Nonetheless, it is still recommended that you participate fully and complete the assignment so that you may learn from the field trip and succeed on exams.

All field trips require walking and climbing stairs, and some field trips may have specific dress requirements, which will be announced in lecture. To keep yourself safe, plan on wearing flat, close-toed shoes that are good for walking and avoiding skirts or dresses for all field trips. Several field trips require wearing hardhats and safety goggles. These two items will be provided at the field trip site.

Some field trips will be outdoors, and you should consider wearing a hat, dark glasses, and sunscreen. To stay hydrated, bring water but no soft drinks or other types of beverages because they do little for keeping you hydrated.

If you require an accommodation on the field trips due to a disability, please tell your instructor one week in advance of the field trip. Last minute requests cannot be accommodated because of the amount of advance planning involved. The all-day-bus-trip requires getting on and off of a motor coach. If you require an accommodation for the all-day-bus trip, please tell your instructor the first week of class.

All aspects of this class, including field trips, will be conducted in accordance with the college student code of

conduct. Field trip attendance is a privilege that can be revoked if unsafe, illegal, or inappropriate behavior occurs. Tour guides determine specific dress and behavior requirements for each field trip. Failure to adhere to these requirements will result in exclusion from field trip attendance and associated benefits, including learning and credit.

#### Thank-you letters

Because other community members are donating their time and expertise for us to have field trips, it is necessary that we thank them. For each field trip that is lead by someone other than me, we, as a class, will send a thank-you letter to the tour guide. After each tour, a lab group will take responsibility for writing the letter, after which all members of the class will be given an opportunity to approve or disapprove of the letter's contents. Every member of the lab group is expected to contribute to composing the letter. Every lab group will take responsibility for a letter throughout the course. If lab groups do not volunteer to write letters after each tour, I will assign the letters to specific groups. Each letter must be typed, in a letter format, and include the following:

- 1) Date of tour, the fact that your are from San Diego City College and toured with an environmental issues class (use Biology 101 or Environmental Biology or Environmental Issues);
- 2) An expression of your appreciation for the tour;
- 3) A description of what you learned during the tour;
- 4) A description of how the tour has changed your behavior or your perception of our environment;
- 5) Must be addressed Mr./Ms./Ranger/Dr. not Marya, Mary, Joe, Sam;
- 6) If you are asked to make changes and resubmit, you must include the original with your resubmit;
- 7) Original is due one week from the tour;
- 8) Resubmit is due one week from when it was returned to you. The date when it was returned appears on the original.
- 9) If you do not attend the tour, a thank you letter may be written, but no credit will be given. If

you are late to an off-campus laboratory, a thank you letter may be written or an end of lab quiz may be taken, but no credit will be given.

If you have difficulty writing letters, please seek help from me, your lab group members, or go to the English Writing Center in C-226. I will read each letter and either accept or return it for grammar corrections and resubmittal. Letters must be resubmitted until accepted for credit. Once they are corrected for grammar, the whole class will have an opportunity to add or reject content of the letter. Thank-you letters are worth 10 points.

#### Reflections

For each unit, you will be asked to write one or two reflections in your composition notebook. Specific prompts will be given for each reflection. The purpose of these reflections is to encourage you to think critically about what you learn in class and make it relevant to your real life. You will be graded on your thoughtfulness and thoroughness in responding to the prompt, not grammar (although good grammar helps with thoroughness). Each reflection is worth 10 points.

#### Exams

Five exams will be given during the semester. They will be worth 100 points and consist of short answer questions, multiple-choice questions that accompany an explanation, and guided essay questions. They may consist of any combination of these question types. Your lowest exam score from Exams 1-4 will be dropped. Exam #5 is a final exam that covers general ideas from the entire semester and therefore must be taken. Your results from Exam #5 cannot be dropped. If you do not take Exam #5, it will count as a zero and your next lowest exam score will be dropped.

#### Group project

You get to choose, in collaboration with your group, an environmental issue from the schedule that is particularly interesting to you and investigate it. You and your group members will be asked to become experts about your chosen issue, construct an environmental action plan to help solve the environmental problem, and share your findings with your classmates and me. You will be asked to lead a whole-class discussion or activity about the issue (I will help you devise this if you like). Your

presentation/activity will take place during the week that your issue is scheduled. This project is worth 50 points.

#### Participation

Much of the learning that happens in this class is dependent on how much we communicate with each other and share our ideas about the environment and how to protect it. If we do not collaborate with each other, it makes learning almost impossible, which defeats the purpose of this class.

Therefore, you will be given credit for the effort you devote to participating in class activities, discussions, and assignments. Each day, you will be assigned a participation grade on a scale from 0-2. A score of 0 indicates you did not participate at all; 1 indicates you participated minimally; and 2 indicates that you participated at the level that is expected of college students. This may not seem like much, but 6 points a week adds up and can mean the difference between a B and C.

#### Make-ups & late assignments

There will be no make-ups for reflections, the group project, or laboratory assignments, including thank-you letters. If you miss an exam for an emergency, such as the death of an immediate family member or a car accident, you may be allowed to take a make-up exam that differs from the one given to the rest of the class. However, this exam must be taken before the class receives their exams back, which is typically a week after the exam is taken. There are no make-up exams for non-emergencies.

Reflections will not be accepted late because they are very closely related to what is being discussed in class. By the time you turn them in late, they are no longer relevant to what is being covered in class. Laboratory assignments will only be accepted one day following its due date (i.e., one week from the lab session), and you will only be given half of the credit that you earned on the assignment.

#### Grading

Your grade will be based on the total points you accumulate during the semester according to the scale below.

A	=	90-100% of the total points possible
B	=	80-89% of the total points possible
C	=	60-79% of the total points possible
D	=	50-59% of the total points possible

F = 0-49% of the total points possible

I will periodically offer a grade sheet in class, but you should keep track of your own grade. Errors or missing grades must be brought to my attention within two weeks of the posting of the last grade sheet. To correct errors, you must show me the returned assignment. For this reason, it is important that you save all returned items in your folder and make certain you receive your graded items back. If you are absent or late when an item is returned, check with me when you return. If you miss an assignment, check the file folder on A-227 marked Bio 101, section 1. When I try to distribute an assignment in class but some students are absent, all unreturned assignments left are placed in this folder.

Below is a breakdown of the points offered in this class.

Exams	500 points
Laboratory assignments	150 points
Reflections	300 points
Participation	90 points
Group project	<u>50 points</u>
TOTAL = 1090 points	

#### Other information

1. If you need extra help, please make an appointment with me. PLEASE don't wait until it is too late to bring your grade up.
2. The Science Resource Center (A-207) is open several hours during the week. Materials from some laboratories and supplementary materials are available during these times. A schedule is posted on the door of A-207 and in rooms A-201 and A-230.
3. If you have a disability and need academic accommodations, please inform me during the first week of class to discuss possible options available to you.
4. From time to time this syllabus may need to be modified. Students will be notified of syllabus changes during a regularly scheduled class. It will be the responsibility of the students to ensure they possess the latest version of the class syllabus.



5. This class will be conducted in accordance with the college student code of conduct and basic standards of academic honesty. Cheating, plagiarism or other forms of academic dishonesty are not acceptable and will result in one of the following: a zero for the assignment, an “F” in the class, or forwarding of the matter to the Campus Disciplinary Committee. If the definition of plagiarism is unclear to you, check with me before turning in an assignment, not after.
6. Cell phones are a disruption to the learning that occurs in our classroom, and most (including me) consider it rude and disrespectful when someone does not silence their phone before entering a classroom. If your cell phone rings during any portion of a class meeting, you will not receive participation credit for that day. If you answer your cell phone or leave class to answer your cell phone (audible ring or not) without speaking to me before class (see below), you will be counted absent for that day. I understand that there are important situations in which cell phone access is needed. For instance, if your child is ill and you need to be reached while in class, I understand. However, you must speak with me before class about the situation and put your phone on vibrate so class will not be disrupted. In a situation like this, you should discreetly leave the room if your phone rings and wait until you have exited before you answer it. If you do not speak to me before class, the above rules apply.
7. Assignments will always be accepted early. All assignments must be
  - a. Given directly to your instructor
  - b. Given to a staff person in the Science Resource Center, A-207. Ask them to write the date and time on your assignment.
  - c. Emailed.
  - d. Snail-mailed with a legible date and time stamp.

No other method of turning in assignments is secure. If you do not submit an assignment in one of these manners, the responsibility for your instructor receiving the assignment is yours.

**Tentative Schedule**

<b>Week</b>	<b>Lecture Topic</b>	<b>Laboratory</b>
1	Reliability, arguments, & scientific evidence	Lab: Reliability & dichotomous keys
2	Environmental science, nature, & necessities for life (Ch. 1-3)	Field trip: Torrey Pines State Reserve
3	Ecology (Ch. 5-6)	Field trip: Tijuana River Estuary
4	<b>EXAM #1</b> , Ecology continued (Ch.5-6)	Lab: Ecosphere
5	Energy (Ch. 15)	Field trip: General Atomics Fusion Research
6	Future energy (Ch. 16)	Lab: Global warming
7	<b>EXAM #2</b> , Pollution (Ch. 20-21)	Field trip/lab: Water quality along San Diego coastline
8	Toxic substances & hazardous materials (Ch. 19, 24) Guest speaker	Field trip: UCSD Environmental Management
9	Food & agriculture (Ch. 11) Guest speaker	Field trip: Egg ranch
10	<b>EXAM #3</b> , Water resources (Ch. 14)	Field trip: Padre Dam Water Recycling
11	Mineral resources (Ch. 17)	Lab: Sand and gravel
12	Preserving biological diversity (Ch. 12) Guest speaker	All-day-field-trip on Saturday
13	<b>EXAM #4</b> , Grasslands, forest & wilderness (Ch. 13)	Field trip/lab: Tropical rainforest/San Diego Zoo
14	Human evolution (Ch. 7-8)	Lab: Fossils of San Diego County
15	Population & population control (Ch. 9)	Lab: Populations and evolution
16	<b>EXAM #5</b> , Environmental careers & schools Guest speaker	Field trip/lab: Marine conservation/Sea World

### APPENDIX III: INSTRUMENTS

*Questionnaire A*

*Birth date:* \_\_\_\_\_

Month/Day/Year

*There are many behaviors that one can do for the environment. For example, some people recycle old bottles and newspapers, others participate in organizations for the protection of the environment, etc. Please try to think of behaviors that you do for the environment and write them in the space provided:*

*Consider these behaviors while you complete the following section of the questionnaire. Listed below are several statements concerning possible reasons why people might do environmentally friendly behaviors. Using the scale from 1-7 below, please indicate the degree to which the proposed reasons correspond to your reasons for doing the environmentally friendly behaviors you listed above by circling the appropriate number to the right of the item.*

	<u>Does not</u>						
	<u>correspond</u>						<u>Corresponds</u>
							<u>exactly</u>
1. For the pleasure I experience while I am mastering new ways of helping the environment.	1	2	3	4	5	6	7
2. Because I'm not satisfied with myself when I don't do anything for the environment.	1	2	3	4	5	6	7
3. For the pleasure I experience when I find new ways to improve the quality of the environment.	1	2	3	4	5	6	7
4. Because it is a reasonable thing to do to help the environment.	1	2	3	4	5	6	7
5. Because I like the feeling I have when I do things for the environment.	1	2	3	4	5	6	7
6. I don't really know; I can't see what I'm getting out of it.	1	2	3	4	5	6	7
7. I think I'd regret not doing something for the environment.	1	2	3	4	5	6	7
8. I wonder why I'm doing things for the environment; the situation is simply not improving.	1	2	3	4	5	6	7
9. For the pleasure I get from contributing to the environment.	1	2	3	4	5	6	7
10. Because it's a sensible thing to do in order to improve the environment.	1	2	3	4	5	6	7

11. Because it's a way I've chosen to contribute to a better environment. 1 2 3 4 5 6 7
12. Because I'd feel I wouldn't be doing the right thing if I was neglecting to do things for the environment. 1 2 3 4 5 6 7
13. Because other people will be upset if I don't. 1 2 3 4 5 6 7
14. For the recognition I get from others. 1 2 3 4 5 6 7
15. Because I would feel bad if I didn't do anything for the environment. 1 2 3 4 5 6 7
16. Because taking care of the environment is an integral part of my life. 1 2 3 4 5 6 7
17. Because my friends insist that I do it. 1 2 3 4 5 6 7
18. Because it seems to me that taking care of myself and taking care of the environment are inseparable. 1 2 3 4 5 6 7
19. Because I would feel guilty if I didn't. 1 2 3 4 5 6 7
20. Because being environmentally-conscious has become a fundamental part of who I am. 1 2 3 4 5 6 7
21. Because it's part of the way I've chosen to live my life. 1 2 3 4 5 6 7
22. Because I would feel ashamed of myself if I was doing nothing to help the environment. 1 2 3 4 5 6 7
23. Because I think it's a good idea to do something about the environment. 1 2 3 4 5 6 7
24. Because it is what the experts tell us to do. 1 2 3 4 5 6 7
25. Honestly, I don't know; I truly have the impression that I'm wasting my time doing things for the environment. 1 2 3 4 5 6 7
26. I don't know; I can't see how my efforts to be environmentally-conscious are helping the environmental situation. 1 2 3 4 5 6 7

*Items 27-47 below are several statements concerning possible ways someone might generally feel in their life. Using the same scale from 1-7, please indicate the degree to which the proposed statements correspond to how you feel your life by circling the appropriate number to the right of the item.*

- |   | <u>Does not<br/>correspond</u> | <u>Corresponds<br/>exactly</u> |
|---|--------------------------------|--------------------------------|
| 27. I feel like I am free to decide for myself how to live my life. | 1 2 3 4 5 6 7                  |                                |
| 28. I really like the people I interact with.                       | 1 2 3 4 5 6 7                  |                                |

29. Often, I do not feel very competent. 1 2 3 4 5 6 7
30. I feel pressured in my life. 1 2 3 4 5 6 7
31. People I know tell me I am good at what I do. 1 2 3 4 5 6 7
32. I get along with people I come into contact with. 1 2 3 4 5 6 7
33. I pretty much keep to myself and don't have a lot of social contacts. 1 2 3 4 5 6 7
34. I generally feel free to express my ideas and opinions. 1 2 3 4 5 6 7
35. I consider the people I regularly interact with to be my friends. 1 2 3 4 5 6 7
36. I have been able to learn interesting new skills recently. 1 2 3 4 5 6 7
37. In my daily life, I frequently have to do what I am told. 1 2 3 4 5 6 7
38. People in my life care about me. 1 2 3 4 5 6 7
39. Most days I feel a sense of accomplishment from what I do. 1 2 3 4 5 6 7
40. People I interact with on a daily basis tend to take my feelings into consideration. 1 2 3 4 5 6 7
41. In my life I do not get much of a chance to show how capable I am. 1 2 3 4 5 6 7
42. There are not many people that I am close to. 1 2 3 4 5 6 7
43. I feel like I can pretty much be myself in my daily situations. 1 2 3 4 5 6 7
44. The people I interact with regularly do not seem to like me much. 1 2 3 4 5 6 7
45. I often do not feel very capable. 1 2 3 4 5 6 7
46. There is not much opportunity for me to decide for myself how to do things in my daily life. 1 2 3 4 5 6 7
47. People are generally pretty friendly towards me. 1 2 3 4 5 6 7

*Questionnaire B*

**Birth Date:** \_\_\_\_\_  
**Month/Day/Year**

**Instructions:** Please respond to each statement by indicating on the 1-7 scale how true it is for you while you participated in class today. Please only answer according to how you felt **today**, not at another time.

**Scale:**

Not at all true Very true  
 1 2 3 4 5 6 7

1. While participating in class today, I felt free to be who I am.

1 2 3 4 5 6 7

2. While participating in class today, I felt like a competent person.

1 2 3 4 5 6 7

3. While participating in class today, I felt cared about.

1 2 3 4 5 6 7

4. While participating in class today, I often felt inadequate or incompetent.

1 2 3 4 5 6 7

5. While participating in class today, I had a say in what happened, and I could voice my opinion.

1 2 3 4 5 6 7

6. While participating in class today, I often felt a lot of distance with my classmates.

1 2 3 4 5 6 7

7. While participating in class today, I felt very capable and effective.

1 2 3 4 5 6 7

8. While participating in class today, I felt closeness and familiarity.

1 2 3 4 5 6 7

9. While participating in class today, I felt controlled and pressured to be a certain way.

1 2 3 4 5 6 7

*Questionnaire C***Birth date:** \_\_\_\_\_

Month/Day/Year

*The items on this questionnaire are related to your experiences in this class. Please use the 1-7 scale to indicate how much you agree with each statement. Your responses will not be viewed by your instructor until after she submits your final grades. Please be honest.*

**Scale:**

1	2	3	4	5	6	7
strongly			not			strongly
disagree			sure			agree

1. I feel that my instructor provides me choices and options.  
1      2      3      4      5      6      7
2. I feel understood by my instructor.  
1      2      3      4      5      6      7
3. My instructor conveys confidence in my ability to do well in this course.  
1      2      3      4      5      6      7
4. My instructor encourages me to ask questions.  
1      2      3      4      5      6      7
5. My instructor listens to how I would like to do things.  
1      2      3      4      5      6      7

6. My instructor tries to understand how I see things before suggesting a new way to do things.  
1      2      3      4      5      6      7
7. I feel that students in this course care about each other.  
1      2      3      4      5      6      7
8. I feel connected to others in this course.  
1      2      3      4      5      6      7
9. I do not feel a spirit of community in this course.  
1      2      3      4      5      6      7
10. I feel that this course is like a family.  
1      2      3      4      5      6      7
11. I feel isolated in this course.  
1      2      3      4      5      6      7
12. I trust others in this course.  
1      2      3      4      5      6      7
13. I feel that I can rely on others in this course.  
1      2      3      4      5      6      7



14. I feel that members of the course depend on me.  
 1      2      3      4      5      6      7

15. I feel uncertain about others in this course.  
 1      2      3      4      5      6      7

16. I feel confident that others in this course will support me.  
 1      2      3      4      5      6      7

*Questionnaire D*

*Birth date:* \_\_\_\_\_

Month/Day/Year

*There are many behaviors that one can do for the environment. For example, some people recycle old bottles and newspapers, others participate in organizations for the protection of the environment, etc. Please try to think of behaviors that you do for the environment and write them in the space provided:*

*Consider these behaviors while you complete the following section of the questionnaire. Listed below are several statements concerning possible reasons why people might do environmentally friendly behaviors. Using the scale from 1-7 below, please indicate the degree to which the proposed reasons correspond to your reasons for doing the environmentally friendly behaviors you listed above by circling the appropriate number to the right of the item.*

	<u>Does not</u> <u>correspond</u>	<u>Corresponds</u> <u>exactly</u>
1. For the pleasure I experience while I am mastering new ways of helping the environment.	1 2 3 4 5 6 7	
2. Because I'm not satisfied with myself when I don't do anything for the environment.	1 2 3 4 5 6 7	
3. For the pleasure I experience when I find new ways to improve the quality of the environment.	1 2 3 4 5 6 7	

4. Because it is a reasonable thing to do to help the environment. 1 2 3 4 5 6 7
5. Because I like the feeling I have when I do things for the environment. 1 2 3 4 5 6 7
6. I don't really know; I can't see what I'm getting out of it. 1 2 3 4 5 6 7
7. I think I'd regret not doing something for the environment. 1 2 3 4 5 6 7
8. I wonder why I'm doing things for the environment; the situation is simply not improving. 1 2 3 4 5 6 7
9. For the pleasure I get from contributing to the environment. 1 2 3 4 5 6 7
10. Because it's a sensible thing to do in order to improve the environment. 1 2 3 4 5 6 7
11. Because it's a way I've chosen to contribute to a better environment. 1 2 3 4 5 6 7
12. Because I'd feel I wouldn't be doing the right thing if I was neglecting to do things for the environment. 1 2 3 4 5 6 7
13. Because other people will be upset if I don't. 1 2 3 4 5 6 7
14. For the recognition I get from others. 1 2 3 4 5 6 7
15. Because I would feel bad if I didn't do anything for the environment. 1 2 3 4 5 6 7
16. Because taking care of the environment is an integral part of my life. 1 2 3 4 5 6 7
17. Because my friends insist that I do it. 1 2 3 4 5 6 7
18. Because it seems to me that taking care of myself and taking care of the environment are inseparable. 1 2 3 4 5 6 7
19. Because I would feel guilty if I didn't. 1 2 3 4 5 6 7
20. Because being environmentally-conscious has become a fundamental part of who I am. 1 2 3 4 5 6 7
21. Because it's part of the way I've chosen to live my life. 1 2 3 4 5 6 7
22. Because I would feel ashamed of myself if I was doing nothing to help the environment. 1 2 3 4 5 6 7
23. Because I think it's a good idea to do something about the environment. 1 2 3 4 5 6 7

24. Because it is what the experts tell us to do. 1 2 3 4 5 6 7
25. Honestly, I don't know; I truly have the impression that I'm wasting my time doing things for the environment. 1 2 3 4 5 6 7
26. I don't know; I can't see how my efforts to be environmentally-conscious are helping the environmental situation. 1 2 3 4 5 6 7

*Items 27-47 below are several statements concerning possible ways someone might generally feel in their life. Using the same scale from 1-7, please indicate the degree to which the proposed statements correspond to how you feel your life by circling the appropriate number to the right of the item.*

- |  | <u>Does not<br/>correspond</u> | <u>Corresponds<br/>exactly</u> |
|--|--------------------------------|--------------------------------|
| 27. I feel like I am free to decide for myself how to live my life.                      | 1 2 3 4 5 6 7                  |                                |
| 28. I really like the people I interact with.  | 1 2 3 4 5 6 7                  |                                |
| 29. Often, I do not feel very competent.   | 1 2 3 4 5 6 7                  |                                |
| 30. I feel pressured in my life.   | 1 2 3 4 5 6 7                  |                                |
| 31. People I know tell me I am good at what I do.  | 1 2 3 4 5 6 7                  |                                |
| 32. I get along with people I come into contact with.                                    | 1 2 3 4 5 6 7                  |                                |
| 33. I pretty much keep to myself and don't have a lot of social contacts.                | 1 2 3 4 5 6 7                  |                                |
| 34. I generally feel free to express my ideas and opinions.                              | 1 2 3 4 5 6 7                  |                                |
| 35. I consider the people I regularly interact with to be my friends.                    | 1 2 3 4 5 6 7                  |                                |
| 36. I have been able to learn interesting new skills recently.                           | 1 2 3 4 5 6 7                  |                                |
| 37. In my daily life, I frequently have to do what I am told.                            | 1 2 3 4 5 6 7                  |                                |
| 38. People in my life care about me.   | 1 2 3 4 5 6 7                  |                                |
| 39. Most days I feel a sense of accomplishment from what I do.                           | 1 2 3 4 5 6 7                  |                                |
| 40. People I interact with on a daily basis tend to take my feelings into consideration. | 1 2 3 4 5 6 7                  |                                |
| 41. In my life I do not get much of a chance   |                                |                                |

- to show how capable I am. 1 2 3 4 5 6 7
42. There are not many people that I am close to. 1 2 3 4 5 6 7
43. I feel like I can pretty much be myself in my daily situations. 1 2 3 4 5 6 7
44. The people I interact with regularly do not seem to like me much. 1 2 3 4 5 6 7
45. I often do not feel very capable. 1 2 3 4 5 6 7
46. There is not much opportunity for me to decide for myself how to do things in my daily life. 1 2 3 4 5 6 7
47. People are generally pretty friendly towards me. 1 2 3 4 5 6 7

*For items 48-52, please circle and/or write the response that best describes you.*

48. What is your gender? **Female**                      **Male**
49. What is your age range?            **10-17 years**            **18-29 years**            **30-39 years**  
    **40-49 years**            **50+ years**
50. How do you describe your ethnicity? \_\_\_\_\_
51. Are you a first-generation college student?            **Yes**    **No**
52. Is your first language a different language than English?    **Yes**    **No**
53. If you have already decided, what is your major? If you have not decided, what field(s)/career(s) are you considering?

### *Whole Systems Rubric*

*Which of the following best describes how your group rates the completion of your group project? Have a discussion with your group and come to a consensus about where your project fits. Please be honest and be able to back up your decision with an explanation. You will be asked to provide this explanation individually in writing. These are not listed in any particular order.*

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
<p>This project shows that: I can identify and describe parts of the system; I can describe the connections between the parts of the systems and explain how the parts depend on each other through those connections; I see patterns in those connections; I recognize that diverse perspectives can enable us to recognize interdependencies in systems and come to better environmental solutions.</p>	<p>This project shows that: I can identify and describe parts of the system.</p>	<p>This project shows that: I can make choices and decisions and take actions that benefit the health of the whole system; I know that these actions are beneficial because I can explain how parts of the system depend on the health of the whole system; I know how to participate in a functioning team that represents diverse perspectives; I know these perspectives enable us to recognize interdependence in systems and come to better environmental solutions.</p>	<p>This project shows that: I can identify and describe parts of the system; I can describe the connections between the parts of the systems and explain how the parts depend on each other through those connections; I recognize that diverse perspectives can enable us to recognize interdependencies in systems and come to better environmental solutions.</p>	<p>This project shows that: I can identify and describe parts of the system; I see the system itself as a whole; I looked for and identified connections between the parts of the system.</p>

*NEP Scale*

Listed below are statements about the relationship between humans and the environment. For each one, please circle how strongly you agree or disagree with the following statements. There are no right or wrong answers; your opinion is what is important. Please be as honest as possible.

- |  |                  |           |                     |                   |
|--|------------------|-----------|---------------------|-------------------|
| 1. We are approaching the limit of the number of people the Earth can support.                   |                  |           |                     |                   |
| Strongly agree   | Moderately agree | Undecided | Moderately disagree | Strongly disagree |
| 2. Humans have the right to modify the natural environment to suit their needs.                  |                  |           |                     |                   |
| Strongly agree   | Moderately agree | Undecided | Moderately disagree | Strongly disagree |
| 3. When humans interfere with nature it often produces disastrous consequences.                  |                  |           |                     |                   |
| Strongly agree   | Moderately agree | Undecided | Moderately disagree | Strongly disagree |
| 4. Human ingenuity will insure that we do NOT make the Earth unlivable.                          |                  |           |                     |                   |
| Strongly agree   | Moderately agree | Undecided | Moderately disagree | Strongly disagree |
| 5. Humans are severely abusing the environment.  |                  |           |                     |                   |
| Strongly agree   | Moderately agree | Undecided | Moderately disagree | Strongly disagree |
| 6. The Earth has plenty of natural resources if we just learn how to develop them.               |                  |           |                     |                   |
| Strongly agree   | Moderately agree | Undecided | Moderately disagree | Strongly disagree |
| 7. Plants and animals have as much right as humans to exist.                                     |                  |           |                     |                   |
| Strongly agree   | Moderately agree | Undecided | Moderately disagree | Strongly disagree |
| 8. The balance of nature is strong enough to cope with the impacts of modern industrial nations. |                  |           |                     |                   |
| Strongly agree   | Moderately agree | Undecided | Moderately disagree | Strongly disagree |
| 9. Despite our special abilities humans are still subject to the laws of nature.                 |                  |           |                     |                   |
| Strongly agree   | Moderately agree | Undecided | Moderately disagree | Strongly disagree |
| 10. The so-called "ecological crisis" facing humankind has been greatly exaggerated.             |                  |           |                     |                   |
| Strongly agree   | Moderately agree | Undecided | Moderately disagree | Strongly disagree |
| 11. The earth is like a spaceship with very limited room and resources.                          |                  |           |                     |                   |
| Strongly agree   | Moderately agree | Undecided | Moderately disagree | Strongly disagree |

12. Humans were meant to rule over the rest of nature.				
Strongly agree	Moderately agree	Undecided	Moderately disagree	Strongly disagree
13. The balance of nature is very delicate and easily upset.				
Strongly agree	Moderately agree	Undecided	Moderately disagree	Strongly disagree
14. Humans will eventually learn enough about nature works to be able to control it.				
Strongly agree	Moderately agree	Undecided	Moderately disagree	Strongly disagree
15. If things continue on their present course, we will soon experience a major ecological catastrophe.				
Strongly agree	Moderately agree	Undecided	Moderately disagree	Strongly disagree

*Environmental Literacy Diagnostic Test*

\*The primary source of energy on Earth is the sun.                      True                      False

\*For a person to get the most food energy out of 100 pounds of vegetables and grain, the person should

- eat the vegetables and grain.
- feed the vegetables and grain to an animal and eat the meat.
- feed the vegetables and grain to a cow to produce milk, feed the milk to an animal, and eat the meat.

To protect an area from flooding, walls are constructed along riverbanks. As a result, downstream flooding will

- increase.
- decrease.
- stay the same.

\*Flooding on a river renews and replenished the environment.                      True                      False

Landowners sometimes build dams on streams to create ponds. What is the impact of a dam on a stream? The dam causes

- no major impact.
- changes to the stream in the pond area.
- changes to the entire stream.

Wetland areas have been drained in the United States for decades. New efforts are in place to restore wetlands to their natural state. Filling those drained areas again with water

- a. restores a wetland to its natural state right away.
- b. begins a restoration process that will take years.
- c. will not be effective, because once destroyed, a wetland cannot be restored.

\*Phosphorus fertilizer is applied to lawns, gardens, and crop fields to encourage plant growth. What happens when phosphorus washes into a lake or stream?

- a. The phosphorus kills the fish.
- b. Phosphorus will increase the growth of algae.
- c. Not much will happen.

\*PCB, a toxic chemical, can be found in very low levels in Great Lakes water. The PCBs are taken up by small shellfish that live in the water. Which will have the highest level of PCBs?

- a. the shellfish
- b. fish that eat the shellfish
- c. birds that eat the fish that eat the shellfish

The amount of water on Earth is

- a. increasing.
- b. decreasing.
- c. staying the same.

\*Nitrogen fertilizer is applied to gardens and crop fields to increase food production. The nitrogen is taken into the food. When a person eats food, s/he produces sewage waste. Human sewage contains some of the nitrogen that was first applied as fertilizer.

True                  False

The warming of the Pacific Ocean influences the weather

- a. just in California
- b. just in the U.S.
- c. throughout North and South America

Burning fuel in California to heat homes, operate cars, and produce electricity contributes to air pollution

- a. only in the city where it is burned.
- b. throughout California and neighboring states.
- c. not at all.

\*At the present rate of use, the world's supply of coal, oil, and natural gas

- a. will last forever.
- b. will be used up eventually.



c. will renew itself.

A major volcanic eruption in the Philippines creates dust and reduces sunlight only near the volcano during the eruption. True False

\*As California and other western states were settled, people encountered mountain lions that hunted deer and other wild animals. As the mountain lions were eliminated to protect people, what happened to the number of deer?

- a. increased
- b. decreased
- c. stayed the same

\*Fruit, vegetables, milk, and meat produced in rural California are sold and trucked to grocery stores to feed people in many large cities. The people who live in these cities produce sewage sludge. Spreading sewage sludge from big cities on farmland

- a. pollutes the soil.
- b. is a form of recycling.
- c. eliminates the sludge.

\*A farmer plants corn one year, soybeans the next year, and follows with wheat. This is called crop rotation. The need for pesticides on a farm using crop rotation will

- a. increase.
- b. decrease.
- c. stay the same.

\*Maria plants tomatoes in the same garden spot every year. Leonard also plants tomatoes but plants them in a different part of the yard each year. With everything else the same, who will harvest the most tomatoes?

- a. Maria
- b. Leonard
- c. Both will harvest about the same amount of tomatoes.

\*In the United States, chickens are raised in large buildings containing thousands of birds. Under these conditions, in the mid-1980s, poultry flu killed millions of chickens, eliminating entire flocks. Today's farming practices will prevent this from happening again. True False

People living in a rural area have grown only potatoes year after year, with great success. To join in their success, more people in the area start growing potatoes. As more potatoes are planted, the risk of disease damage each year to the potato crop will

- a. increase.
- b. decrease.
- c. stay the same.

\*The land area need to protect an endangered animal should be

- a. large enough to support one animal family.
- b. large enough to support several animal families.
- c. the same size for all endangered animals.

\*Saving an endangered plant species is just as important as saving an endangered animal species.      True      False

The most effective way to save an endangered animal is to

- a. stop hunting or eating the animal.
- b. provide it with an adequate food supply.
- c. establish a large enough reserve for it to live and reproduce.

Some tropical birds that live in Central and South American migrate to and live in California for part of the year. Which of the following is the greatest threat to these birds? Loss of habitat in

- a. Central and South America.
- b. California.
- c. both places.

\*Each summer your neighborhood is sprayed with the same bug killer to control mosquitoes. After a few years of spraying the same product, what do you think will happen? The mosquitoes will likely

- a. disappear.
- b. become resistant to the spray.
- c. remain the same year after year.

When colonizing a new area, plants, animals, and even people compete for resources to live, grow, and reproduce.      True      False

\*Tremendous numbers of flies are bothering people who live near some of California's chicken farms. Special fly-eating beetles were imported to California and placed in the chicken houses to solve the problem. While the beetles do a good job of controlling the flies in the chicken house, once the beetles get out, they become so numerous that they get into nearby homes and become pests. Why are the beetles pests?

- a. They are pests everywhere in the world.
- b. They are only pests in a new area that has no natural controls on the growth of their population.

c. They are not as problematic as people think.

There is a limit to how many people the world can support. True                      False

The total space being used to produce food for Californians is adequate even if the population of California increases.    True                      False

\*As the population in an area increases, the potential for pollution

- a. increases.
- b. decreases.
- c. stays the same.

\*People around Californian cities are moving into mountainous chaparral areas to build homes, clearing away the chaparral plants to plant a lawn. Why type of care will be needed to maintain these lawns?

- a. no special care
- b. watering and fertilizer to maintain the conditions necessary for grass.
- c. none; the lawn will not do well no matter what care you give it.

What usually happens when an area gets crowded?

- a. Organisms compete against each other; only some get enough resources to survive.
- b. Organisms cooperate with each other so that everyone gets enough resources.
- c. All the organisms usually die out.

## APPENDIX IV: INTERVIEW PROTOCOL

I will have the tape cued up to the section I am most interested in – a section in which the students are doing some sort of problem-solving related to the environment. Please ask the follow questions. You're welcome to ask clarifying questions and do "active listening." Please try to pause the tape if the student talks for a long time to make transcribing easier.

1. I have here a section of the videotape that we are going to watch together. As we watch it, tell me what you were trying to do with your group.
2. Did you feel like solving this problem was important? If you weren't asked to solve this problem in class, would it still be important to you? Why or why not?
3. As you were trying to work through this problem, is there anything (e.g., knowledge, group members' comments, teacher's comments, etc.) that helped you or that you found useful in solving the problem? Please explain. (In explaining, encourage the student to fast-forward/rewind to a particular spot in the videotape that shows what they found helpful).
4. Did you feel like you could effectively contribute to solving this problem? Why or why not? (In explaining why, encourage the student fast-forward/rewind to show you why they could or couldn't contribute effectively).
5. Did you feel like your suggestions were taken seriously by your group mates? Why or why not? (In explaining why, encourage the student fast-forward/rewind to show you why they didn't think their suggestions were taken seriously).
6. Is there anything you thought of contributing but didn't because you thought it was out of place for some reason? If so, what was what?
7. Tell me what your favorite part of class was today. (Have them fast-forward to that part; repeat questions 4-6 with their favorite part).

## APPENDIX V: CONCEPTUALIZATION PROBLEM SETS

This appendix documents the problems sets used in the course, as they were given to the students in the experimental section. Problem-solving began when the teacher read the first prompt aloud to the class. Each student group then received a piece of paper with the first prompt on it and a dry erase board to draw diagrams as needed. Student groups discussed the prompt and devised the group's solution to the question asked in the prompt. After every group had prepared a response, a whole class discussion was held so that students' ideas could be shared with the whole class and so the instructor could guide the construction of ideas toward the learning goals for the problem. Then the next prompt was given, and this process was repeated.

### *Problem #1: American Robins*

#### *Prompts*

1 – American robins spend their winters at lower altitudes in the Rocky Mountains. When the temperature begins to rise in the spring, the robins migrate to higher altitudes where they spend the summer. At the higher altitudes, snowmelt stimulates the growth of plants that the robins depend on for food and building their nests. Over the past three decades, spring temperatures have come earlier and earlier at both the lower and higher altitudes. However, the melting of the snow still occurs at the same time it has historically. How do you think American robins are affected by the early onset of spring temperatures?

2 – Yellow-bellied marmots also live in the Rocky Mountains. Instead of migrating, however, they deal with winters by hibernating in their dens at the higher altitudes. How do you think yellow-bellied marmots are affected by the early onset of spring temperatures?

### *Learning Goals*

The purpose of this problem was to get students to reason about how organisms are affected by climate change. I anticipated comments about timing of migration, obtaining food, depletion and replenishment of energy, mating, and reproduction. By working through this problem and participating in the whole class discussions, I would have liked students to develop an understanding of how these behaviors (i.e., migration, eating, mating, etc.) are connected through space and time. Therefore, if climate changes one of these behaviors, such as the timing of migration in this case, all other behaviors are affected, which leads to substantial changes in the natural histories of species.

### *Problem #2: Colorado River Water Pollution*

#### *Prompts*

1 – Just to understand what these maps are representing, use maps A and B to locate the following landmarks: San Diego/ Tijuana region, the Colorado River Aqueduct, Lake Havasu, Parker Dam, the Colorado River's delta (a delta is a place where a river empties into an ocean or sea), and the Upper and Lower Colorado Basins. If it helps to picture things on a larger scale, make a rough sketch of your own, showing these landmarks, on your white board.

2 – Map C shows several facilities that are located along the Colorado River. Which of these have the potential to affect our drinking water? Of those that have the potential to affect our drinking water, which of them probably do? Be prepared to justify to the class why you think that.

3 – Map D shows a more detailed picture of the Colorado River's delta. The Colorado River delta once was lush with vegetation and wildlife, but now it's not. Devise at least 2 hypotheses that could explain this change. Then, on a piece of notebook paper, right down your group's two hypotheses (be sure to put your names on it) and hand them in. Be prepared to explain your hypotheses to the class.

4 – It turns out that because the delta was a wetland, which require wet conditions, the development along the Colorado River and U.S. citizens' use of the river's water is what has led to the demise of the health of the Colorado Rivers delta's ecosystem. The delta's largest remaining estuary is called Cienega de Santa Clara, and its primary source of water is drainage from an irrigation district in Arizona. What do you think the quality of this drainage water is like? How do you think this water quality affects the ecosystem in Cienega de Santa Clara?

5 – The Yuma Desalting Plant currently collects some of the drainage water from the irrigation district and removes the salt from it. The salt is sold, and the desalted water is dumped back into the main channel of the river. If the Yuma plant were to operate to its fullest capacity, it would collect all of the water from the irrigation district and use it in its operation. How do you think this would affect the health of the Cienega de Santa Clara ecosystem?

6 – Recall from our field trip to the water recycling facility that Arizona has rights to 60% of the water in the Lower Basin of the Colorado River. Southern California has rights to the remaining 40%. If both Arizona and southern California claim all of the water to which they are entitled to by U.S. law, how will the health of the Colorado River delta ecosystem be affected? What can we do to maintain the health of the delta ecosystem? One last question... do you think Mexico got a fair "slice of the pie" when it comes to the Colorado River? Why or why not?

### *Learning Goals*

The purpose of this problem was to compel students to think about where their drinking water comes from, the various factors that affect its quality, and how their water usage affects other people and far-away habitats. I would have liked them to learn that (a) most of their water comes from the Colorado River, (b) pollutants are released into the Colorado River before it arrives in San Diego, (c) San Diegans' high water usage leaves less water to be used by people and other organisms downstream from where the Colorado River Aqueduct leaves the

River, and (d) such a decrease of water has changed the habitat in the once biodiverse Colorado River delta.

*Problem #3: Channel Island Foxes*

*Prompts*

1 – The Channel Islands are a group of islands off the coast of southern California. On six of the islands, there is a different subspecies of the island fox. The island fox is an endangered species and is endemic to the Channel Islands. On these same islands, there are populations of introduced feral pigs. How do you think the presence of the feral pig populations affects the ecosystems on the Channel Islands? How do think the island foxes are affected by the feral pigs?

2 – Because the Channel Islands are a state reserve, many ecologists and natural resource managers work there to try to maintain the native biodiversity of the Channel Island ecosystems. They planned to eradicate the feral pig populations in 2004. Do you think this is a good idea? Why or why not?

3 – Recently, golden eagles, which are on the federal endangered species list, colonized these six Channel Islands. The golden eagles prey on the island foxes and have caused two of the fox subspecies to go extinct. A third fox subspecies has been reduced to less than 100 individuals in the population. The golden eagles also eat the feral pigs. Ecologists and natural resource managers who work there are trying to figure out what to do in this situation. Although they were planning on eradicating the pigs, they are now questioning the wisdom in that decision. If you were one of these scientists, what would you do and why?

*Learning Goals*

Because this problem does not have an obvious answer, it requires students to be creative in the solutions that they devise, which in turn compels students to use their knowledge about ecosystems. The purpose of this problem was to use this knowledge to solve an authentic natural resource management



problem. I would have liked them to learn that (a) real science problems do not have obvious solutions, (b), finding solutions to these problems requires creativity everyday knowledge that we all possess, (c) there are often conflicts in which natural resource managers have to decide how/if to protect one endangered species over another, and (d) knowledge about organismal interactions is applicable in authentic contexts.

*Problem #4: Western and Arroyo Toads*

*Prompts*

1 – Consider two toad species that live in southern California – the Western toad and the Arroyo toad. Males of the Western toad perform advertisement calls, which are special vocalizations that are used to attract females for mating. Although male Arroyo toads do not make advertisement calls, female Arroyo toads are still attracted to the calls of male Western toads. Considering this situation, which males (Western or Arroyo) would be more likely to mate with female toads? Which males would have greater *fitness*?

2 – Occasionally, a male Western toad will attract a female Arroyo toad, and they will mate. The male offspring are often able to perform the advertisement calls. Do you think these offspring would be more or less fit than the Western or Arroyo toad males? Be prepared to explain your group's reasoning.

3 – Like most hybrids, the offspring of a male Western toad and a female Arroyo toad are usually sterile. Considering this, do you think these offspring would be more or less fit than the Western or Arroyo toad males? Be prepared to explain your group's reasoning.

4 – By a lucky fluke, there is a slight chance that a Western-Arroyo toad hybrid could be fertile. What affect do you think this fertile hybrid would have on Western toad populations? Arroyo toad populations? If this were to happen tomorrow, do you think Western toads and Arroyo toads would be considered the same species 200 years from now? Be prepared to explain your group's reasoning.

*Learning Goals*

The purpose of this problem was to compel students to think about what they mean when they use the phrase “survival of the fittest.” In other words, I wanted them to develop a more scientifically accurate concept for the term fitness. My learning goals for them were to (a) define what they thought fitness means, (b) put it into the context of real evolutionary problem, (c) identify its non-functionality in that problem, and (d) devise a more scientific definition for fitness, in the context of biology. I would also have liked this problem to serve as an introduction to the concept of gene flow, a major process in microevolution.

*Problem #5: Baja Rodents**Prompt*

Five million years ago, Baja California was attached to mainland Mexico. Thanks to the active San Andreas fault, the peninsula has migrated northward, which has slowly caused the creation of the Sea of Cortez. When the peninsula was attached, a single species of rodent was distributed across the landmass. Now, the rodent species in Baja California is considered to be different from the species in mainland Mexico. How could this have happened? Be prepared to explain your group’s reasoning to the class and in writing.

*Learning Goals*

The purpose of this problem was to introduce students to the fundamental process of macroevolution, speciation. I wanted them to become aware of factors that contribute to the process of speciation (e.g., various environmental conditions) by interacting with their group mates and considering their ideas.

*Problem #6: A day in the life of an average Joe**Prompt*

Joe lives in Pacific Beach and works at a business in downtown San Diego. He is married to Maria and has two children, a 5-year-old (Mark) and a 3-month-old (Brian). Joe and his wife wake up at 6 a.m. to shower<sup>1</sup> and get ready before their kids wake up at about 7 a.m. As he is getting out of the shower, he notices Brian is crying, so he proceeds with the morning routine of changing the baby's diaper<sup>2</sup>, giving him a bottle<sup>3</sup>, and dressing him in fresh clothes. Joe and his family sit down to have breakfast – cereal with banana and a glass of orange juice for the kids and coffee for the adults<sup>4</sup>. As Maria is preparing the last bowl of cereal, she notices the cereal box is empty. She throws it away<sup>5</sup>. After breakfast, Maria helps Mark get ready for school while Joe makes Mark's lunch<sup>6</sup>. Then Joe and Mark get into their Toyota Camry<sup>7</sup>, and because it's a warm late-summer day, they turn on the car air conditioner and let the inside of the car cool off before they leave<sup>8</sup>. Joe takes Mark three blocks down the street to his elementary school (which happens to be across the street from a trolley station), drops him off, and then continues to work<sup>9</sup>. When Joe arrives downtown, he circles the city block where he works for about 10 minutes, looking for a parking spot<sup>10</sup>. He finally finds one, parks, and gets to work at about 9 a.m. Joe works at his desk until noon when he leaves for lunch with two of his colleagues. They walk a block to a bar & grill restaurant where they have lunch<sup>11</sup>. Joe decides to have grilled salmon with seasoned French fries and a side salad<sup>12</sup>. He doesn't eat the salad<sup>13</sup>. Meanwhile, Maria is getting ready to go grocery shopping. She turns the car on, turns on the AC, and when it's cool enough, puts the baby in the car seat. After she shops, the bagger asks her, "Paper or plastic?"<sup>14</sup>. After dropping off the groceries at home, Maria then goes to get Mark from school<sup>15</sup>. At 5pm, Joe begins getting ready to go home. He files away important papers, puts his computer to hibernate, and leaves his office, closing the door behind him<sup>16</sup>. He gets into his car, turns on the AC, and drives home. When he arrives home, Maria has begun making dinner, a favorite of Joe's – vegetarian chili with cornbread<sup>17</sup>. After dinner, Mark watches T.V.<sup>18</sup> while Maria and Joe begin talking about the improvements they feel need to be done to their house. They need a new roof<sup>19</sup>, but Maria would also like to replace their carpet with hardwood floors<sup>20</sup>. They both would also like to install granite countertops in their kitchen<sup>21</sup>. After about 20 minutes of discussing the home improvements, they are worn out and decide to veg in front of the T.V. with Mark and Brian until 9 p.m. when they all turn in for the night.

*Learning Goals*

The purpose of this problem was to ask students to put themselves in routine situations (each labeled with a superscript number), reason about what everyday decisions are more/less environmentally sustainable, and offer convincing explanations for why those decisions are better. I would have liked their explanations to draw on their scientific understanding.

*Problem #7: Environmental Careers**Prompts*

**Henry** likes science topics, especially those that involve the environment, but he doesn't really like to take science classes. Rather than take science classes, he prefers reading pop-science books and just talking with scientists about what they do. He doesn't really know what he wants to do in his career, but he knows he wants to help protect the environment in some way. Henry also likes to write and is known by his friends for being a good communicator. He doesn't mind school and wouldn't mind continuing on to graduate school.

**Julio** is confused because he has two interests that do not seem to go together very well. First, he has a ton of fun with kids. He is the oldest of a bunch of siblings and enjoys spending time with them, helping them with their schoolwork, and introducing them to the world. However, he is also very concerned about the environment and wants to work to protect it somehow. He doesn't mind school but doesn't want to spend a ton of time in school. He is looking forward to getting a stable job right out of college and beginning a family of his own.

**Glenda** is known by everyone for being really energetic and hard-working. She is interested in protecting the environment, but what really interests her is handling and protecting wildlife. She likes to go on hikes, identify the animals she sees, and sometimes she handles them if she knows they are not dangerous. She doesn't mind school but doesn't want to spend a ton of time in school. She would much rather figure out what career she could have that would allow her to handle wildlife. Glenda isn't interested in making a lot of money, as long as she gets to do what interests her.

**Margo** is most interested in how humans' and other organisms' bodies react to environmental toxins. She loves science and math, but she doesn't want to spend a lot of time in school. She would like to be able to get a job with just a bachelor's degree, although she may someday go on to get a graduate degree. She cares a lot about the environment but doesn't want to spend all of her time outdoors doing "fieldwork." She likes to work indoors also. She would also like to make a lot of money.

**Wildlife rehabilitation** is the treatment and temporary care of injured, diseased, and displaced indigenous wildlife and the subsequent return of healthy animals to appropriate habitats in the wild. There are many aspects of wildlife rehabilitation: daily feeding and cage cleaning, medical treatment, public education, accounting and record-keeping, biology, behavior and natural history of animals, and fundraising. Publicly funded jobs exist at some city, county, and state nature and environmental education facilities. Jobs in the private sector tend to be with non-profit foundations and organizations. Although a degree is not required, a college degree in biology or ecology is highly recommended. The curriculum should include ornithology, mammalogy, animal behavior, ecology, and related wildlife and environmental subjects. To find out more about wildlife rehabilitation, go to [www.owra.org/becoming.htm](http://www.owra.org/becoming.htm).

**Environmental Education** is an educational field that tries to facilitate the development of an environmentally literate citizenry that can compete in our global economy; has the skills, knowledge, and inclinations to make well-informed choices; and exercises the rights and responsibilities of members of a community. Environmental educators teach outdoors or indoors, formally or informally. Although environmental educators don't get paid much, they report very high job satisfaction. Many states are now requiring environmental education to be integrated into public school K-12 curricula, so there are emerging opportunities to teach in public schools in other states and hopefully someday in California. California high school curricula include environmental science courses at some schools, so it is possible to be a formal environmental educator in California public schools, although opportunities are limited. The informal sector involves giving tours at State Parks or developing exhibits for science museums. To work in the informal sector, a bachelor's degree (and perhaps a master's) in an environmentally related field and experience working with kids in informal educational settings, such as working during the summer at Scripps' Birch Aquarium with their summer programs or as a camp counselor for outdoor summer camps is recommended. More information can be found at [www.naaee.org](http://www.naaee.org).

The field of **environmental journalism** seeks to responsibly cover complex issues of the environment so that the public can be well informed about the environment and our effects on it. Environmental journalists need to not only be able to write and speak clearly for others to understand, but they must also be well-versed in science issues involving the environment. Many opportunities, including scholarships and fellowships, are available for minorities in this field. Opportunities may be emerging for bilingual environmental journalists as the U.S. public becomes more diversified and as Latin American countries become more concerned about their environment. Jobs are plentiful. More information can be found at [www.sej.org](http://www.sej.org).

**Environmental toxicology** is a unique science that combines the principles of biology and chemistry to study the harmful effects of chemicals on organisms' (including humans) health and the environment. Career paths often depend on a student's specific interests and creativity and can range from environmental chemistry, to aquatic toxicology or pharmacology. There is enough flexibility in the field to study the environment, environmental regulations, and/or the health of organisms, including humans. Because of this flexibility, jobs are plentiful, and pay is usually quite comfortable with only a bachelor's degree. For more information, go to [www.setac.org](http://www.setac.org).

The Environmental Studies & Planning Department at **Sonoma State University** offers a program in Education & the Environment ([www.sonoma.edu/ensp/academic\\_plan.htm](http://www.sonoma.edu/ensp/academic_plan.htm)). Their program allows students to combine this degree with a multiple subject credential, which would allow someone to become an elementary teacher in California's public schools. Elementary school teachers are responsible for teaching the basics – reading, writing, arithmetic, basic science, etc. Because a single teacher teaches all of these subjects, s/he has more freedom to have environmental themes across the curriculum and thus have a lot of influence on children's environmental attitudes. Also, "green schools" are becoming more common and may offer greater opportunities to teachers seeking a green curriculum.

At **Northern Arizona University**, a student can specialize in Environmental Communication through two different departments. The Department of Journalism offers a bachelor's degree in journalism with an emphasis in Environmental Communication (<http://www.comm.nau.edu/>). Alternatively, the Department of Environmental Sciences offers a bachelor's degree in environmental science with an emphasis in

Environmental Communication (<http://www.nau.edu/~envsci/>). NAU also offers ample resources and opportunities for these students through their Environmental Communication Resource Center ([www.comm.nau.edu/ecrc/](http://www.comm.nau.edu/ecrc/)).

**UC Davis University's** Department of Environmental Toxicology offers both undergraduate and graduate degrees in environmental toxicology ([www.envtox.ucdavis.edu/](http://www.envtox.ucdavis.edu/)). A bachelor's degree in environmental toxicology is a great launch pad for applying to medical school or working for government or private agencies that seek to protect human and animal health from environmental toxins. UC Davis' program has relationships with several outside agencies (<http://www.envtox.ucdavis.edu/research/default.html>) that allow for awesome internship opportunities that help to guarantee job placement after graduation. One particular program, NIEHS Undergraduate Summer Training in Environmental Toxicology, offers specialized experience to students from under-represented groups (i.e., women, minorities).

**Humboldt State University** is internationally known for its environmental focus, and it offers over 40 undergraduate programs that are environmentally related. Because of this university-wide emphasis, HSU offers a wonderful community to students who are environmentally minded and creates an unforgettable undergraduate experience. The campus is located near almost five million acres of national forest, parks, and public wilderness lands, which provide ample practical experience that helps with job placement after graduation. HSU's Department of Wildlife ([www.humboldt.edu/~wildlife/](http://www.humboldt.edu/~wildlife/)) offers bachelor's degree in Wildlife with specialization options in Conservation Biology/Applied Vertebrate Ecology or Wildlife Management & Conservation.

### *Learning Goals*

The purpose of this activity was for students match the person with an appropriate career and university degree program. My goal was for students to learn that one does not necessarily major in the field in which they eventually want to work. I also wanted to introduce students to other environmentally related career choices other than the quintessential "environmental scientist." I also wanted to know if students were considering an environmentally related career as

a result of this class and whether or not they considered themselves capable of pursuing such a career.



## APPENDIX VI: TRANSCRIPTS

### *Problem #1: American Robins*

#### *Prompt #1*

Instructor: Are there any questions about the problem?  
(students reading prompt)

Carol: I'm wondering if um it's snowy in this area even though um there's snowmelt. Do you think it snows or does this place primarily depend on snow melting?  
5

Juan & Meg: hmm

C: because if it doesn't snow then that place is going to turn into like a desolate area 'cause no plants will be able to survive.

M: Wouldn't it cause them to migrate earlier too because spring's coming earlier then they're going to migrate sooner.  
10

C: yea

M: and there might not be as much food.

M: Like if they think it's already spring and they migrate but the snow isn't melted up there yet there's not going to be very much food.

I: There's actually a typo. Where it says 'simulates' it should be 'stimulates'. S T instead of S I.  
15

C: (to I) Does it snow in this area even though there's snowmelt in the springtime? Or d-

I: What do you mean? So at t- at the higher altitudes?

C: I mean does it rain?  
20

I: umm

C: Or does it cause prob- so they depend on the melting of the snow?

I: Yes. Th- when the snow melts, that's what stimulates th-

J: the plants

I: the plants to grow and that's what they eat. So what are you thinking?  
25

C: I'm guessing that if the snow isn't melting then the plants are going to die

I: ok

C: and the birds aren't going to hav- and like she said (points to M) it's going to disrupt the migratory process also.

I: Ok, so the plants actually like when the snow eventually does melt like at the normal time, the plants come up like normal. So-  
30

M: But wouldn't if they were migrating earlier, wouldn't they get up there and the snow wouldn't have already melted?

I: ok

M: Or is it changing throughout, like even up there the snow is melting earlier and earlier?  
35

- I: Um, it's not (points to prompt). Yea, that's what th- that's what actually he found.
- 40 M: So they're thinking that spring is coming sooner. They're like 'ok it's time to go' and then they go up there and then there's snow still there, right?
- I: yea
- M: and no food?
- I: Right. So how do you think that would affect them then?
- M: Well if there's no food a lot of them would die.
- 45 J: would die
- M: or they would go somewhere else. They'd like realize it and fly somewhere else.
- I: Hmm. That's a pretty cool hypothesis about the idea of them going somewhere else. I wonder if they'd get up there and be like 'op this isn't cuttin' it' and go back
- 50 down.
- M: yea
- I: I don't know. So-
- M: But if they got up there would they have like enough strength to go back down or go somewhere else or would they...?
- 55 I: That's a good question because flying up there, they're expending a whole lot of energy.
- J: To get to recover the energy.
- M: And they're like expecting food to be up there on the other end.
- I: What what did you say? (to J)
- 60 J: Just the same thing (points to M) to recover the energy at the end. What will they do next?
- I: So these sound like good predictions. I have another one for you. But hold on. We'll see how everyone else is doing. (leaves)
- C: Go Meg! (laughs)

*Prompt #2*

- 65 I: Ok, so let's um work on the yellow-bellied marmot one. We have about 5 minutes.
- M: I think it's almost the same as the other ones. When they're getting out and they're like 'op no food'.
- J: So pretty much the same thing?
- 70 M: yep
- J: thirty days earlier °let's see° That's just a month de- earlier, right?
- C: And then they have to go thirty days without food.
- J: um-hmm
- C: I just don't understand why they won't just don't stay at the bottom of the
- 75 mountain.
- M: Yea, but if there's nothing down there why would they stay?
- C: yea
- M: Or why these birds don't go back in their house. They're like 'oh it's really not that warm out.'

*Stimulated-recall Interview: Meg*

- 80 I: Ok, ready?  
M: (nods)  
I: Woohoo, here we go. Alright, so I'm going to play this section of the tape which is your discussion section. Um so what I want you first to do while we're watching this is tell me what was going on, what were you trying to do in your group um and describe the problem that you guys were discussing and trying to solve.
- 85 M: ok  
I: Ok, we can start to watch it and you can talk over the tape, let's see where the volume is (looking on camera).
- 90 M: We can probably hear it better when we start talking because we have a microphone right in front of us.  
I: oh ok  
M: So she's like talking way away from us.  
I: Let's see if it gets louder then. Can you see it ok?
- 95 M: um-hmm  
M: Like right here we had a little prompt about um these little birds that are going. There's a big mountain and the top is covered in snow and then during the fall they migrate down to the bottom of the mountain.  
I: ok
- 100 M: And the problem was that spring keeps coming earlier and earlier so we had to decide what was that causing to the birds.  
I: ok  
M: And so here we're talking about how 'cause they're going up there earlier. They're getting up there because the snow up there isn't melting sooner. It's staying the same, like the snow is still melting at the same time, but down at the bottom of the hill like that's where spring is coming earlier.
- 105 I: oh  
M: So they're like 'Oh ok it's springtime. Time to go up.' And so they're going up there and they get up there and there's still snow.
- 110 I: um-hmm  
M: And so we're trying to decide here what's going to happen to the birds like what's gonna happen to them.  
I: ok  
M: And like we came together and we decided that if they go up there, they're gonna get up there and save all this energy to fly back up there and they're counting on that food being up there. And then they get up there and it's not there.
- 115 I: right  
M: So we decided they're going to be like starved. They're just gonna get up there and like the strong people ... birds could survive if they could like survive long enough until the snow melts but like the weak ones, they're gonna die of starvation.
- 120 I: 'Cause their food is still going to be covered with snow.  
M: Yea, 'cause their food is still covered in snow.

- I: ok  
 125 both watching tape).  
 M: Yea, this is like before we had figured it out.  
 I: ok  
 (still watching tape)  
 I: Does she keep giving you more sheets of paper?  
 130 M: Yea we keep getting well normally we get like one problem, like when we did these ones about tundras, we got like one problem and then we get like what if this happened and what if this happened. On this one in particular we get one about the um American, I think they were American birds or something. I have the problem (turns to bag), and then the next one was about another thing. It was  
 135 the same thing almost except they were coming out of hibernation instead of just migrating.  
 I: Oh ok. So it was a different problem in a way but similar.  
 M: Yea it was different but the outcome was similar.  
 I: Oh ok.  
 140 M: (Gets papers from bag). This one was the American robin and this one was the yellow-bellied marmot.  
 I: Nice. Ok, so this one you're discussing is the robin.  
 M: Yea, the robin. So we get the background and then the problem. So this one is like the spring is coming too early so then we decided what would happen.  
 145 I: Nice.  
 M: And here we're just talking about our water samples. For the lab we just did, we did a water quality lab  
 I: Oh cool.  
 M: So we were talking about who brought in what.  
 150 I: So this was before the lab.  
 M: Yea this was before the lab.  
 I: Oh cool.  
 (both laugh)  
 I: What did he bring?  
 155 M: He brought in rainwater and then like just some Dasani water, like bottled water.  
 I: Oh ok.  
 M: 'Cause he wanted to see if it was actually like really good water.  
 I: Interesting. Ok, well let me ask more about your descr- er your discussion of  
 160 the American robin section.  
 M: Ok  
 I: So when you guys were talking about this did you- I'm just going to pause it right here, and we can go back to it if you like. Um did you feel like that problem. (Person enters room). Do you have a class that meets in here?  
 165 (interruption)  
 I: Ok, so when you guys were talking about this problem did you feel like it was something that was important to you?  
 M: Yea, like personally important or important to the class material, like the part that we're studying right now.

- 170 I: I'd say both.  
M: Yea, it was important. Like when we did the biomes and stuff we did a lot of the migration and stuff and then also we're learning about the energy forms. So this kind of relates to it because the migration patterns are all messed up with a lot of the energy we use.
- 175 I: oh  
M: So this kind of related to that a little bit. And then we're talking about global warming as an effect of some of the fossil fuels burning, so this kind of went with everything because the global warming is causing the spring to arrive earlier.  
I: Interesting, so it was able to tie in with everything.
- 180 M: Yea, it tied in with a lot of things.  
I: And how about if um someone just came up to you out- totally irrelevant to this class and came up and told you this problem or you read about it in the newspaper, would it still be important to you personally?  
M: yea  
I: even if wasn't a part of this class?
- M: It'd still, it's not like I'd go out there and like change the way the birds migrate or something but it'd be like interesting and important. Yea, I'd care about it.  
I: And why?  
M: Because I think it's important that if someone came up to me and was talking to me about it, then that shows that they're interested in it too. And if enough people get interested in it then maybe there will be like changes happening, like with oil drilling and the pipelines and everything. If enough people know about how the migration things are getting messed up from all of like what we're doing then maybe something will get changed.
- 190 I: (nodds)  
M: If someone came up to me and asked me about it then it shows that they care about it too, so that's kind of good.  
I: Right, ok, nice, awesome. So when you were working through this problem with your group, was there anything that helped you solve the problem or that you found useful like anything any particular knowledge that Ms. Darnier gave you or that you got from your other group mates, like any comments that helped you guys.
- 200 M: Well like when she came up well usually when we're in our groups she'll go around and like help each group and so she came over and kind of pointed us in the right direction. So we'll like tell her what were thinking so far and then she'll tell us like 'Ok that's a good idea. Go with that.' Like point us in the right direction, which helps a lot.
- 205 I: um-hmm  
M: But like with this one, it was just like prior knowledge of the global warming and then knowing ... we had already learned about what could be like the bad effects of screwing up someone's migration. We've already talked about how if you mess up the migration, with certain animals, like what could happen. Like if we hadn't talked about that, it might have been a little bit more difficult, but we had already had a little bit of background on like when there is a migration, what the effects are.
- 215

- I: Yea, what the consequences are for that. Cool. That's good. Would you mind um rewinding it or fast-forwarding it to a place where one of her comments was helpful to you guys?
- M: Yea, but I don't know how to do it.
- 220 I: Here, I'll show you.
- M: It was just right back there when she came in
- I: Right when it happened?
- M: Yea, when she came up and she was
- I: (rewinding)
- 225 M: Yea, this was before she came up.
- I: So fast-forward a little bit
- M: just a little  
(fast-forwarding)
- M: Oh there. She's right there.
- 230 (both watch video)
- M: She kind of helped us there by telling us that the snow doesn't melt yet. So we knew ok when they get up there the snow's not melted so that kind of helped us get more ideas.
- I: Because it wasn't perfectly clear the way it was written.
- 235 M: Yea, it wasn't, it wasn't perfectly clear in here that when the birds get up to the top of the hill that the snow is still there.
- I: Ok. So the part that's changing is what's at the bottom of the mountain.
- M: Yea. Spring is coming early at the bottom of the mountain but it's not changing at all at the top where the snow is.
- 240 I: And did Carol say anything that was helpful in solving the problem?
- M: Yea, Carol pointed, well Carol was the one who asked the question about whether when they get up there, is the snow still there. And then um Juan came up with the idea of when they're going to be migrating earlier. Like what's going to happen to them and stuff. But it's like different with every problem. One of us
- 245 could be like knowing it all and then another one of us on the next day might know a bunch of other stuff.
- I: Um-hmm. So your expertise kind of changes depending on what the problem is.
- M: yea
- I: That's cool. That's pretty neat actually. Um, so did you feel personally did you feel like you could effectively contribute to solving this particular problem? The robin problem?
- 250 M: Um-hmm, yea.
- I: Why did you feel personally about that this time?
- M: Um, well I came up with the idea of when they get up there, um when they migrate they might not have any food. So when I said that, she gave a lot of encouragement to that, so I thought 'Ok good, that's a good idea.' So I knew a lot with that idea with the starvation, so that was good.
- 255 I: Ok, awesome. Um do you feel, did you feel in this example or in this discussion that your suggestions were taken seriously by your other two group mates?
- 260 M: Yea, yea we always take each other seriously unless we're like joking around but yea. Like when we say something like according to the problems then

- everything was taken into account. Like if I had thought personally 'Oh that wouldn't effect it.' We'd still take it into account and we give everything a fair shot. Like if one of us said something then the other two of us would talk about it and decide 'Ok that's a good idea. We'll go with that.' or something. We come to an agreement all the time, so that's good.
- 265 I: Nice. That's good. That you give each other equal time and that you  
M: Everyone kind of gets to say what they want and then we just kind of go from there or pull pieces from everybody's idea.
- 270 I: That's awesome. It's good to be part of a group like that you know?  
M: Yea. It's good.  
I: Yea, it feels really good. Um, let's see. Oh, I guess we should find a particular spot where you gave a comment and you felt like they took it seriously or that they really listened to you and gave you equal opportunity.
- 275 (watching video when C says "Go Meg!")  
M: (laughs)  
I: Like there! That was a good example where she goes, "Go Meg!"  
M: Yea, they were-  
I: So tell me what just happened, what did you just say?
- 280 M: Oh that's when I was telling Ms. Darner about the when then get up and there's no food, and she said that was really good and then she walked away. And so Carol was like "oh go Meg! You did a good job".  
I: Nice.  
M: So that was good. And now we're just talking about the water and that's like.
- 285 I: Oh right, the water that you brought in. Does it go back to the- when you were having the the discussion about the-?  
M: Yea well we do kind of like a class discussion where we put a big idea on the board after this so.  
I: But once you start talking about the water, you guys have probably finished talking about the robins?
- 290 M: Yea, once we talked when we started changing the subject to the water, we pretty much had our idea like the get up there so then we started talking about something else.  
I: Ok, cool. Um let's see what else do I want to ask you about this. Was there anything you felt during this discussion that you wanted to contribute but you felt it might be out of place or you know might not fit in with the discussion or would be taken weird by your group mates so that made you not want to contribute it?
- 295 M: Um, not really. I kind of well I think there was like one question I had but I can't really remember what it was but it was something like ridiculous well not ridiculous but me and Carol had just wondered if they had if or if spring is arriving earlier and earlier why don't they you know anticipate that for the next year and just stay down the mountain for longer.
- 300 I: mmm  
M: So it was not really a stupid question. It was more of question pertaining to like don't the birds think next year that they should stay down the mountain.
- 305 I: mmm, ok  
M: We didn't ask it but it was just like a random question.

- I: Yea. But you didn't ask it because why?
- 310 M: 'Cause it didn't really pertain to anything. It didn't really matter. It was just completely off the subject of like. I don't know. It was just like really random, so we didn't ask it.
- I: Something that just made you think-
- M: Yea, it just us think of another thing and instead of like getting off on a tangent in class we just decided we didn't really care that much to know. Because
- 315 we thought that ok if the birds were realizing like 'Ok this spring is coming earlier.' Well when they get up there, they should remember. But then if they were all dying then they wouldn't remember but.
- I: That's a good point (laughs) 'cause they'd be dead.
- M: Yea (laughs) yea. But if some of them lived then you'd think that like I don't
- 320 know if birds talk or not but they would tell them next like 'Oh maybe we should stay down here where there's food.'
- I: Hmm. That's interesting, yea. That's a neat question.
- M: That was one of our questions too.
- I: Yea it's a very good question. Ok. Cool so last question I have for you is what
- 325 was your favorite part of class today? And I guess let's limit it at first just to the class you had in here before you went over to your lab. So what was your favorite part of class in here today?
- M: Mmm, my favorite part today was probably ... just about the birds or the whole lecture.
- 330 I: The whole lecture.
- M: Um, probably when we were doing we took notes on the energy chains. And it's cool when she gives notes on the energy chains and stuff in my head is clicking. So that was probably my favorite 'cause I could go along with the steps without having to like refer to my notes because I just remembered it, so that was
- 335 probably my favorite.
- I: Nice.
- M: 'Cause I like feeling like I am knowing what she is talking about so that's good.
- I: Awesome. Does that come later after this discussion (pointing to camera)?
- 340 M: Yea.
- I: Or is it earlier in class?
- M: I think it's ... It might be earlier. It's either earlier or before.
- I: Let's try earlier (rewinding). Yea you know what 'cause I think it's already at an hour here and how long is your lecture?
- 345 M: An hour and a half about.
- I: We can look right before and you can tell me if it looks familiar.  
(Both waiting for rewind).
- I: Ok, let's look.
- M: Yea, this is where were taking notes. I don't know if there was any sound. I
- 350 know she was talking there.
- I: Hmm, no sound in this part though, huh? So she was writing notes on the board about energy chains, well what was she writing? Do you remember?



- M: Um yea. (Gets notebook out). She was writing about the sun and then the different things that that gives off.
- 355 I: Ok
- M: (pulls paper out) Like these energy chains where we have the sun, and then how it goes along to all of these.
- I: Oh cool.
- M: When she was writing them up there, I liked that when she was like when she talked about photosynthesis, I was I was already like ok fossil fuels is going to come next. And then I knew some of the problems for each of them like we have problems coming off of each of them. For fusion er fission, it's radioactive, so it was kind of. I like when I know something and I'm not just sitting here like confused and staring off like trying to figuring out what's going on.
- 360 I: Yea (laughs).
- M: So that was my favorite part of today.
- I: Nice. Oh that's cool. It's very neat and pretty how you've drawn all the colors in there too. That's awesome.
- M: (laughs) Yea.
- 370 I: Were these notes that you took during class today or were they just-
- M: Um-hmm. Yea, no this was during class today.
- I: Wow. You write very nicely when you take notes.
- M: Thank you. (laughs) I like to be color coordinated.
- I: Yea, no that's a great idea. Um so did you during this part of class was she asking people to help contribute-
- 375 M: Yea, she was asking, yea she'll like start off with like the sun, and then she'll say 'Ok which one do you guys want to talk about?' And so the first one we picked was about fossil fuels, so then we tell her like what to write.
- I: Like what to put next.
- 380 M: Yea were like 'Ok, it starts off with ancient plants and photosynthesis and that goes to fossil fuels and then burning them.' (lights go out)
- I: Whoops, why did the lights go off. (Other enters the room; I asks them to be quiet). Um so during this whole section while you guys are taking turns giving her information for the board, did you feel like you could effectively contribute to putting something.
- 385 M: Yea, I feel like-
- I: Did you during that time?
- M: No, I don't think I did. I think I said one thing because she called on us about like this (points to paper). That's all we said. Like my group's really quiet and we don't say anything.
- 390 I: Oh really.
- M: Like there's a couple other groups that they have a couple people in them that are like the people that answer the questions you know like in classes-
- I: Really talkative?
- 395 M: Yea, there's talkative people and there's people like my group you know we know what's going on but we don't speak up and say it.
- I: Oh ok
- M: So like we knew what was going on but we didn't like contribute.

- I: But you said like you definitely like she could have called on you and would  
400 have been able to-
- M: Yea, she could have called on
- I: like tell her about radioactivity.
- M: Yea, um-hmm. If she called on us or if the talkative people hadn't said the  
answers first or something.
- 405 I: (laughs)
- M: Yea, it would have worked.
- I: That's good. That's good to know. Um, so let's say in general, like if you would  
have raised your hand during that time and said something, do you think the class  
would have taken you seriously
- 410 M: Um-hmm (nodds)
- I: or your group mates would have? Like do you have that kind of atmosphere in  
your classroom?
- M: Um-hmm, yea. (nodds)
- I: Ok. And again for this one (points to camera) I'm going to ask you the same  
415 question again. Did you think of anything that you could contribute when you  
were having this discussion about the energy chains that but you didn't because  
you thought it might be out of place or it might have been off topic or something?
- M: Um, I don't ... like when we're talking in lecture I always get these random  
questions like don't really pertain to anything and I can't really remember what  
420 they are but I don't usually ask them just like I don't want to get off on a tangent  
and direct the class in whole different direction, but like I can't really think of an  
example for like this one but like maybe for the windmills. I always wonder about  
the ones like when you're driving out to Palm Springs.
- I: Oh yea.
- 425 M: So I was going to maybe ask something about like where do those provide  
electricity to or something
- I: Oh cool.
- M: But then that would take the class in a whole different direction. 'Cause when  
one person says something random it's like it's fun but we get off from where  
430 we're trying to go.
- I: Right, ok.
- M: So that was a question that I had today about the ones out there in Palm  
Springs.
- I: Ok, that's a good example. Ok, I think that we're good. And so I'll just repeat  
435 what you said just to make sure I understood. So um, there are a few times when  
you do have questions like for example the windmills that you feel like you  
wouldn't like um it wouldn't feel like the right time to bring that up during class  
because it would detract or it would take time from what you're like the focus that  
you're trying to stay on.
- 440 M: Yea, yea I don't really ever have questions of clarity or anything. I just have  
questions of more in detail like a better example. Not specifically what we did  
today but when we were talking about the alternate energies, we talked about the  
gasoline and difference between gasoline and electric. And so I had question  
about like the gasoline-electric cars.

- 445 I: Oh yea.  
 M: But I had asked that day but that was kind of just random but  
 I: yea  
 M: Sometimes I just get questions but  
 I: That's good.
- 450 M: Not like I don't really ever get questions like 'Oh I have a questions about clarity' or anything, but if I did I could ask.  
 I: Did you ask the question about the gasoline and-  
 M: About the cars, yea.  
 I: electric car?
- 455 M: yea  
 I: And how was your comment received by like by the class. Were the also  
 M: Yea, I think they were interested and I think like a couple people probably had the same question I had. And then we talked about it and everybody seemed like they were interested in it. It wasn't like people were like 'Oh why did she ask that?' or something.
- 460 I: Ok, cool. Nice. Awesome. Alright, well, I think that we covered this discussion for today. So cool, we're done. Thank you.  
 M: Yep.

*Problem #2: Colorado River Water Pollution*

- 465 M: That's over here.  
 C: Where's Lake Havesu?  
 M: Yea  
 J: This is California, so it's between uh California and here. Right here, right?  
 M: Yea, I think it's right there.
- 470 C: It's about right here.  
 J: yea  
 C: Because the two like meet in uh Arizona, so it's like in between.  
 I: You guys finding things?  
 J & M: yea
- 475 I: So what did you just highlight (to J)? What did you just find?  
 J: The Colorado River Aquaduct, which is (points to label)  
 I: So that's where it's labeled  
 J: ok  
 I: But what is the aquaduct? Think about it. It's this long basically canal of river er canal of water, so this whole thing is the aquaduct.
- 480 J: And then the-  
 I: So I would write on here, can I write backwards? Is that right? Is the C backwards. No, that's right (writing). Ok, so you label it. You get it?  
 C: So it connects to the Parker Dam?
- 485 J: yea  
 C: right there?  
 I: So then you'd put Parker Dam, and Lake Havesu is north of it.  
 J: So Parker Dam is, this is north and south? (gestures over board)

- C: No, it's right there in the corner. So Parker Dam is right here.
- 490 M: It's just like yea, right there. Just a circle and a dot, and Lake Havesu is above that.
- J & C: (laughs)
- M: (laughs) Just put like (takes the marker)
- J: This circle represents the uh this one, right?
- 495 M: yea, and then
- C: And what's next?
- M: Lake Havesu.
- C: It's like a little bit up here or something.
- J: And then here is the delta. And the Upper and Lower Colorado River. Upper
- 500 and Lower Colorado River...
- M: This... see how this is dotted. It's like a river, right? So this kind of like jots down over here to this river and gets to San Diego. See?
- J: This is the Lower and this is the Upper? Well, after right here, it's Lower.
- C: Right here it says (inaudible)
- 505 J: Ok, Upper. Lower. Lower Colorado River.  
(guest speaker goes to answer a question of the group behind the focus group; Jose turns to pay attention)
- M: How do we draw these things, I mean if they're right there,
- J: I don't know.
- 510 M: but how do we draw them? Do we draw the whole river going up to them?
- J: (talking to himself; inaudible) Should we draw a different picture, right here? I don't know.
- M: Like draw this coming out of here. This is Lower. This is Upper.
- J: I guess.
- 515 C: So um, do you want to connect it to Lake Mead because it seems like the Upper and the Lower is connected through Lake Mead, and then it flows to all these other ones.
- J: From here down (pointing to a map)
- C: See what I'm talking about?
- 520 J: Umm
- C: Upper and Lower and it goes right here (pointing to map), and it goes to Lake Mead and then to everything else.
- J: Oh, ok. Should we draw a different picture then? Starting from here, well here, and (gestures vertically and then horizontally across board) smaller?
- 525 C: You can make it right here.
- J: yea
- C: Start it going up and then branching out.
- J: Yea, like this and then up to Parker Dam and then going up and this is Upper and the Lower. Which was this one? Lake Mead?
- 530 I: (to whole class) Ok, so I'm passing out the next one. The next says 'Map C'. So it asks you to look at Map C. Guys listen up real quick. 'Map C shows several facilities that are located along the Colorado River. Which of these have the potential to affect our drinking water?'
- J: (inaudible)

- 535 I: 'Of those that have the potential to affect our drinking water, which ones really do? Be prepared to justify your reasoning.' (hands out new prompt)  
 J: Ok, (reading to himself) ability to affect our drinking water.  
 M: They all do, don't they?  
 C: Yea, they all do yea. Because they empty into the sea each other.
- 540 M: This river right here, is over here, and the bay (?) was over here. Cuz basically this are all along right here where Lake Havesu is and these other things.  
 I: What were you saying?  
 M: That they all pretty much cuz if they all run into the Colorado River they're all gonna like. They're basically coming from over here, going in through like this is
- 545 where the Parker Dam and Lake Havesu was  
 I: ok  
 M: And so that's going they all connect and it's going into the river down there and then it's coming down here and coming to San Diego there.  
 I: Ok, so wait a minute. The drinking water that we get is through the Colorado
- 550 River Aquaduct.  
 J: um-hmm  
 I: So I want you guys to pay attention to where it comes off the Colorado River and compare that location with where all these facilities are. So it's a little bit trickier here because it doesn't show you where it comes off. So Lake Havesu City
- 555 is right at Lake Havesu.  
 J: um-hmm  
 I: So you can use that then as like a reference point. Does that make sense?  
 J: Lake Havesu?  
 M: Sort of. We have Lake Havesu, which connects to that, which connects to that.
- 560 I: Right. So like this southern-most facility would be like right here, next to Lake Havesu. (J draws it in)  
 M: So then that one probably affects it the most, right?  
 J: Well with this, the other two are pretty close, which is from here to here and here to here. It goes really close to the Colorado River, so it's I don't know.
- 565 M: This one's probably the only one that doesn't really  
 J: um-hmm  
 M: have a real major.  
 J: Cuz it goes down, right?  
 M: yea
- 570 J: over to another place. So we think, is she looking for just one, or for different ones? (reading) Which of these have the potential to affect our drinking water? Of those-  
 C: I was just wondering, don't they run into each other anyway? Like you said, don't they flow into the same area? If some of it might, then why is it only just one place?
- 575 M: Maybe the location. Maybe if one of them is like closer so it has more of an effect than the one that's further away.  
 J: So in this case it's going to be Lake Havesu City?  
 C: Does it say which one has the most effect or?

- 580 J: No, well it did, it just asks if there's more than one. (reading) Of those, which have the potential to affect our drinking water? Well, each of them probably.  
M: Does it say which one (grabs prompt and rereads). Which one did we decide? The Lake Havesu one is the most?  
C: It is the closest, so
- 585 M: Well this one remember how they said the uranium is diluted and they can't find it when they do to like study it?  
J: oh yea  
M: It gets diluted because it's so far away.  
J: So it's something with this one and this one going down, so this one, which is
- 590 the closest one to the Colorado River, it's going to be the lake. Havesu City.  
M: (playing with highlighter from guest speaker) My whole marker turned into an erasable one.  
J: (laughs)  
J: Did you go to the interview already?
- 595 M: yea  
J: How was it?  
M: It was ok. People kept coming in. Like people who were in the class next. They were coming in.  
C: How long was it?
- 600 M: I think I was only here for like only 20 minutes. Not that long.  
C: Is there like (inaudible).  
M: It's really for each of us I think.  
C: How many times have you done it?  
M: Once. She said she was going to come like nine times between now and the
- 605 end of the semester. Did she ever email you?  
C: Yea. (to J) Mine are after yours. Mine are like the last ones. She sent your email along with mine.  
J: I think mine is today. Today but I don't know what time.  
C: Did you email her back?
- 610 J: No. Well actually she gave me the time already which was a reminder. She was like, 'I'm just sending you a reminder.' I guess it's going to be at the end of the class.  
M: When is it, today?  
J: um-hmm

*Juan's Contribution to Whole-class Discussion*

- 615 I: Ok. I have a question. Why is no one worried about that Yuma Desalination-  
S: I am.  
H: Is it desalination?  
I: Why are you worried about it, Susana?  
S: It's gross! I think I think I think that stuff is I disagree with them (points to her
- 620 group; class laughs).  
I: Ok, so what is different about that facility versus all the other ones up here?  
J: (to himself) It's downriver (points downward)

- H: (to whole class) There's no flow.  
 I: What'd you say, Juan?  
 625 J: It's down. The other ones are up and that one's going down.  
 I: It's downstream.  
 J: (nods)  
 I: That's why I wanted you guys to pay attention to where our drinking water is coming off that Colorado River Aquaduct? Most of those facilities are north of  
 630 where that comes off. The Yuma facility is south of it.  
 J: um-hmm  
 I: And think about the direction the water flows. It doesn't go backwards unless there's some crazy earthquake.  
 GS: (laughs)  
 635 I: (to GS) Has that ever happened here?  
 GS: not that I know of  
 I: The Mississippi has flowed backwards before because of earthquakes, but I don't know about the Colorado River.  
 R: So where does it discharge?  
 640 I: Where does what discharge?  
 R: Does it just go back up?  
 I: It doesn't go up, that's what I'm saying. It's downstream. It's goes towards the Sea of Cortez.  
 J: um-hmm

*Stimulated-recall Interview: Juan*

- 645 I: So why don't you just start by explaining to me what these are and maybe problem 1, problem 2 (laughs)  
 J: Ok (reading to himself)  
 I: Explain to me what you guys did and  
 J: Ok what we did just um, let's starting with the first question, I need to find out  
 650 which, ok (reading as he talks), this one, the first. Well, we read the directions and tried to find um these different landmarks, which is the different, different locations de Colorado River Aqueduct, and then we went to find the Parker Dam, and then  
 I: To get a big map?  
 655 J: Exactly. A big map and just link it to this upper and lower Colorado basins. And then from here, well we sketched it on the board. She sketched it on the board and then from this one to probably number one, which is map C.  
 I: (reads "locate facilities along the Colorado River")  
 J: Yea, we got, I don't know (looks around for map), we're supposed to have a  
 660 little map with different facilities all linked to the different rivers. And we need to figure out which one its the ones that is going to affect the drinking water, which is to the Colorado River, the water that we use.  
 I: Ok, what's a facility mean?  
 J: The um place where some I don't know chemicals or something used and then  
 665 put into the water.

- I: Oh, like a factory or a, oh ok.
- J: Exactly. Yea, different facilities. And then we um then we have to choose one and then we came to the conclusion that the ones that are far away from this, uh river, which is the Colorado, it won't affect as much as the ones that are closer.
- 670 The ones that are closer are the ones that are going to put the most toward our drinking water in this case.
- I: Ok, why would farther away not affect it as much?
- J: Because um many of these chemicals will um will be um will taken or filtered from the river different rivers that are upstream, along the sand.
- 675 I: Ok
- J: The different will-
- I: Like natural filter, on its way.
- J: Exactly. Exactly.
- I: Ok, ok. And then ...
- 680 J: And then ok then for this one, we went to map D which uh to think about there used to be a lot of vegetation and wildlife on the Colorado River delta. And then we need to figure out, well we need to get two hypotheses about why or um why there was no more vegetation or wildlife.
- I: Ok.
- 685 J: So we had to think about, well first look at the picture, and see the different, well in this case there was another facility that pulled out um I don't remember the name of it, but it's um basically this facility was pulling out uh the salt to sell it to different places.
- I: Oh, uh-huh
- 690 J: So um we were um one of the hypotheses that we thought about was um that this facility took out the salt from the water where these vegetation and wildlife used to live. So in some cases, these animals and vegetation need the salt in order to survive.
- I: Gotcha.
- 695 J: So um this um, by taking out the salt, so it would be the destruction of these surroundings.
- I: And that was one of your group's hypotheses?
- J: Exactly.
- I: Ok
- 700 J: Exactly.
- I: Did you have a second one?
- J: Yea, the second one was um, the, I need to see a picture of the (closes eyes to remember), mmm, I don't remember. I need to see the picture of it. Can I (points to bag)
- 705 I: Oh absolutely.
- J: Can I take it out? I just (gets into bag)
- I: Absolutely. This is not at all about how much you learn.
- J: Ok.
- I: Or how much you remember. It's not at all about that.
- 710 J: Ok.
- I: She's just interested in your understanding.



- J: Alright. So, actually we got three different hypotheses.
- I: Oh good.
- J: This is the first one the salt, about the salts and the plants. And then we thought  
715 about this one which-
- I: the Imperial Dam, ok.
- J: The Imperial Dam, which our hypothesis was that this dam was changing the  
720 pattern of the water so it will change the pattern of the migration of the different  
animals or in this case, the water was going just one way and by having the dam,  
the water will go different ways
- I: ok
- J: instead of just one. I will have different ways which will affect over the long  
way long run the um vegetation and the animals.
- I: ok
- 725 J: We were also thinking about this bypass drain which is well we talked to the  
teacher and she told us that it's not that much different because the pipeline is not  
that big so it will not affect that much the animals.
- I: oh
- J: But um she told us that it would change the temperature of the water. In this  
730 case, talking about the Yuma desalting plant because this bypass drain is coming  
from this plant.
- I: The bypass leaves the plant and heads a different way, ok.
- J: Yea, exactly, so when they take the salt and they put back the water, they only  
(inaudible), they change the temperature of the water, which would change the um  
735 affect the animals and the vegetation that have maybe adapted to a certain level of  
temperature.
- I: I gotcha.
- J: So and well, then other water, taking from this protection ground water  
pumping area (pointing to map).
- 740 I: (reads) "groundwater pumping area", ok
- J: They take uh they're taking too much water. So um and then by doing that they  
basically you know from the delta to a wetland which is only is filled by water.  
And all these uh well adding together affects the vegetation and the animals.
- I: Oh she had a bunch of hypotheses.
- 745 J: Um-hmm. Yea, well but I think this one the first one where the most similar,  
which is this one.
- I: The salt thing? Oh ok.
- J: The salt and we were kind of thinking of different ones.
- I: The pumping area.
- 750 J: This one was the ones she told us about, taking a lot of water from pumping the  
pumping area but so
- I: Ok
- J: So that's basically it.
- I: Ok, let's see what I have. Um, so we were going to watch a little segment of the  
755 video when you guys were working together, I'd say to come up with your  
hypotheses.
- J: Alright.

- I: And um and I was going to ask you as we watch it, tell me what you were trying to do with your group. But why don't you instead just tell me a little bit about your group as you solved these, not what your hypotheses were, but how did you guys talk and communicate. Were all three of you here?
- 760 J: Uh, yea, but Carol is up to I think the second, well the first question, we got it. We three got it.
- I: Which one? The first question was map C, problem 1.
- 765 J: Yea, No I think this one.
- I: Oh, the sketch
- J: yea
- I: Ok
- J: And then I think she went to the bathroom or something like that.
- 770 I: So she was gone for
- J: Yea, I'm not sure, yea, yes I think she was gone for the second two, two questions we have.
- I: For the next two problems, so it was you and ...
- J: Meg
- 775 I: Meg, and how did it go? Did you guys work together to talk about it or do you kind of come up with your own answers or?
- J: Exactly. We kind of um come up with a different answer and then compare and then maybe get to one, just one single solution or uh
- I: So you had an idea, and she, she had an idea, and then you guys 'ok so what's your idea'
- 780 J: yea
- I: and then you tell me and 'what's your idea.' And then we decide what one makes more sense?
- J: Um-hmm, well actually we put something we kind of like mix it together to just make one single idea.
- 785 I: Ok, ok great. So let me refresh my memory of the first one. Oh why it affects your drinking water and then your hypotheses. Um, did you feel like solving this problem was important? In other words, you're talking about water flow in the Colorado River basin and all that, so do you feel like this problem, these
- 790 problems, the map problems and the hypothesis that you're creating, do you feel like these are important um in life, an important thing to be studying?
- J: Oh yea, for sure.
- I: Ok, how come?
- J: Basically for this chunk of basically for the we, meaning us humans, have been destroying other human beings, which are animals in this case or vegetation. We are polluting water, we are destroying habitat, so it's basically the main idea of these things. Um this whole problem was basically the destruction at the same time I don't know hurting ourselves because by having these different I don't know let's called it facilities, we from these facilities we got different chemicals
- 800 that go into our body and then by having these facilities, destroy different habitat.
- I: Ok
- J: Animals' habitat, so vegetation in this case.

- I: Ok, um. If you weren't asked to solve this problem in this class, would you still think that this is important?
- 805 J: (inaudible)
- I: In other words, you're addressing this because she asked you to.
- J: yea
- I: So it's an assignment in a class to get a grade and units.
- J: yea
- 810 I: If she wasn't asking you to do this, would this be something that might interest you if you learned a little bit about it through the news or something?
- J: Yea. Yea, actually yes, actually yes, because I'm kind of sometimes not all but I look at the news sometimes. I see people basically, what was the last one I see, about dolphins, if I'm (inaudible), and I think it was in Asia, people killing just
- 815 dolphins, just to just eat it. And I can't do anything about it because I don't just I don't know. I guess when I see that I just um think about the government of that place instead of what somebody, I can't I can't do anything. If it wouldn't me being be able to go and maybe I don't know say something to them, but even that. I wouldn't be able to do nothing.
- 820 I: So you don't feel like you can affect it or change it.
- J: No, it has to be a bigger I don't know, power, in this case the government.
- I: Do you think that you have any ability to affect, you mentioned that the thing that you really got from this was how the facilities were hurting the habitat and the water the people drinking the water and the animals and plants using the
- 825 water. Do you think that you can have any effect on this?
- J: What do you mean by having an effect?
- I: You said you can't really have an effect on them killing the dolphins. You feel like you are kind of powerless.
- J: yea
- 830 I: You were just watching TV.
- J: Yea, exactly.
- I: Do you feel like you're powerless to have any impact on how we're hurting the water and losing habitat and animal life?
- J: Well, in this case, I remember her saying something about writing letters to our
- 835 legis- lature.
- I: legistures
- J: Uh-huh. And then I don't know, think about the stuff that we're doing in our environment and maybe write letters to them and say something that we are not, um we are not happy about it.
- 840 I: uh-huh
- J: And maybe I don't know maybe get some laws or something against well facilities or people that have or are doing this to our environment. That's what I can do, I don't know. I don't really feel like I answered your question.
- I: You did. Do you think you'd ever do something like that?
- 845 J: No
- I: Realistically?
- J: No I haven't.
- I: Do you think you ever would or not really?

- J: Yea, I think I will.
- 850 I: You think you would?  
J: yea  
I: You would?  
J: yea  
I: Well that's neat. That's neat.
- 855 J: Yea, I think I will. Yea, I like animals I don't know. I like every every (laughs) everything that moves. I got a dog. I used to have different I don't know creatures. But I don't know they just lasted me like two months and they die.  
I: oh no  
J: That's basically because of the well I see it the the um total change of their  
860 temperature and stuff like that because many of these animals that are being sold, they're coming from places way from away from here.  
I: oh ok  
J: so  
I: change in environment
- 865 J: Exactly, so I don't think they would survive that long like pets, pets. I don't think they would last long because they are not, they have to be adapted to this environment, and many of the I don't know I don't remember the names of the different creatures that I used to have but they are not native to this-  
I: area
- 870 J: area, exactly. So they are not going to be able to survive that long.  
I: I gotcha.  
J: so  
I: too many changes  
J: Um-hmm, exactly.
- 875 I: Ok, um, let's see, so as you were trying to work through this problem, so you can either choose the hypothesis problem or which one did you spend more time on? The identifying what would affect our water or creating some hypotheses?  
J: I think, mmm, this one  
I: the one-
- 880 J: The one about which facility in this case will affect our drinking water. Because we're not sure about because we found a lot of facilities really close, so we were not sure if this one would affect this one, specifically, the-  
I: The Bullhead City  
J: would affect our drinking water in the Colorado River, so we just thought about  
885 getting the closest one  
I: Lake Havesu  
J: Um-hmm, Lake Havesu. So I guess that was our because at first thought about this one, the Las Vegas-  
I: Las Vegas (inaudible)
- 890 J: But this one going being far away from here, and I think according to the presentation from the guy from the water company. He told us that many people, we basically the guys that are in charge of this, they wouldn't find any type of chemical up to here, from here up to here (pointing at map), they wouldn't find

- 895 any chemicals, because it's just a long way from here. So the filters in rivers,  
different rivers, these different chemicals will be lost, so
- I: So he explained that the distance
- J: Um-hmm, something about the distance
- I: So you used that idea to decide that it wasn't Bullhead but Lake Havesu that  
would have more of an effect.
- 900 J: Um-hmm, um-hmm, yep.
- I: So you and Meg spent a long time kind of talking and figuring that out.
- J: yea
- I: Ok so in that instance, um, as you were trying to work through that, was there  
anything that helped you or that you found useful in solving the problem? Your  
905 own knowledge or Meg's help, and you already mentioned the guy and what he  
said.
- J: um-hmm
- I: Is there anything else that helped you to come up with an answer to that  
problem, other than what the guy said.
- 910 J: Mmm, well I guess Meg came up with the realistic answer, which was to  
choose the closest one. Not the ones that are on the top.
- I: uh-huh
- J: Well at first we were thinking about choosing this (inaudible) which is well on  
top of Lake Havesu. But then we came up with just one answer. Well, basically  
915 that's when we ended up choosing Havesu City. That's basically just
- I: Ok, nothing that you brought with you from another class or from any personal  
knowledge or ...?
- J: Mmm, not really. Not really. Just by looking at it and just by thinking a little bit  
about it.
- 920 I: Ok, ok. Um, did you feel like you were effective, it says do you feel like you  
could effectively contribute to solving this problem? In other words, um when do  
you feel like you and Meg worked together or do feel like it mostly Meg, do you  
feel like you really were helpful in coming coming up with an answer to the  
problem? You, yourself.
- 925 J: Mmm, for this one, in this case I guess Meg got the strongest um well she got  
pretty much all the credit because um she kind of explained a little bit more. And  
um, I kind of agreed with her
- I: uh-huh
- J: So that's basically why we came up with an answer. And again, I don't really  
930 remember what was the answer, because I think the teacher gave us the different  
answer, but we went to start talking about this one
- I: the Yuma facility
- J: The Yuma one not affecting that much our water because it's going  
downstream.
- 935 I: It's past it.
- J: Yea, exactly. It's not going up into the uh, water can't go up, just down. So  
that's-
- I: Do you think that um Meg benefited from your conversation or your  
contribution? Do you think you brought something?

- 940 J: Well, I I think so well I think so a little bit because um maybe she got the point and just by maybe listening to me saying, "Oh I agree" with her she just felt more comfortable about her answer.  
I: more confident, yea  
J: about her answer. I guess.
- 945 I: Ok, ok. Um, do you feel like your suggestions were taken seriously? It was only Meg, so Carols wasn't there, but do you think that suggestions you made were taken seriously by Meg or do you think she was just like 'uh whatever' and kind of stayed with her answer?  
J: No, I think she, yea she considered my uh my opinion in this case. Yea, I guess.
- 950 She considered a lot my uh-  
I: And how about the second question, with the hypotheses, you guys came up with several. And you said you came up with some and she came up with some, and then you talked and decided-  
J: Yea, and then actually for the hypotheses Carol got to help us with the
- 955 hypotheses too.  
I: Oh good.  
J: She actually we kind of I mean we were together working with this one basically, and then when we got to this, our hypotheses, she started asking the teacher to make sure these hypotheses were right.
- 960 I: That was Carol?  
J: Yea, so yea Carol basically, she's the kind of girl that we say something and she starts thinking 'what if, what if' so in this case, I said something about the bypass drain that was crossing around here, and then she started to ask some questions to the teacher to make sure that it was at least (lights go out; get them turned back
- 965 on)  
I: Um, so you were talking about how Carol was getting the teacher's approval, kind of?  
J: yea  
I: Ok, so do you think that that, you said Meg listens to you, do you think that
- 970 Carol like takes your suggestions  
J: yea  
I: and yea?  
J: Yea, I think well I guess in this case uh um, Meg and Carol work, well they take suggestions really good, so they take into account our suggestions.
- 975 I: They do a lot of the (gestures talking back and forth with hands)  
J: yea  
I: And then do you input things here and there?  
J: um-hmm (nodds). They kind of, I kind of listen to them when they start with the conversation and then I just uh start thinking about their opinions and then
- 980 agree or disagree or say something or add to it.  
I: Ok, ok. And they listen to you?  
J: yea  
I: Do you think they ever change their opinions because of what you say?  
J: Mmm, I guess a little bit. A little bit. Just uh the just um, maybe when either
- 985 Meg or Carol says something, when I I don't know add to it, maybe they will ask

another question just to make sure they're idea is right or wrong or maybe it's better by my opinion.

I: Ok, so to also get your approval and your confirmation.

990 J: So yea, they try to make sure that their thoughts are right or maybe having more people agreeing with the idea

I: Gotcha.

J: they will be confident.

I: And so you feel that way in general?

J: Um-hmm

995 I: Ok um, is there anything that you thought of contributing to either question, the hypotheses or the things affecting water, but you didn't because you thought maybe it was out of place or 'cause they were yappy yappy yapping (gestures talking back and forth with hands) and you just didn't bring it in, like is there anything that you felt you wanted to give input in or

1000 J: Actually no because I think well, specifically for any question, we kind of cover everything. Well, at least, we thought we covered everything. Maybe we wouldn't be right but uh we kind of cover as much as we could.

I: Ok

J: So I don't think I would.

1005 I: Nothing you're bringing from outside experiences that you had, or something that you wanted to say that-

J: I don't remember for this time but I think that sometimes kind of relate to stuff that are happening or stuff I had seen, but in this case, I don't think so.

I: Ok, ok

1010 J: I don't think so, on this one, no.

I: Um, what was your favorite part of the class today?

J: My favorite part ... maybe um, since we have been doing these type of problems, I don't think, maybe the presentation part.

I: mmm

1015 J: Stuff that I just didn't know. Well, last Tuesday we went to this Padre thing, which we saw the process of recycling the- recycling the water.

I: oh yea, yea, yea, ok

J: And then um, the presentation from today, it was kind of interesting, adding to the stuff learned

1020 I: on your field trip

J: this past, yea exactly

I: And you said maybe because of the problems, you're not like so into the problems. What do you mean by that? And don't worry because she's not watching it until this summer.

1025 J: well, no, no,

I: She won't have any, it won't affect you at all.

J: No, actually, not saying that I didn't like it but uh because every class, every single class we work with some kind of problem so I'm kind of getting used to or not saying that I'm always right or we're always right. We're kind of getting used to solving problems.

1030

I: uh-huh

- J: In this case, in this case, the um uh effects the vegetation and the problems from these different facilities.
- I: So in other classes you don't really feel like you solve problems like this?
- 1035 J: No, this kind of problem, I don't think so, well besides like math. But I'm not taking math this semester but those are ...
- I: in math (nodds)
- J: Yea, in math
- I: So it's kind of unique that you're solving problems in this class?
- 1040 J: Yea, um-hmm, yea
- I: Yet, it, it's interesting just to me that you said your favorite part today you said was the guy talking, rather than the problems. That's interesting.
- J: Yea well actually, it was interesting, because I just didn't know it (gestures toward problems)
- 1045 I: What the guy was sharing.
- J: Exactly, and this too, well this too, well this (puts hands on problem) was kind of related to the presentation because he um the presentation showed some of these uh different parts actually, these different pictures of these places, in general.
- 1050 I: oh ok
- J: So this related to it. It's not that there was a different uh solving of a problem but it was related to the presentation of today's-
- I: Which was related to Tuesday's so it was all kind of
- J: Yea, it was all connected.
- 1055 I: Do you have anything else that you want to add about today and doing the problems or about the talk or anything that I didn't ask you about it that you might want to say about today's lesson?
- J: Mmm, I'm not sure if I had something to say.
- I: You don't have to. It's just I don't want to leave you with something you really want to say and I didn't ask.
- 1060 J: (laughs) Uh-huh. Well, I think that's it. I think that just the fact that uh by solving these kind of problems, I kind of use more my I don't know my thinking or my I don't know how I'm supposed to say it, but my um.
- I: Say it in Spanish.
- 1065 J: No, I don't even know how to say it in Spanish.
- I: Oh (laughs)
- J: My uh what can be the word for it, critical thinking, I guess.
- I: Like you really, you're challenged? Mentally challenged?
- J: Exactly, um-hmm. Sometimes it's kind of hard, the problems, but sometimes they're just good enough.
- 1070 I: Do you feel like you're learning as much as you learned, this isn't even really on my list, but do you think you're learning as much?
- J: Yea, I think I learn a lot, yea.
- I: Oh that's neat.
- 1075 J: A lot, a lot. Just stuff that I just didn't even know before. I just can't say like a specific one (looking up, trying to remember) but I've learned a lot. Sometimes the stuff that I learn, I kind of do this uh each time I get out of my class, I go to



- my home, and I take something to my dads all my family, basically, about all the stuff that I learned. Not what I learned, well yes, the stuff that I learned and the things that we do in our daily lives that I know maybe is affecting or is we're doing good for the environment, basically. In this case recycling, that's what we do a lot, my mom, she does a lot. And maybe when I go home and do something, I start thinking about the stuff that I have learned before. It maybe just start doing it or doing it a different way or buying different stuff or just stuff like that.
- 1080
- 1085 I: Oh that's great. Well that's the whole point of the class, so obviously she's doing a good job.  
 J: Oh yea she's doing a really good job. (laughs)  
 I: Oh that's great. Well thank you so much, Juan. I hope this was painless for you.  
 J: No, it's alright. (laughs)

*Problem #3: Channel Island Foxes*

*Prompt #1*

- 1090 I: (to whole class) So here's the deal. We're going to work on a short problem-solving activity and then we're going to go back to a talk on herps. Um, so I hope we have eno- yea, we're gonna have enough time. There are only three strips (class laughs), and so here's the deal. Um, this one talks about the Channel Islands is are? This is my uh crappy map. Um, but hopefully you'll be able to see it. This line is the coastline. And then we have Santa Barbara, Ventura, Los Angeles, San Diego. And then the Chanel Islands are these islands that are scattered out up and down the southern California coast. Um from like if you go up to the coast here, you can actually look out and see San Clemente. I mean they're really they're close enough that you can actually see them. So these are the islands that we're actually going to be talking about. So here's the deal. On these islands, on 6 of them, there 6 of the islands have endemic subspecies of island fox. So it's like these a species of fox and each island has it's own subspecies because they're not interbreeding because foxes don't swim that far. Um, you guys know what endemic means?
- 1095
- 1100
- 1105 Several: no  
 I: Endemic means this species does not occur anywhere else on Earth. So it's endemic to the Channel Islands. Um, so the island fox is on California's endangered species list. And on these same 6 islands there are populations of feral pig. You guys know what feral means, right? Like wild pig. We introduced pigs and then they like broke out and became wild, so lots of times cats will do the same thing. There will be feral cats. And so they have populations of feral pig. So these were introduced. They're not native. And so what this first question asks (reading) "How do you think the presence of the feral pig populations affects the ecosystems on the Channel Islands?" First of all and "How do you think the island foxes are affected by the feral pigs?"
- 1110
- 1115 C: Don't the foxes eat 'em? Or wouldn't they? Or do they eat things that big?  
 J: huh?  
 M: Maybe the pigs would eat the foxes.

- C: Do pigs eat I mean do foxes eat things that big?
- 1120 J: Yea. Well they might.  
C: I thought I thought they ate like chickens and stuff like that.  
J: Oh well that's true but um anything that's bloody  
C: yea?  
J: yea, meat I guess yea
- 1125 C: Cuz wild pigs are like shroo ferocious. (laughs)  
J: (laughs)  
C: I seen them on the Discovery channel.  
M: So do we do the foxes eat the pigs or do the pigs eat the foxes?  
C: I don't know. What if there are so many of them they'll like gang up on the
- 1130 foxes? Cuz they are extinct.  
M: Yea they're getting yea.  
J: What is what is the question?  
M: It's what is the um wild pig's effect on the ecosystem? Probably affects it because they're not native so they're taking things that native things need.
- 1135 I: (to whole class) I've passed out the boards. You don't necessarily need them but if want to construct some sort of food chain or something, they may help. I don't know.  
M: so  
J: So the pig would be eating some stuff that the fox
- 1140 M: that the fox needs yea.  
J: So they would be probably fighting for food that's native for the fox, not the pig.  
C: My question is will the fox eat the pigs.  
M: Yea what do they
- 1145 C: Yea, and if we know that, then we'll know the rest. Because if they eat the pigs, their population is going to grow too.  
J: yea  
M: But if the pigs eat the fox then that's the reason they're on the endangered species list cuz they should get rid of the pigs.
- 1150 J: Aah yea. Ok let's wait for that one. Take a look at-  
C: Pigs don't eat um are they vegetarians?  
J: I don't know.  
M: I think pigs eat anything.  
J:(laughs; inaudible)
- 1155 C: (puts hand up)  
I: What's up?  
C: So our question is will the fox eat the pigs?  
I: Ok  
C: or are they too big?
- 1160 I: So foxes are about this big (gestures with hands). They're maybe (turns to guest speaker) how much do you think a fox weighs, 20 pounds maybe? Yea 20 pounds I would guess. Um, the pigs are not like bog ole huge you know barn pigs that we think of that make bacon. But they're the big, they're like 30 or 40 pounds maybe.  
J: bigger than the

- 1165 M: So the pigs will eat the fox, right?  
 I: well  
 M: Or is it not really like  
 C: I don't think their teeth is meant to eat.  
 J: But do they eat
- 1170 M: but they're wild  
 C: But if they were wild would they  
 M: I don't know  
 I: So have you guys ever seen like wild boars?  
 M: yea at the zoo
- 1175 C: They're ferocious.  
 I: (to M) At the zoo and they. (to C) Right. And that's wild boars aren't really that different from feral pigs. I mean pigs that are feral would just (inaudible) you know.  
 J: And they'll probably just eat anything.
- 1180 I: And they their teeth you know when we think about pigs they get their teeth ground down because they're eating all this vegetative like vegetable material all the time on farms but if they're out in the wild then they can grow pretty long and nasty teeth.  
 J: hmmm (looks at M & C)
- 1185 I: Um, so these are good things to think about.  
 J: You think they'll eat each other?  
 C: They probably won't go after the foxes though. The foxes are too fast. But they will fight for the resources though  
 J: yea
- 1190 C: like you said (points to J).  
 J: exactly  
 C: It's depletion of resources!  
 M: So the foxes are taking like the same food they want and then how are they affecting the ecosystem?
- 1195 J: depletion  
 M: Yea, they're just taking away things from the natural need of the plants and animals.  
 J: Maybe they're taking out resources from an adapted uh species, which is the fox. They're changing their whole environment or their ways of surviving.
- 1200 C: Either that or it's just going to be worse on them. It's just going to contribute to them being endangered.  
 M: Should I write anything?  
 J: (listens to other group's ideas) Interesting (to C) pigs having diseases.  
 C: um-hmm
- 1205 (M is drawing a diagram on white board)  
 J: You can put 'vs.' for fighting (points to between foxes and pigs on diagrams)  
 M: yea

*Prompt #2*

- 1210 J: Kill them. (laughs)  
 M: Well if they take away the pigs, then all they're going to have to eat is the foxes and that's not going to be good  
 I: (to whole class) So now is when your boards might come in handy.  
 M: because the foxes are going to become
- 1215 C: They can maybe eradicate one species of the eagle that are eating the foxes so then that'll check the foxes and the pigs.  
 J: Is it possible to (laughs) to get a solution to this?  
 C: Do you know what I'm saying? Because if one species is eating the pigs and then one if more species are eating the pigs and then one species of the eagle is eating the um the fox, then that'll balance it out
- 1220 J: (nods)  
 C: cuz there'll be more pigs getting eaten than um foxes and that would give them a chance to grow.  
 J: Yea, I see. (to M) If you were the scientist what would you do?
- 1225 M: I'd probably just... I don't think  
 C: (reading prompt) Oh there's only one. There's only one species  
 M: They've already. Like the birds have already made one species or two species of the foxes go extinct so if you take out the pigs then they're obviously going to make third species completely go extinct.
- 1230 J: um-hmm. So know the problem is that we need to eradicate these (points to 'eagles' on board).  
 C: Yea, but you can't shoot eagles. They're extinct.  
 J: yea  
 M: Maybe if you took the eagles. What if you only took them off one island. Cuz
- 1235 there are like six islands and what if you took a bunch of the eagles and put them all on one island. Would they fly back over there?  
 J: yea I think yea.  
 C: Um-hmm. They will. If they found the islands to begin with.  
 J: Because they didn't they didn't put the eagles on the island. The eagles went to
- 1240 the islands.  
 M: Well I think taking the pigs is a bad idea because then all they'd eat is the foxes. The only reason to remove the pigs is because they're  
 J: They're changing everything.  
 M: because they're changing like the ecosystem but they weren't really causing
- 1245 the foxes. It's just helping like the foxes were already endangered before that.  
 J: uh-huh  
 M: It's only made it a little faster, so  
 J: If only the eagles weren't eating the foxes.  
 M: It's like really confusing because it's either you take one animal that's extinct
- 1250 or you take another animal that's almost extinct.  
 J: yea  
 C: Yep, you would not want to get rid of the pigs.  
 M: What eat the eagles?

- J: The foxes and the pigs. Well, I don't know insects, no rats.
- 1255 C: Supposed to be snakes, right?  
J: Snakes, yea, um-hmm.  
M: Snakes eat eagles?!  
J: oh no no  
C: No eagles eat snakes.
- 1260 M: So what's controlling the eagle population? C: Well they're already extinct!  
M: Yea, why are they though? What eats them? Or do people just shoot them?  
J: yea, something  
M: or they run into airplanes or something. I don't know. I say don't take out the pigs. Just leave it.
- 1265 J: Leave that?  
M: Put more pigs. (laughs)  
J: Yea, put more? (laughs)  
M: We need more pigs. (laughs) And they'll leave the foxes alone.  
M: What if you moved all the
- 1270 J: foxes  
C: Yea!  
M: foxes.  
J: And then put more pigs.  
C: Ew. Then the foxes then the freakin eagles will fly to island with the foxes and
- 1275 just murder them all.  
M: So put them all the way on the bottom one  
M: on the little one (laughs) and hide it. Plant some more trees.  
C: The problem is we don't know much about eagles.  
M: yea

*Problem #4: Western and Arroyo Toads*

*Prompt #1*

- 1280 H: What do you mean by fitness? Like  
I: This is a good question. That's why we're talking about it. That's why we have this one, so we can talk about fitness.  
J: muddy  
C: Do they fight? Do toads fight? You don't know?
- 1285 M: (shakes her head)  
J: I don't know. Yea, why not? Male and male fight for the female?  
C: So if the females are attracted to the what was it, the western toads? Then they'll probably start following the calls of the western. And then the males would have to go find the females, and they'd probably be fighting.
- 1290 M: (reading) 'Which males would be more likely to mate with the females.'  
J: the western, right?  
M: The western are more likely because they're like not only having the female western toads but they're also having the Arroyo ones.  
J: yep, the Arroyo, um-hmm

- 1295 M: and the Arroyo ones are only getting (points to prompt) the female Arroyos. They're just naturally attracted to them.  
 J: Um-hmm. Now which ones would have greater fitness. What do they mean by fitness. Is it his body? (laughs)  
 C: (laughs) Who knows? I'm wondering too.
- 1300 J: Which one would have the greater fitness. Maybe  
 C: I think the  
 J: the greater opportunity to procreate?  
 C: (grabs prompt) Let me see. (reads prompt)  
 J: The greater fitness. I guess the more opportunity to reproduce.
- 1305 C: I think it's the Arroyo toads  
 J: the Arroyo?  
 C: if it's really physical features. I don't know. Because ok these ones these fools do calls, right?  
 J: yea
- 1310 C: And they're not going to be like searching for females if there's going to be one area, I'm guessing like calling. I don't know.  
 J: yea?  
 C: And then the westerner toads  
 J: the Arroyo
- 1315 C: The Arroyo toads will have to go searching for the females I'm guessing.  
 J: Yea, so the Arroyo have the best.  
 I: What are you guys thinking, the western toad?  
 C: We don't know what fitness means.  
 I: ok
- 1320 C: So I'm applying it to like human terms.  
 I: Alright.  
 C: I'm like well the Arroyo toads are the f- the male Arroyo toads are probably having to chase the females.  
 I: ok
- 1325 C: And the western toads are just calling and staying in one place, so I don't know. So the Arroyo might be more fit.  
 I: Ok, so in that case, what would fitness mean to you because they can just lay there and be lazy. They don't have to go out and get their woman?  
 C: Yea. (laughs) I don't know.
- 1330 J: yea  
 C: I'm just guessing.  
 I: (to M) What are you thinking?  
 M: I think it's in the literal sense, like their strength. So like she said with the ones tha- they have to do a lot more work than the western toads who would just sit
- 1335 there and make their noise. So they're gonna the ones that move around are going to become stronger.  
 I: Ok, so you think the male Arroyo toads, because they're getting more exercise, they're gonna be more fit.  
 J: (laughs) yea probably
- 1340 C: (laughs) yea

- I: Ok, let me see what the other groups have.  
 J: (laughs)  
 C: (laughs) I don't know. It sounds goofy but I mean it could be right.  
 J: Yea. It's like she said. The western toad doesn't need to move.  
 1345 C: um-hmm  
 J: The female comes to them so the Arroyo's the one that's moving. Greater fitness, hmmm.  
 C: Oh yea. We're supposed to meet.  
 J: Tomorrow, right? Tomorrow, right? Right? Am I right?  
 1350 C: (nods) Do you want to meet tomorrow or do you want to meet next week?  
 J: Well we can meet tomorrow to just for an hour or something like that to see what we got and maybe just  
 C: at eleven  
 J: Um-hmm. Yea because I get out at a 11:10 from my class.  
 1355 C: That's fine. We'll be at the library  
 J: alright  
 C: in the entrance and we'll wait for you.  
 J: Ok, alright. I get out at 11:10. I'll just  
 C: I have a lot of things going on. I have another presentation  
 1360 J: oh really  
 C: the very next day. No, I have on on the 17th and the 18th would be ours.  
 J: I got a research paper due next week, and now this and the exam.  
 C: I know. It's horrible.  
 J: Yea. Are you doing summers? Do you come in the summer?  
 1365 C: No. This is my last semester.  
 J: Oh really? Ok.  
 C: Nope. I only have four more weeks. I gotta hussle.  
 J: You gonna transfer?  
 C: (nods) SDSU  
 1370 J: oh

*Prompt #2*

- I: Ok, wait wait. Discuss it with your group. We'll take 5 minutes.  
 C: I think it's more because they have like the best of both worlds. They can do like calls and they're both they're fit. That's why I said they're gonna be the next Romeo (laughs). They're gonna get all the females.  
 1375 J: (laughs)  
 C: or the females  
 J: (listens to group behind them; talking about fitness having to do with genes; I asks Arnold Schwarzenegger question to other group)  
 C: yea (to Arnold Schwarzenegger question)

*Stimulated-recall Interview: Meg*

- 1380 I: So can you just first tell me what today was about because I wasn't here. I'm kind of curious.  
M: Yea, today we learned about the loss of biodiversity like what were the causes. So we had eight causes of the biodiversity that we talked about and then we learned about invasive species, hunting, just to name a few. And then we did this
- 1385 problem with the toads about them cross-breeding and things like that. That was our problem for today.  
I: (reading to herself) Ok, ok let's see what she has cued up for us.  
(both watch video)  
I: So if you could stop it for a second there.
- 1390 M: Yea, she's about to pass out the question and then we talk about it for a second.  
I: Ok, so that's this question.  
M: Um-hmm.  
I: So of the three questions, let's see. Um, let me read this again (reads aloud). So
- 1395 what did you come up with as your answer?  
M: Um, well we decided that it was the 'which of these would be more likely to mate' we thought it would be the Western because they were not only making a call that was attracting the Arroyo ones. They were also having just the natural attraction from the female Western toads, and then the more fitness. We weren't
- 1400 really sure what fitness meant in this sense, but we took it as the literal sense like strength and things like that. So we decided that the Arroyo male has to be physically fit because he has to run around and try to get these females attention, while this Western toad could just sit there and make that advertisement call.  
I: Oh that's interesting. Yea, you're right. He has to do more work.
- 1405 M: Yea, that's it. We thought he had to do more work and this guy would just be lazy just sit there and just hang out and make this advertisement call and wait for people to come while the Arroyo one has to run around.  
I: So you're, not I get what you're thinking, so in the first half, 'which males would be more likely to mate with females', you think they both-
- 1410 M: Well we think the Western. In this problem set right here we thought that the Western would be more likely because he has the natural attraction from the females of his own species and then he's also getting the attraction from the female Arroyo toad because of the call he's making.  
I: Oh because these females are Western.
- 1415 M: Yea, see there's like two different females going to him while the Arroyo only has the female of his same species going to him.  
I: Oh gotcha, gotcha, gotcha. Ok, um when you guys, well let me look at the next two problems and then we'll see. (reads prompt about hybrid having call)  
M: Um we thought they'd be more fit because they kind of have the best from
- 1420 both worlds. They have the physical ability from the male Arroyo toad to run around and do things and they also have the call from the Western toad, so we thought they'd be more fit than the Western toad because they have from both people.



- I: Gotcha. (reads prompt about hybrid being sterile)
- 1425 M: We just, this was the last one we just got, so we didn't really talk about it much.
- I: Oh that's when I came in.
- M: That's the one we did as a group.
- I: What do you think?
- 1430 M: I think ... I think they would probably be less fit because of the Western toad. There's probably like still a desire there to reproduce and that but because he can't I think that the other one would be more fit. But I don't know about my group. My group would probably say they're just about the same, not more or less or anything.
- 1435 I: Because you defined fitness earlier as strength and the ability to get females.
- M: um-hmm
- I: So you think they're just as strong, just what might your group argue?
- M: Yep, they're just as strong, but they don't they can't reproduce so that might inhibit their fitness a little bit, so the Western toad might be a little bit more fit
- 1440 because they still have the ability to reproduce but these hybrids don't.
- I: Gotcha. So you were solving these, well at least the first two you had time to talk with your group. Did you feel like solving the problem was important? In other words, if you weren't asked to solve this problem in class, would you still find it important or interesting to be thinking about and pondering?
- 1445 M: Um, it was kind of interesting. I don't really like frogs, just as an animal. So but I couldn't really relate it to what we were doing in class today because I don't I guess it's kind of like the biodiversity loss but with most of the problem sets, I can relate it to what our discussion was. But with this one I had a little bit of trouble relating. But it was still important. It was still cool to learn about the thing with
- 1450 hybrid frogs or toads.
- I: So it was hard to make the connection between mating calls and toads and the ability to mate
- M: Yea, like the relevance of our discussion today about the biodiversity loss. I couldn't really find the relevance of it.
- 1455 I: Yea, that makes sense 'cause you're like 'how are we-'
- M: Yet there's probably connection but
- I: lost, yea
- M: Yea, I couldn't find it.
- I: That's fine. If you were to see a program on TV or a little news advertisement
- 1460 was going to say or going to talk about ...
- M: the toads?
- I: Well, or even if it was just more generic. Like it was just going to talk about animals and mating calls and the ability to get females and stuff, would you find that to be something that's interesting that you might go to watch or something?
- 1465 M: If, like all animals, probably in general yea, but if there was something like if I hadn't done this. Like if I saw something about toads, mating calls like on the Animal Planet channel or something, and I had already learned this, I'd be interested in it and I might watch it to see because I have a little bit of

- background. But if I had no background in it, I probably wouldn't watch it. But if  
 1470 it was just animals in general, then I probably would.  
 I: Because it would be interesting to know why some animals have opportunities  
 to mate and stuff like that.  
 M: Yea, um-hmm  
 I: Ok, so as you're trying to work through either one of these problems, a or b,  
 1475 your knowledge or your group members or the teachers comments, that helped  
 you or that you found useful in solving either one of these problems.  
 M: Um, probably just like my group and their opinions helped us piece together a  
 thing, but we still didn't really know what the fitness meant 'cause it wasn't ever  
 really clear like what fitness meant in that sense. So we still had a little bit of a  
 1480 problem with that part of it trying to solve it.  
 I: Do you think that we can fast-forward to a part when you guys are talking about  
 that? Would that be okay with you?  
 M: Yea. I don't know if we ever figure out what she means exactly.  
 I: Push play. That's ok.  
 1485 (watching video)  
 M: We only talked for like a minute. We talk that long today.  
 (I mumbling about how to work camera - inaudible; then watching video).  
 M: Yea, we were confused about what the fitness was so then we start talking  
 about it but I don't think we ever. I think we just decided to take it literally and  
 1490 think of it as in strength and things like that.  
 I: Was that your idea?  
 M: Well no it was Carol's.  
 I: To go with the strength idea.  
 M: Yea.  
 1495 I: And how did you feel about that?  
 M: That's fine. That's what I was thinking too. I just didn't like spit it out.  
 I: Ok. Um, just so the camera knows, this was at 1:02:29 and we watched like  
 thirty seconds before that. Um, so you found her comments, Carol's comments  
 useful just 'cause it helped articulate what you were also thinking.  
 1500 M: Um-hmm.  
 I: Was there anything that the teacher said or any other knowledge you brought  
 from the past about fitness.  
 M: Not really. I think we just decided that because the Arroyo toads had to run  
 around then they'd be stronger and in better shape. So that could have been it with  
 1505 that, but that's just like a general idea.  
 I: Ok, yea. Um did you feel like you could contribute to solving this problem? In  
 other words, did you feel like you contributed stuff to your group coming to a  
 solution that you could share.  
 M: Yea, not as much as I usually do, but today I was more quiet than usual, but I  
 1510 think I contributed a little bit.  
 I: Any reason you think you might have been more quiet?  
 M: I think this one was an easier one and it was kind of like once we found an  
 answer, that was like. There wasn't really a lot of discussion between the group. A  
 lot of the questions to the problems we have there's like six or seven different

- 1515 steps and there's a lot of different possibilities, and so all three of us have a different opinion. But with this one we were kind of like we had a consensus from the beginning so it was a little easier.  
I: It's like uh 'Here's the answer. Ok, done.'  
M: Yea.
- 1520 I: Ok, in other classes, when you feel like the problems are more complicated, do you feel like you have um you contribute a lot.  
M: um-hmm  
I: Why do you think that is?  
M: Just because we all have different opinions and we all have to share the
- 1525 information to back up our individual opinion. And then we all take into consideration and then like just I think like with the harder problems, it's just better because we talk a lot more. Like on these, once we figure out the problem, then we're done and we don't need to discuss it anymore but with the other ones, we spend a lot more time talking and then just opinions will come out and
- 1530 different points of view and so that I think is better.  
I: If all three of you guys had a different opinion, and you had a harder problem, and each had a different opinion, do you think there's one person in your group whose opinion gets more weight? Do you know what I mean by that? Like maybe let's say it's you or let's just say it's Juan for a second, and then all you guys just
- 1535 give in and say 'Yea, let's just go with Juan's.' Is there one person that that normally happens with or is that you or?  
M: They'd probably say something different but I would say Carol's kind of like if she says something, it's not like we just give in and we're just like 'Ok whatever. We'll just agree with you.' We usually like see her point of view and go 'Oh yea,
- 1540 that's a good idea. Let's go with that.' But usually there's not really one person that we just follow. It's not like we're just like 'Ooo, Juan you got the good answer. Let's just say yours.' or something. It's usually like every different class someone else gives like a different answer.  
I: Do you feel like the answers you give in general are pretty respected by the
- 1545 other two?  
M: Um-hmm, yea.  
I: Like do you get blown off or always ignored?  
M: Huh-mmm. No.  
I: Ok, (lights go out). Um, did you feel like your suggestions were taken seriously
- 1550 by your group. I think I just-  
M: Yea.  
I: kind of answered that. Is there anything you want to add with that one?  
M: no  
I: That's probably because the problem was too easy and your suggestions were
- 1555 all in agreement.  
M: Yea, like this one, this was probably not like a good example to use because in this one was just like we all thought that because this Western toad was making the call, then he's obviously going to get more because he has in own species and then this Arroyo toad female species so it was just kind of like 'That's our answer.'
- 1560 We didn't really have a lot of discussing it or any different points of view.

I: Ok, and this second problem where "the offspring would be more or less fit". Was there any discussion there do you think.

M: Oh we only thought they would be more fit, with this (pointing to third prompt about sterile hybrid), not seeing this last one

1565 I: right, right

M: We thought that they were going to be more fit because they had the best of both worlds. But then we got the third one telling us they were sterile and we changed our opinion so we thought that was a general consensus well they're obviously going to be more fit because they have not only the Arroyo toad traits but they have the Western trait of the call so they have the best of both.

1570

I: And you had that same idea, so you weren't able to contribute as much.

M: um-hmm

I: Ok, is there anything you thought of contributing but you didn't because you thought it was out of place for some reason or you felt like they weren't listening or you just didn't have the energy or is there anything else that you wanted to contribute that you didn't?

1575

M: Mmm, not really, no. I can't think of an example. Um, I maybe thought like on this one that he might not be as fit because the female Arroyo toad, she might not be as fit as the male Arroyo toad, and they wouldn't have like the same genetic traits of the fitness part of it. So maybe he was just the same maybe the same or a little bit less than the Western toad. And I didn't say anything about that just because I didn't it didn't really seem too important.

1580

I: Ok, ok, um what was your favorite part of the class today. Well tell me about the whole class what was the beginning, middle, and end.

1585

M: Well we started out by taking notes on the biodiversity loss. And then we went through or we came up with eight ideas, and then we did this but I think my favorite part was when we were talking about the pet trade 'cause I like animals. And we were talking about how that's contributing to diversity loss because they're going out into the wild and getting just wild parrots and bringing them over here and some of them are dying on the way over here or they're um getting over here and they can't be kept as animals because they were wild and so I thought that was interesting. And so she told us that one way we can contribute is that if we do decide to like buy a wild animal make sure you buy one that was bred in captivity. So I thought that was interesting 'cause I'm interested in animals and animal breeding.

1590

I: Oh neat. You know I don't know anything about all that stuff so it's kind of interesting. Um, was it mostly her talking or was it class participation or ...?

1595

M: Um the class participated when we were making up our list of the like the depletion what were the reasons. We participated.

1600

I: How about when she was talking about the animal trade?

M: Um, I don't think, there's probably like a couple random comments, but nobody came up with that idea. She had to like give us hints like tell us about the wild parrots and then like when people have parrots what can people do. And that was towards the end and we were kind of running out of time so she was kind of just like giving them to us. Like in the beginning everybody talks, everybody gives examples, but then we usually end up running out of time.

1605

I: Yea, um, it wasn't really a problem. Would you have preferred questions. Like these problems that you get at the end, to be about one of the topics that you had today in class? And if so, what question-

1610 M: It doesn't have to be like generally about one of these topics, but if I could have seen a more relation to it, maybe I can't really think of an example but maybe like um 'cause I couldn't think of anything I could put like in all these steps but we did learn about like the gopher tortoises and how they make their holes and all these other animals go in. So maybe she could have a problem about like  
1615 what if the gopher tortoises don't make those tunnels anymore, then what's going to happen to those animals. I mean like that would have had a lot more opinions in my group.

I: And how would you connect that to biodiversity issues?

M: It was one of the um last ... let me think (looks in notebook) loss of keystone  
1620 species. So we learned about the keystone species and one of the keystone species was the gopher tortoise, 'cause he makes all these tunnels and then about ten other animals rely on those like tunnels to go in during the winter to live in and so if those tunnels aren't there, then what's going to happen to the animals. They'll probably die or go somewhere else or figure out another place to stay in the  
1625 winter. So that was one of the things.

I: Was that new information for you or is this something you already knew.

M: Um-hmm. No that was new information. A lot of these were um some of them I knew like a little bit about but others I wouldn't have thought about. Like the  
1630 pest control is biodiversity loss, pet trade, I wouldn't have thought of that but a lot of the other ones I've thought about. So the last ones, the ones that were hard for the class to come up with, were a lot of what I don't think a lot of people didn't really know that much about. So maybe a question about one of those would have been good because it would have helped reinforce us remembering it.

I: And um why in general is biodiversity interesting to you?

M: Um, I think it's important and interesting because I think I like how I like  
1635 learning how they put like invasive species or the non-native species in to like kind of control the native species and then they end up with like a bigger problem. Like she was telling us about in Puerto Rico how they put how they have a bunch of rats, so they got mongooses to take care of the rat problem but then they didn't  
1640 realize that mongooses are daytime animals and rats are night-time animals so they never meet. And so I thought that was interesting.

I: (laughs) Yea, it's lots of times how those things go.

M: Yea, and I like learning about like pollution and then I thought it was  
1645 interesting about hunting, like the commercial fisheries, how they're taking away fresh wild salmon and things like that.

I: Yea, fishing is a huge problem. Interesting. Anything else that you would like to add about today's lesson or your contribution or your interest in today's lesson.

M: I can't think of anything. Well I liked when we talked about well I learned a  
1650 new thing when we talked about generalists vs. specialists animals. And we learned about how a specialist animal can only eat like a certain thing and we had an example of um a panda and 'cause I like pandas, I'll remember that for a while.

And then the generalists will eat almost anything. And I thought that was kind of cool 'cause I'll go around telling people if they're specialists or generalists.

I: Right, right. Cool. Anything else?

1655 M: Can't think of anything else.

I: Are you enjoying? You don't have to worry about ... she's not going to listen to it until (waves into the future).

M: Yea, um-hmm. I like this class a lot.

I: Oh that's good. You think you're learning a lot?

1660 M: um-hmm

I: What do you think what component of this class helps you learn, as compared to another class?

M: Um, I think these problems really help a lot because it helps connect it to real life. So usually we'll take like notes during the first half of the class and then we'll get a problem and then we're taking a test, we're going to remember, like if we have a question about these toads, then I'm going to remember it because talked about it with my group and it's connecting with like real life because these toads are in southern California so it's something I can relate to. So I think the problem sets is really what helps makes the information stick. And also our field trip labs.

1670 Those are really good.

I: Thank you so so much for taking time out. She really appreciates it.

M: Um-hmm. Did you teach a class also?

I: I did, I taught a class (talks about own course)

*Prompt #3*

1675 C: Do you think it's gonna change anything?

J: I don't think so, just that fact that it's sterile. It can't reproduce. I don't think that, she just said it. The offspring is gonna be the same, strong and everything but it's not going to be able to reproduce, that's all.

C: You think?

1680 J: yea

C: yea

J: More or less fit. hmhhh

C: I think it'll be the same too, I mean.

J: More or less than who, the

1685 C: than before. They were fertile.

(listen to H's group, who is working with the NP group)

C: Yea, they came to the conclusion that everything's going to be the same.

J: Yea. It's about the same. I don't I don't see the problem with the fitness, I don't. The new the offspring um

1690 C: What about the female frog. Would she know if she's pregnant or not? And if so, would she be willing to go with the other frogs instead of the one that's sterile?

G: (from H's group, talking about door) You know why it's like that? Because it's missing the hinge. It's missing the hinge up there on the door.

C: (to G) You're right!

1695 G: I kept noticing that during our presentation.

J: Ok, so what about the female. Hmm, interesting, yea. She's focusing on the male, right? What about the female?

*Carol's Contribution to Whole-class Discussion*

I: Ok, so Carol, repeat yourself for the people who can't hear you.

1700 C: Um, it'll make more of a difference in the long run because these frogs will be less umm

I: the hybrids

1705 C: Yea, the hybrids. There will be um there will be more of the other frogs since these can't reproduce, so the competition between those two would be even harder on these hybrids cuz there will be more of these frogs competing against these frogs.

B: When you say more of 'those' you mean more of the

Ho: more of the western and the Arroyo

C: the other ones, yea

*Stimulated-recall Interview: Juan*

1710 I: Ok good. So we're going to do the same sort of thing and we'll watch the section of tape.

J: Ok, actually that day we couldn't see anyth- anything. Back there we didn't have a tape either.

I: Really?!

1715 J: No we didn't see any tape. It was just words but the problem that we worked on was the same day.

I: Oh, ok. And so you didn't watch any tape at all?

J: No, we didn't.

I: You talked about the problem on the paper instead.

J: Yea. Yea.

1720 I: That's so funny. Well this will just be really mellow. And um so we're just going to watch the section that she just Ms. Darner just brought up on the tape from today. And then as we're watching it, describe to me what you're doing with your group. So just tell me what's going on and what's the problem that you're trying to solve.

1725 J: Ok, let me remember, ok.

I: Well let's just see what it is first.

J: Ok

I: You don't have to say it all it once. Like we can just watch it for a little bit.

J: Ok

1730 I: And you can tell me what's going on.

(begin watching video)

J: You can see Carol right there (points to camera), right there (points to her seat), so she can't

I: Oh, yea (laughs)

1735 J: Yea, I don't know.

- I: Carol was sneaky.  
 J: Yea.  
 I: It was kind of tilted down too, wasn't it? And Meg wasn't here?  
 J: No, Meg wasn't, no. Actually we were supposed to meet last Tuesday, and she  
 1740 calls me and tells me she wasn't going to be able to come because we're working  
 on a project.  
 I: Oh right.  
 J: And we're going to be presenting in two weeks, yea.  
 I: (nodds)  
 1745 (both watch video)  
 J: Ok, well in this part we're trying to define what does it mean to be uh fit,  
 biologically.  
 I: biologically fit  
 J: Yea, exactly so what I got or what I know is to be able to reproduce and I don't  
 1750 know then we went on to the problem, which was why the hybrid, which was the  
 um mixture between two different types of toads  
 I: ok  
 J: And then the result er the offspring was not able to reproduce.  
 I: oh, ok  
 1755 J: So we were discussing why, or no not why, but um was it oh was the question.  
 Well actually I got the questions in my (points to bag).  
 I: Ok, do you want to get it out, go ahead.  
 J: Yea, I got it right here. (gets into bag)  
 J: This is this one, the last one, which is (reads) "like most hybrids, the offspring  
 1760 of the male Western toads or toad and the female Arroyo toad are usually sterile.  
 Considering this, do you think this offspring would be more or less fit than the  
 Western?" And then we had to find the reason.  
 I: Hmm, ok.  
 J: So we came to the conclusion that we think that the um fitness of the offspring  
 1765 is not going to change at all  
 I: ok  
 J: thinking about the body structure and stuff like that, just that the only thing is  
 that the offspring is not going to be able to reproduce, that's it so  
 I: Mmm, that's the only difference.  
 1770 J: Um-hmm, that's the only difference that we could actually came up and then  
 actually the teacher told us that in order to have uh this um ability to um or to be  
 really fit, it meant to be able to pass the genes to future generations, which this  
 new offspring was not able to do.  
 I: mmm  
 1775 J: So it was, so basically this new offspring, or the hybrid, is not fit.  
 I: Mmm, because it can't.  
 J: Yea, it can't pass the genes to future generations, so yea.  
 I: Mmm, interesting. So when you and Carol were discussing this. Tell me, ok so  
 that was the problem that you were trying to solve.  
 1780 J: yea



- I: And the conclusion that you just told me, that the offspring would not be would be less fit, right?
- J: Um-hmm, yea, basically that was-
- 1785 I: Did you and Carol come to that conclusion or was that after you talked with the whole class with Ms. Darner.
- J: Yea, after we after we talked to the whole class because our first conclusion was that um the we got a different um say a different meaning to fit to be fit
- I: mmm, a different meaning of fitness
- 1790 J: so we just said within this we just said be able to reproduce and since this offspring the hybrid was not able to reproduce so we came to the conclusion that it was not fit.
- I: Ok
- 1795 J: And then after we discussed it with the class, the teacher just basically gave us the answer, that it was not physical fitness of the offpspring was unable to pass the genes to future generations, which was this hybrid.
- I: Ok, great. Did you feel like um this problem that you were talking about was an important problem? What do you think, just-
- J: Ok, what I think more than important, I think it was interesting.
- I: hmmm
- 1800 J: interesting but not-
- I: More interesting than important, yea.
- J: Yea, yea (laughs) well.
- I: Tell me why. Let me pause this for a sec.
- J: ok
- 1805 I: We'll go back to it if we need to.
- J: Interesting because um these were things I just didn't know, first of all.
- I: uh-huh, yea
- J: And then uh, one of our class mates came with a similar idea, talking about a horse and donkey.
- 1810 I: ok
- J: And that's how they got the mule, so that's what they got. That's a similar example that I just didn't think about before.
- I: right, right
- 1815 J: So that's kind of interesting to see how these um uh I don't know, behavior can different species can have it.
- I: Yea, different toads can cross and a horse and a donkey can cross.
- J: Yea, exactly exactly.
- I: Yea, that is strange, isn't it?
- J: And the offspring is not reproduce, that's the basic idea.
- 1820 I: mmm, um-hmm
- J: And it was kind of interesting, and even though they can do everything, or sometimes they are even um more stronger, or not just stronger but um like the other class mate told us too that many times mules are used to work instead of using horses.
- 1825 I: hmmm
- J: So that's kind of interesting.

- I: So they, yea, so in that example with the mule, the mule is a better choice if you need it to do certain work.
- J: Yea, exactly.
- 1830 I: Interesting.
- J: Yea, it is interesting.
- I: What do you think about this toad problem, why would that be important to a biologist, a scientist that was studying them? Would it be an important problem to them?
- 1835 J: Ok, to them I think yea, it is really important because um they need to in order to understand the behavior of basically this species, they have to uh know the different of course the different mixture between the toads, I don't know, and what is the result of those mixtures, in this case the hybrids. And then have to understand uh or many times the consequences of the mixtures of different
- 1840 species.
- I: right
- J: Even those that are toads that are from different places. In order to um, an interesting thing about these ones, the Westerns, and how they um by whistling, they will attract the um Arroyo toads, that's another interesting thing.
- 1845 I: Mmm, is that something that you learned today or you knew that already?
- J: Yea, we actually studied, we went over it last class
- I: oh, ok
- J: which was Thursday, last Thursday
- I: oh wow
- 1850 J: So actually like we have been working on this one which these are the first ones (shows I prompts from previous class).
- I: Those are the first ones.
- J: Yea these are the first ones from this same problem.
- I: Mmm, interesting. (reads) Oh, that's interesting how they use the-
- 1855 J: They call these advertisement calls.
- I: advertisement calls, ok
- J: yea
- I: Ok, wow. So if you um if this was a problem that you heard about outside of class, that if you were um well, let me put it this way, yea if this was a problem
- 1860 you heard about outside of class would it still be important to you or as interesting? Or was it more important or interesting because you had to solve it in the class? Do you know what I mean?
- J: Yea, yea, yea. I know what you mean.
- I: ok
- 1865 J: Well, I guess if it would be outside of class, it would be a lot more interesting than it was in class
- I: mmm
- J: because we uh every or every two classes we basically we try to solve a different problem, so since we have we are here to solve the different problems in
- 1870 the environment, this time it was more important than interesting, in this class, yea.
- I: Ok, in the class it was more important than interesting, ok.

- J: Yea, if it would be outside of class, it would be a lot more interesting than  
 I: Like if you read it in the newspaper or saw it on TV.
- 1875 J: Exactly, yea, just like a fact. I don't know, saying that the mixture or the hybrids of these two different toads they um they um as a result they give this offspring that don't have the ability to reproduce. That's kind of interesting. And then I don't know if they would compare it to the uh again the example that the other class mate told us about the horse and the donkey giving the mule. It's kind of interesting to compare those different animals, toads and horses.
- 1880 I: Yea, definitely. So why was it, why was it in class, compared to if you heard it you know on TV?  
 J: Because um well I don't know if well yea, because in class, especially this class is dedicated to solve problems in the environment. So uh since the first class, we met, we started to solve different problems.
- 1885 I: from the beginning  
 J: Yea, exactly. So we're kind of getting used to solving different problems.  
 I: Um-hmm, so that's really your goal in this class  
 J: yea exactly
- 1890 I: is to work with all the environment problems.  
 J: Yea, even though sometimes we might not even get a I don't know a solution because it's not even the scientists get a solution.  
 I: mmm, right  
 J: But we sometimes get up to the point that they got, the scientists, the ones that are studying the same thing. We just got to the same level or idea
- 1895 I: Oh  
 J: or solution, if that's the case, even though  
 I: Because it might not be something you can solve in one day or something.  
 J: Exactly.
- 1900 I: Interesting. Nice. Alright. Cool. So when you were talking with Carol about the problem and working through it, um is there anything that helped you or that you found useful to solve the problem? So was there anything that you had known about or anything that um someone else in the group or in the class said or that Ms. Darner said that helped you understand and solve the problem better? You mentioned something already about the class mate's comments.
- 1905 J: Yea, yea.  
 I: Was there anything else that you were thinking of or tell me about how that might have helped you understand or solve the problem.  
 J: Um, actually the way Ms. Darner gave us the lecture starting last week. She started to actually, everyday we have a problem, she starting giving us different facts, and different points, in this case, it was 1A, 1B, giving different facts about this problem, and then getting to the point where we need to solve the problem. In this case, she gave us facts about the way they reproduce, and then um and then she gave us another problem, which was this one, about the fitness of the offspring. And then she got to the point where she told us (lights go out; get them back on). Ok, it so it got to the point where she told us that the result of these offspring, we didn't know it, were sterile and they're not able to reproduce.
- 1915 I: Mmm, so she was building up to to that final point today that they were sterile.

- 1920 J: Exactly, yep, exactly. That was basically the whole thing that helped me a lot, I just needed to back in my mind remember stuff that I had learned before and apply it to solving the problem or to-
- I: So the giving you a couple facts at a time
- J: exactly
- I: and building on that sounds like it was really helpful
- 1925 J: yea a lot
- I: to understand.
- J: a lot
- I: A lot of times? (laughs)
- J: yea
- 1930 I: That's good. Ok, nice. Did you feel like you could contribute well to solving this problem effectively, I mean did you feel like you were able give the information you wanted to to help solve it?
- J: What do you mean by-
- I: In your group. Maybe just when you and Carol were talking about it.
- 1935 J: uh-huh
- I: Did you feel like um the information that you wanted to share with her was um helpful or was effective in solving the problem?
- J: Yea, I guess so because we kind of came up with the same idea. I told Carol my idea and then she kind of I don't know think about it and then she thought about her idea and then she agreed with me. In this case, just about even though we were not right, about the exact solution, we kind of came to the conclusion.
- 1940 I: Ok, ok. And um the conclusion that you and Carol came to before you talked with the whole class was that the offspring would have the same fitness?
- J: The same fitness, yea.
- 1945 I: Because they were probably just as strong and all that stuff?
- J: Exactly, just not just not able to reproduce, that's the only thing.
- I: Ok, ok. Nice.
- J: But other than that, they're pretty much the same, pretty the same thing, the same body structure, the same um are able to eat the same things, everything.
- 1950 I: Yea, yea, all of it was the same, just the ability to reproduce was different.
- J: exactly
- I: Ok. Do you feel like when you and Carol were discussing in your group that um she took your ideas seriously?
- J: yea
- 1955 I: That she really listened to you?
- J: Yea, definitely, yea.
- I: Why? Why do you feel like she did that?
- J: Because um-
- I: Like how did she react that told you that she took you seriously?
- 1960 J: Well the way she react was um when I told my idea, when I told her my idea, she just kind of um I think the same thing from the previous idea. I just went over the information that we just got before, in the class before, and just decided to, in some way, the most oh how should I say it, the most, the most common sense, I guess?

- 1965 I: um-hmm  
 J: We just came into the, we kind of didn't discuss it that much, this answer, we just came up to the same idea that these new offspring were going to just um, this um (pointing to paper)  
 I: the hybrid offspring
- 1970 J: Yea, would have the same fitness.  
 I: (simultaneously) would have the same fitness  
 J: But the thing that we didn't take into account was the meaning of the fitness  
 I: mmm, right  
 J: so that's why we came up with the idea that offspring would have the same fitness.
- 1975 So yea.  
 I: Nice. Ok, and let me see, let me see if I can just play that section right here where you and Carol are just talking about it. Oops, I think this is when we already got back to your big group. Let me rewind it just a little bit here. See if we can find that little section. (tape begins when instructor is acknowledging the horse-donkey example)  
 1980 (both watch video)  
 I: Uh-huh it looks like you were thinking, "Wow."  
 J: um-hmm  
 (both watch video)
- 1985 J: Yea, we were just thinking "more or less" what does she mean by "more or less." We just can't think that it's  
 (both watch video)  
 J: (laughs) And then we started to listen to the different ideas that got  
 I: From the other group?
- 1990 J: Yea, exactly. And then we just, well we just came to ...  
 (still watching)  
 I: So it looked to me like both of you were doing you know listening well to each other. Did, would you feel that way?  
 J: Um-hmm, yea. Yea, definitely.
- 1995 I: And then you started talking with the other groups?  
 J: Um-hmm, yea.  
 I: Nice. Was there anything that you wanted to say or contribute to the discussion that you didn't because you thought it might be out of place for some reason?  
 J: Not really, not really, no. Not really. I just um, I said what I I just came up with
- 2000 the input that got before and I don't think I got anything left.  
 I: No, you didn't leave anything out?  
 J: no  
 I: ok  
 (both watch video)
- 2005 J: Oh, I just remember this part. We're thinking about the female, what about the female frog because she (points to prompt) was only thinking about the males.  
 I: oh  
 J: And then we were just thinking  
 I: comparing it to the males
- 2010 J: yea, what happened to the female?

- I: hmmm  
 J: So is the female able to reproduce in this case?  
 I: hmmm, interesting  
 J: And I don't know why she the teacher she focused on the male.
- 2015 I: hmmm  
 J: This (points to camera) is the part where we were thinking about the female.  
 I: And you said, "what about the female?"  
 J: And then she told us.  
 I: Um-hmm, she's doing the big group again. Talking about fitness. Nice. That's a
- 2020 very good question. I mean maybe she put males because they react differently than the females? I don't know. It'll be interesting. Maybe there will be a 1D, huh? (laughs)  
 J: yea (laughs)  
 I: Probably, right? Knowing Ms. Darner?
- 2025 J: Yea, we just came up with the question, what happens to the females then?  
 I: Yea, right.  
 J: Where's the what about the ones the ones that are able to reproduce trying to mix with the ones that are hybrids, in this case female, what happens in that case? We just didn't know.
- 2030 I: Oh, hmm, that would be an interesting question, huh?  
 J: Yea, that could be the question that we just that we couldn't answer ourselves.  
 I: between you and Carol, didn't know the answer to that one  
 J: Yea, we just didn't know. Yea, that's the only thing.  
 I: Interesting, I don't the answer to that one either.
- 2035 J: (laughs)  
 I: Um so tell me what was your favorite part of class today?  
 J: Uh my favorite part ... hmmm, let's see. I guess when uh the teacher gave us the answer.  
 I: at the very end?
- 2040 J: Yea, at the very end, when she gave us the answer and then we kind of understand it better and then uh well, we basically understand the idea or the whole problem that we started last week in coming to the conclusion. Well I think it's we didn't up to the whole conclusion. She just gave us part of the of the um solution or conclusion, 'cause I think I saw her having more
- 2045 I: more papers? (laughs)  
 J: Yea, more papers. I don't know if that's a continuation for the problem or the answer, many times it's the answer for the problem.  
 I: oh  
 J: Or more questions to the problem, so I don't know.
- 2050 I: It could be either one, huh?  
 J: yea  
 I: Interesting. So why was that your favorite part, that she told you what it means to have biological fitness?  
 J: Because um because since we were kind of not, we were having different
- 2055 questions or having different ideas. We didn't know if we were right or wrong, and then she had given us the answer, or basically the meaning for the fitness part,

- of the fitness word, she totally give us the answer, which is that fitness does not mean just to able to have good body structure and good ability to eat, to everything, same as the other ones, then they key was this part was this part,
- 2060 which says not able to pass the genes, which these hybrids are not able to do. So that was a good part.
- I: So that's your answer there then.
- J: Yea, um-hmm, so we got our answered question, er our question answered.
- I: You got your question answered, yea.
- 2065 J: yea
- I: Yea, that's nice. Um, did you feel like, hmm, some of these questions may not be applicable. Um, you kind of answered that already. Um, so once you found that out, once you figured out that that was your answer, that the hybrid probably did have a lower fitness because it cannot reproduce. Was there anything that you
- 2070 wanted to contribute at that point but you didn't for any reason?
- J: Mmm, not really because it was just that fact that again, she gave us the the meaning the biological meaning for this fitness part because it's not uh, fitness is not meaning physical many times, but biological which is the genes in this case. Once she gave us this, the total answer, we just 'ok' (shrugs, laughs).
- 2075 I: (laughs) And it made sense?
- J: Yea, it made a lot, yea, a lot.
- I: Nice. Ok. Cool. Alright. Anything else you want to say about the problem or the discussion you had about it?
- J: Well, what I said before, it was really interesting to me, basically because the
- 2080 learning, the learning is really interesting in this lab, basically.
- I: Yea?
- J: Yea, solving problems and I think I'm learning about different species and I'm being able to many times explain other people.
- I: Um-hmm, oh cool.
- 2085 J: That's one of my favorite parts.
- I: Nice.
- J: Being able to in some way look smart about different stuff because of this class.
- I: Yea! That is a good feeling.
- J: yea
- 2090 I: So do you feel like with this Western and Arroyo toad hybrid example that you have some enough information now where you'd be able to go out and you know explain to someone, your friend or your family or whoever.
- J: Up to this point, yea, um-hmm, um-hmm. Yea, absolutely.
- I: Nice. That feels good.
- 2095 J: Yea, a lot (laughs) a lot. Basically, what I do most of the time is just go to my dad or my mom and tell something like that. Basic- well the basic idea of why I go to my parents is because they didn't have education, many times. And many times they have different questions that I can't be answered and they wonder about different things about the world many times, about the environment, or the
- 2100 fact that we're using many times, pesticides on many things. Or why the, the biggest question I have gotten from my dad I think is global warming and all this stuff that is going on in the world right now. So many times the stuff that we learn

- in here, I try to go to my family and many times, "look smart" (goes quotes gesture) and start talking about anything or questioning them. And they're, well
- 2105 many times they are happy about it.  
 I: Nice, good, so you're sharing with them everything that you're learning.  
 J: Yep, um-hmm.  
 I: That's great, good. Do you sometimes bring their questions (lights go out) back into class? You know if like you said your dad, your dad asked a question about
- 2110 global warming, do you ever bring their questions into class and say 'hey I was wondering this or that about global warming'  
 J: huh-uh  
 I: or is it after you've already learned about it?  
 J: Yea, after, after. And the stuff that I remember from them asking or wondering
- 2115 about, I just try to I don't know many times compare it to the stuff that I learned and then try to bring it up in questioning them and then tell them.  
 I: Yea, yea, nice. That's awesome.  
 J: Yea, it's cool.  
 I: We need lots of people like you in the world. Yes!
- 2120 J: (laughs)  
 I: Very cool. Great. Alrighty. Well thank you so much. This was great.

*Prompt #3*

- M: It wouldn't really change the population, would it? It would just make more of these hybrid toads. So, like, the question about what effect would it have on the Western and Arroyo toad population, it really wouldn't affect it, would it? There
- 2125 would just be more of these hybrids running around.  
 J: Exactly. And the same with all the-  
 M: It's not like the hybrids are going to go around, like, killing the other ones or something.  
 J: No. For sure. It's not going to be a change between them.
- 2130 M: But I don't know if they'd be considered the same species.  
 J: Probably 200 years from now.  
 M: Probably 200 years from now, then they would.  
 J: OK. From this point on, there's gonna be a new species, which is the hybrid of either Western or Arroyo. Either one is gonna be a total new species. What do
- 2135 you think?  
 C: I think that...it would like evolve somehow...because since the hybrids are gonna be more powerful they'll be able to multiply...better, I guess, 'cause they'll be more fit. Then I think that the other frogs will have to evolve in order to catch up to them or else they're just not gonna...
- 2140 J: Does that mean that they're gonna be considered the same species 200 years from now? It says that if you consider that from 200 years from now they're going to be considered the same species. Do you think so? Because from this point on, the hybrids are gonna be almost the same amount as Western and Arroyo- they're gonna be a new species. I think...they're gonna be considered,



- 2145 um, the same species (pause) Oh wait, no! This is hard. I don't know. I'm very confused.  
I: You're confused?  
J: Yep, totally.  
C: So, when you say by being the same species, do you mean they're gonna stay
- 2150 the same, and not evolve?  
I: Um...who's "they"?  
J: The-  
C: The toads, or whatever.  
I: I know that!
- 2155 C: All of them!  
I: OK. So the Western toads are a different species than the Arroyo toads. So those are two separate species. But, in this rare instance, a hybrid is formed that is fertile. So the question is, if this hybrid has the ability to do the advertisement call, and attract the females, then how is that gonna affect the whole population of
- 2160 Arroyo toads? over time?  
M: Over time it might decrease.  
I: Decrease the population of Arroyo toads? How so?  
M: Just because they're not as good? Because they don't have that advertisement call, so they're not gonna be as, like, as good.
- 2165 I: OK. And what about the Western toads then?  
M: I think they'll be OK because they still have the advertisement call.  
I: OK. So the Western toad females, however, are gonna be attracted to this hybrid 'cause it can do that advertisement call. So if a Western toad female mates with a male hybrid, what are their offspring?
- 2170 M: A new species? Like a new frog?  
J: Yeah.  
M: That gets confusing.  
I: It is confusing.  
C: But then it's like they're not introducing, like new, like, uh, I guess like you
- 2175 could say, like, techniques in reproducing. If they're the same then even though the hybrid is kinda like different, it has the calling, or the call, but that, you see what I mean? It's not introducing anything different.  
I: So it's nothing new. It's perhaps just a new combination.  
J: Yeah.
- 2180 I: OK. That's a very good insight because that kind of leaves the question where does new stuff come from? Like, for instance, you know, the advertisement call sounds a particular way. Say it sounds like, "Baarp." But then all of a sudden, a toad is born, and it doesn't do "Baarp." It does...  
J: Bohp.
- 2185 I: Bohp! (all laughing) So where did that variation come from?  
J: From the mixing?  
I: From the mixing? Could be.  
C: From homework, I've found out that, um, in order...if you have a species that's like, the top dog, in order for another species to catch up with it they have to
- 2190 sometimes do things differently, and that's how they evolve. Like, the ones that

are doing things differently, and the ones that are able to reproduce, are the ones that are gonna survive.

I: Uh-huh

2195 C: And the ones that are, you know, lacking, they're gonna be left behind. They're not gonna reproduce.

I: Uh-huh

C: So therefore, the ones that are reproducing are gonna...make more offspring and therefore the future generation is gonna...be more frequent, or something like that.

2200 I: OK. So does it matter if they're doing things differently? Or is it better some way? That's a question that I have. And what makes it better? Try to think about fitness.

J: They'd probably...be...they're better...because they are...they keep having children...just like, uh...many kids...

*Problem #5: Baja Rodents*

2205 J: Isn't the climate, uh, a lot different in Baja from the rest of Mexico?

M: Uh-huh

J: That could be one of the causes...

M: What?

2210 J: That could be one of the causes, why there's a big difference... (long pause) and then-

C: I think it like, you know, there was a different species?

M: Yeah, maybe. Since there was...yeah, they probably found a different species over there and were like, "Oh, OK."

2215 J: What about the fact that Baja is surrounded by water? Could that be some...in Mexico... now we're talkin' about-

M: It's probably like with the toads, how just...yeah...(long pause)... I think it's like with the toads, how they just mate with other people and then they just created, like, a whole new species. So that's probably what they did when they separated.

2220 J: OK. (long pause) Let me think (inaudible)...

C: It could be like with (inaudible) attracted maybe differently to different species...and since they're divided or previously spread out in different places.

M: Yeah

J: And they're mixing...

2225 C: Both sides aren't the same, right? They're totally different.

J: Yeah

C: So... (long pause) It's like, the chemicals and stuff can cause them to change also, right?

M: I think so

2230 J: Yeah, that definitely could be...

C: And it could be like (inaudible) But then, both sections would be mutating at the same time.

J: Exactly

C: Causing them to be the same species.

2235 J: Exactly

*Stimulated-recall Interview: Carol*

I: Ok, so we already talked about this part of the tape. Just tell me again, briefly, what was this problem that you were discussing with your group?

2240 C: We um, the new question states that these new hybrids of um Arroyo and Western toads are fertile now. So what are the advantages of the hybrids, like what advantages would they have on you know over the Western and the regular Arroyo toads. And we came up with the fact that they'll have an advantage over both of the regular toads because both they have um some of traits of the Western and the Arroyo toads. So they can do the call and they'll have the same appearance that attracts you know the Western toads.

2245 I: Ok, so they have the advantages from both of them.

C: yes

I: Ok, nice. And um and then the second part that you were telling me about was that this 200 years from now, that part of it right?

C: Um-hmm.

2250 I: So what was that part that you were discussing?

C: Um the questions says in 200 years from now will they evolve would they evolve into a different species? And I figured that they would because you know they're having to uh they have like they're more advantageous than like the regular toads so they're going to be more fit and so

2255 I: Because they have the advantages from both of the both of the regular toads?

C: Yea, so they're gonna have a different species.

I: Hmm, ok, nice. So that was the general problem that you were discussing with them and um just repeat to me again for the sake of the videotape what you said when I asked you if this problem was important, solving this problem was important to you.

2260

C: Um, in a way it is because it pertains to us too and our revolution, revolution as human beings, but talking toads isn't very interesting to me. Um because I said that I guess we as human beings think we're superior so we just want to know about us, us, us.

2265 I: (laughs)

C: But I see the importance of you know talking about the Arroyo toads and how they're they're evolutionizing because we can also apply it to different species and not only toads.

2270 I: So we can take whatever we learn from what they're doing and look at other animals and see if it's happening the same or different, that sort of thing? Is that what you mean?

C: (nods)

I: Ok, cool. And how might this help us understand about human evolution? What do you think about that? Or natural selection in humans? You were starting to talk

2275

about that a little bit too I think.

- C: That um, well what we learned was that we don't adapt to, I mean we don't um, react to our surroundings. Sometimes it just happens naturally that we become different, like or we change, that our make up is usually dependent on our DNA and our genes. So if um in the process of um creating a new cell or reproducing, if  
2280 the process becomes like, kind of like messes up somehow, and we get stuck with a mutation that we could pass on to um our offspring.
- I: Mmm, ok. And learning about how these mutations work in the toads might help us understand how mutations would work in people then?
- C: um-hmm
- 2285 I: Is that what you're saying?
- C: um-hmm
- I: Cool. Ok, neat idea. And then I was asking you before we realized the videotape was not on, I was asking you if there was anything that anyone said or any information that you had that you found helpful to help you solve this  
2290 problem. So did any of your group members say anything that was helpful to you to understand it or did Ms. Darner say anything or did you say anything? What do you remember. We can watch it a little more too if you want to. Should I turn it on?
- C: No, it's fine. Um I remember. Well, I forgot which frog does the call or  
2295 whatever. It turns out that the Arroyo toads are the ones that does the calls so that was helpful because then I can compare the Arroyos and the Westerns and also the hybrids.
- I: And who reminded you of that?
- C: It was Meg.
- 2300 I: Meg
- C: Meg and Juan. Uh, and also I had a difficult time trying to answer this question because I just didn't think of it much and I guess I didn't think it was very important at the time.
- I: Um-hmm.
- 2305 C: But um you know they were talking about it and it gave me some ideas and I just you know started communicating with them and you know just putting things out there.
- I: Yea. It sounds like your group is good about that, like all three of you feel comfortable just saying an idea and then talking about it with each other. Do you  
2310 feel that way?
- C: Yes.
- I: Yea? Alright, nice. Did you feel like you could contribute pretty well to help solve this problem?
- C: Yea, I could. Um, I'm usually the type that like you know I just throw things  
2315 out there, even if if it's wrong or right and even if someone thinks something is right, I'm always the one to be looking at it like, 'Wait a minute, you know what if, what if this, what if that?'
- I: Right, right.
- C: So I'm like looking at it with all perspectives, not just like narrowly.
- 2320 I: Nice. Let's see if we can find a spot where you remember just throwing an idea out there.

(both watch video)

- 2325 C: Ok, I just brought up the fact that um from reading the book and from doing the homework that was assigned and due today, I kind of like brought up the fact that it'd be a good idea, I mean it would be a good thing if they're like evolving because you know, they'll be able to reproduce more, but then they're also affecting the other toads, the Western and the Arroyos
- I: Um-hmm
- 2330 C: because then the Western and Arroyo would have to work hard to catch up to them
- I: Why? What do you mean?
- C: Because the hybrids are have better fitness. I mean like the got the best of both you know, traits.
- I: Right, right.
- 2335 C: And I figured that the other toads would kind of have to adapt in a way and like work harder and those one's that are working harder are going to be more likely to survive and have offspring that might carry the same trait and work harder.
- I: mmm
- 2340 C: Then I found it's wrong.
- I: Oh (laughs) but you felt comfortable just saying that idea and with Ms. Darner standing right there.
- C: Yea.
- I: You didn't feel shy about, at least it didn't look to me like you felt shy about you know just putting your idea out there?
- 2345 C: (shakes head)
- I: That's awesome.
- C: 'Cause we're pretty comfortable around each other. We're not like negative and just be like, just like, we're not telling each other to shut up or anything. (laughs)
- 2350 I: Yea, that's good. That's great. That's really good. And so do you feel like when you gave that idea that that your idea was taken seriously by your group mates?
- C: (nodds)
- I: Yea? And what do they how do they show you that, that they take your ideas seriously?
- 2355 C: Well, you know when I'm explaining it, they're you know, nodding their head, and sincerely, not like 'oh whatever, whatever.'
- I: Oh (laughs)
- C: But yea they're taking into consideration and kind of like thinking about it instead of just pushing it aside. Yea.
- 2360 I: Yea. That's nice. That's great. Was there anything that you wanted to contribute to this problem but didn't because you felt that it might be out of place or strange or something?
- C: See she didn't want to talk about evolution, but she keeps on touching on it. I'm talking about the human evolution. And I was like she passed out a sheet of like you know like a of like websites that we check out to learn more about it, but the question that was bothering me was like back then there used to be two species of human beings that lived along side together. I was just wondering how did they

- other ones just like disappear and we're still here. And I know it has to be something to do with fitness. So I was like, I kept on waiting for her you know
- 2370 answer the question, and then she was like, 'No, we're not going to talk about it' so
- I: Yea, so you said that you know one of the human species was alive a long time ago died out because you think it was due to fitness? What makes you think that? (long pause)
- 2375 I: I think it's a great idea. I'm just wondering was it something that because you were talking about the fitness of these different animals that made you think that? Or did you learn that already, like before the class?
- C: We were talking about that when we had our field trip to the zoo.
- I: Mmm.
- 2380 C: And um I think we just we were just talking we just got done looking at primates or something like that and that's how we started talking about evolution and stuff but it just like bothers me that I'm guessing that so they died out because of us? Were we smarter than they are or were or something like that? So I don't know. Or did we just evolve, we evolved from them. I don't know, but I'm going
- 2385 to do research on that so.
- I: Yes, it sounds like it really interests you.
- C: yea
- I: Yea, that's cool. So you are wishing that you could relate that to when you were talking about the toads and their fitness and the hybrids, and all that stuff.
- 2390 C: Yea, I mean I have ideas of my own like you know about the fitness and stuff like that related to um our evolution and what happened back then, but I'm going to do some research and see you know how close I get to I don't know. 'Cause I know there's different ideas about what happened, so I don't know.
- I: Yea, that's great. I'm glad, I'm glad you're interested to do your own research
- 2395 and that you're really curious about it. That's awesome. Um, what was your favorite part of the whole class today?
- C: I don't know. I kind of didn't want to be in class today.
- I: Really? Why? Was it one of those days?
- C: Yea, it was just one of those days, but if I had to pick, I'd say ... talking about
- 2400 going on the field trip on Saturday.
- I: Yea? (laughs) Why was that your favorite part?
- C: I don't know. I'm the type of person that likes to have a hands-on experience. I really don't like to um, I'm like a visual person (lights go out; get them back on)
- I: Anyway, so sorry, go on about, when you were talking about the field trip was
- 2405 your favorite part of class today. And you were saying why that was.
- C: Um, I just like to have a hands-on experience when I'm learning 'cause that I can um contain memory easier that way if it's something memorable.
- I: Where are you going this Saturday?
- C: We're going to the desert.
- 2410 I: Fun!
- C: Yea, it's going to be fun. And we're going to stop at other places too, so
- I: Do you know where or is it a surprise?
- C: No, we know where. We have a list.

- I: Yea? Nice. That's good, that's really good. Cool and are you um what are you  
 2415 looking forward to most about the field trip? I mean you said you like having  
 hands on experience 'cause it helps you remember stuff better.  
 C: I guess just getting out of the classroom environment.  
 I: yea  
 C: I think it's kind of boring just sitting here 'cause when you talk about biology,  
 2420 it's like learning about your surroundings I guess, natural surroundings. And that's  
 what we're doing. You can't just really learn everything from a book or copying  
 the board or something like that. You have to actually go out and explore.  
 I: Mmm, that's cool. Yep, that sounds like fun.  
 C: It's going to be.  
 2425 I: Awesome. Ok. Great. Well, cool. Thank you so much.  
 C: Alright.

*Stimulated-recall Interview: Juan*

- I: So uh you just want to do a quick overview of what these problems had to do  
 with? What the content was today? Just give me a general  
 J: Ok the content of today's actually had to do with our presentation today about  
 2430 our population. So we did our presentation. And we kind of missed the first part  
 of this (points to prompts) discussion and that is about what is the main causes of  
 our population, is the developed countries or the undeveloped countries.  
 I: ah, ok  
 J: And the impact that lead to the overpopulation  
 2435 I: (simultaneously)  
 J: from the two uh the two parts, developing and developed. And then we just um  
 came up with the following, actually, (reading prompts), tell us, we were  
 analyzing the main causes. So we came up with this, the directions to this (points  
 2440 to the prompts). Population size per capita, which means population size per each  
 person consumption, times the pollution per unit of consumption. And then we  
 just kind of analyzed it, we um just talk about a little bit compare the U.S. and  
 Africa in this case, a little bit, how Africa has a 2.5% growing populaton overall  
 each 40 years, so like in 40 years, it's going to double the population.  
 I: ok  
 2445 J: And then the same with the U.S. The U.S. is a lot smaller, it's 1.1% each same,  
 40 years, or a certain amount of time, and well that's basically the um idea of this  
 problem, you know?  
 I: So when it says "reanalyze the government's claim that less developed countries  
 cause more impact than environmental impact than developed countries," what  
 2450 did that mean to reanalyze it. Like, do you agree with that claim? That less  
 developed countries cause more environmental impact than developed countries?  
 J: Less developed. Uh, no I don't agree with this part. Saying that less developed  
 countries cause more, no.  
 I: environmental impact  
 2455 J: No, not environmental. Well in some ways yea, I guess so because of the  
 growing population was going so fast, causing more pollution, more everything,

because of the big population. So in some way I would agree. But in the other case, the more developed also have a really big impact on the environment

I: because?

2460 J: Because um the developed countries have less people but they have more technology, more everything, and so they need more resources and they have more resources than undeveloped countries. Let's say-

I: (nods) They use more.

2465 J: Exactly. So for the United States it has, this is developed, and Africa. Africa is just pretty much desert, so even though they have a really high population and they didn't have enough to well in this case affect the environment. On the other hand, the United States has a small population, smaller than Africa, but um they use a lot more than the undeveloped countries.

2470 I: Ok, and then the third question (reads) "with your group, consider the population strategy that your group chose". What does that mean "population strategy"?

J: Ok, the population strategy is this one sheet the teacher gave us (looks in notebook) a strategy for each of the groups. And this was ours-

I: Oh, and you had "push the government toward free and fair global trade". Ok.

2475 J: Yea, that's the strategy that we-

I: (reads) "Then with your group, come up with a rationale for the strategy ... why it would help solve our human population problem and the benefits that would result ... be prepared to share your ideas with the class." Ok?

2480 J: We didn't share the book so we didn't have enough time. We just kind of came up with um some ideas because we needed to think about it during the weekend and then come up with the next class, with a better idea. But we just shared some of the ideas about how was it that this this id- free and fair good trade was a really a good idea with the government because um by having that the governments from two different countries are able to trade, like for example food. Sometimes

2485 we just have a lot of food, well not a lot. How do I explain this? Like um we have food left that we can just trade it to other countries, poor countries in this case, and by having this free and fair trade, we can do that, instead of right now, our government has the idea of trading with countries that are developed or they have the economy really good. So um, by having this one, it is a really good idea

2490 because of well we're going to be able to uh to move to other countries and at the same time benefit the other countries. It's one of the basic ideas that we came up with. We still need to read a little bit about the table that's in our book to understand better.

I: Ok, so let me take a peak, looke at the piece of video that she gave us.

2495 J: ok

I: As we watch it, try to tell me what you're trying to do with your group.

J: Alright.

(both watch video)

I: There appears to be no sound on the video.

2500 (both looking for volume on camera)

I: And you have no sound?! Looks like you guys are writing notes?

J: Yep, we are.



- I: So might this have been a section of lecture.
- J: Yep, this is basically, which um, we're working with this different theories  
 2505 about the environmental impact, which is population size per capita of consumption-
- I: Oh, the equation that she gave you here?
- J: Yea, it was not basically a matter of numbers but I'm saying how developed  
 2510 countries have a low population, they have a high per capita consumption, and they have high pollution.
- I: uh-huh
- J: The same in undeveloped we have the same ones. We got the high population, a  
 low per capita consumption, a low increase in pollution as time as going on. So  
 this is basically what we're getting (points to camera).
- I: That's kind of what you think she was talking about there.  
 2515 J: uh-huh, yep
- I: (reading off J's paper) Developed countries have a low population, high  
 consumption, high pollution, right. Undeveloped is a high population but low  
 consumption, low pollution, ok. Ok, alright we're just going to push pause here  
 2520 because we have no sound and the girls in the video are just writing. Um, so it doesn't appear that you're actually doing anything with your group there.
- J: Not right now, no.
- I: ok
- J: Because we were, we were fighting with the projector, and then came up with  
 2525 the we started to work on the project. And then um we kind of after this part, I think we started talking a little bit about the uh because we missed the first part (points to prompts).
- I: oh, ok
- J: Then we came up, and we got to, let's see, just writing about the different facts  
 2530 that she the teacher was giving us. About this part (points to second prompt), the second part in this case. And then and then she gave us, she actually didn't give us this one. She just read it to us. And then gave us the strategy that we needed to discuss sometime way and come up with our solution.
- I: Ok, do you feel like solving, let's look at problem two, since that's the problem  
 2535 that you thought about the most at least in class, um the claim that less developed countries cause more environmental impact, now you have this formula that helps out to rethink that. Do you feel like solving this problem is important? Do you feel like thinking about this ideas about low developed and high developed, less developed and more developed countries and contribution to environmental
- 2540 pollution and stuff. Do you think these are important?
- J: definitely
- I: questions to ask?
- J: Yea, because by having this or taking into consideration this all the facts, on the  
 2545 one side, developed countries and the other side, undeveloped countries. By comparing them, then the government or the people that are aware of dealing with this issues they will have maybe a goal to complete or something like that. So I think it's really important to ... and to reduce overpopulation that is causing,

overpopulation is causing more problems, in this case, pollution. That's one of the biggest impacts on our environment. So it's really important to address it.

2550 I: Ok, um, if you weren't particularly asked to discuss this issue about less developed and more developed countries, but um if you weren't specifically asked it in class, do you think that you'd be interested in discussing it with someone out you know outside of class if they would have brought it up, or is it not something that's relevant to your life?

2555 J: No, since this one is the biggest problem right now, in our our country and all over the world, I think I will discuss in some way. Even though I don't know if I'm going to be so involved in it, in some way I will maybe, I don't know, I aware other people about these problems.

I: Ok, so

2560 J: So people can know, or something at least.

I: Ok, um, as you were, did you guys actually have a time, the three of you to actually talk about this problem, you and Meg and Carol, or did you just listen to the teacher.

J: Yea, we were listening the teacher

2565 I: She didn't give you time to-

J: No, not really, we didn't get that much time to to um discuss this part.

I: Ok, was there anything particular that you found helpful or useful in thinking about this problem, like even me when I just ask you do you agree with it, um, what do you think you found useful in solving this problem? And doesn't have to be today. I could be something that you did in the past or some of your own personal experience or it could be something that you heard today.

2570

J: Maybe the fact that um, one of the main causes of overpopulation is poor ... some countries are getting higher population and the countries are getting poorer, poor. In this case, not not talking about the population, but the economy of other countries are going down

2575

I: right

J: instead of up. So by having other countries, or developed countries having more people, they are in some ways were they are affecting the other countries that are poorer. They are in some ways affecting the other countries by I don't know not improving their economy. Something like that.

2580

I: So I just want to make sure I understand what you're saying. Countries that are with a lot of people, or are we not talking about people right now, we're just talking about money?

J: Mmm, both.

2585

I: Ok, so countries that have a lot of people but they're really poor?

J: Um-hm, well, in this case, I'm talking about people um developed countries having more population and dealing with their own people and forgetting about other countries that need the help.

I: Oh, and forgetting about, oh so like the United States ignoring issues in Africa, for example.

2590

J: (nodds) Exactly. That's-

I: And so that's particularly interesting to you or that's something that you have knowledge about or that was helpful in solving this?

- 2595 J: I think it was the interesting points about- so I just maybe by having the in mind the consequences of population growing or something like that, where, where it affects other people, or something about that. Just by having-
- I: Ok, so you hadn't really thought about those things before.
- J: Hm-umm. Just by the (waves hand over prompts) pictures and plus I was working on our project, working with the same kind of like issue, how people in
- 2600 other places. In this case we were focusing on San Diego and people from other counties coming to San Diego.
- I: oh
- J: And there was a lot of different (lights go out). Ok in this case we were talking about San Diego and how many counties, people from other counties are coming
- 2605 to San Diego. There is a lot of difference, people coming to San Diego who are from San Diego or outside. You know what I mean?
- I: yes
- J: So there's a really big difference between people coming to San Diego, which is making the population to increase, than the people who are leaving San Diego.
- 2610 I: And this was a project you did?
- J: Yep.
- I: For this class or a different class?
- J: Yea, we just did it today, the presentation we just did.
- I: Do you think that when you worked on that project that you um contributed a
- 2615 lot to making sense of that project and to the group's work?
- J: Are you talking about the group?
- I: The San Diego project. So your group worked together on that?
- J: Yea. We did.
- I: Yea, do you feel like you had a lot to contribute to that?
- 2620 J: Um, I guess so because I did all the research.
- I: You did a lot of research. (nods)
- J: Yea, I had to make sure that I got the um, on the way in the research, I was looking well, we kind of divide the different um, like I got the numbers in this case.
- 2625 I: uh-huh
- J: of people coming and leaving. And Meg got the effects of the overpopulation, and Carol got the solutions. So on the way of research, I was finding some of the info that um maybe Meg or Carol would need. So I just pass it over to them.
- I: (nods)
- 2630 J: I guess I kind of did my job, and as I was helping-
- I: was helping them. Ok, so you felt that you had a lot to contribute. Um, do you feel like when you working on that particular project, that your group members took your research and your data seriously, the stuff that you had to contribute?
- J: Definitely, actually they were impressed in the numbers sometimes, that I got
- 2635 all the info that I got because they just, well plus they were not putting attention to all that information, just their information, in this case, the solutions or something like that. And in my case, I was looking for more info, or general info, and I was finding stuff that I just didn't need but I just put attention on it. So when they um,

- they actually, I added some info to their presentation or to part of their  
 2640 presentation, so-
- I: So you had something to contribute to their sections,  
 J: yea, um-hmm  
 I: just 'cause you found it interesting when you were studying it.  
 J: Um-hmm, because that way they would use the info for their part of the-
- 2645 I: Oh neat.  
 J: pretty much for the whole project, and plus then I was, the biggest part was the picture part  
 I: The what?  
 J: The graphic part. Pictures?
- 2650 I: Pictures, yep.  
 J: Or graphics. I was I pretty much found all of them. They actually find really interesting ones about the one I think it's 5th and J or K I think, straight through downtown?  
 I: uh-huh
- 2655 J: They are old pictures, two different pictures, old ones, no houses, well just small houses one right here, one over here, like I don't know how many houses. And then we got another picture, which we found it together, of Petco Park, which is next to K and 5th or something like that. And so those er that was the before and then the ending that I found out about, even though I don't think some
- 2660 people didn't like it, about saying, "Save the planet, kill yourself."  
 I: (laughs)  
 J: I don't know. I think it was funny. I don't know.  
 I: I thought it was funny. (laughs)  
 J: Yea, I thought it was funny too. (laughs) I don't know, at first I just didn't want
- 2665 to put it because would say 'what's this crazy guy doing?' or something like that. But then I ask my class mate or my group, and they think it was going to be funny, so I just put it down. Anyways. But yea, just to make it more interesting or something.  
 I: It's nice when you do a group project and you feel like people are...
- 2670 J: Yea, plus I just leave it to the end. Not to- not include it in my presentation.  
 I: right  
 J: Just stay it to the side. So  
 I: fun closure, humorous  
 J: Um-hmm, and actually all the class mates were laughing at it, so that's
- 2675 I: Is there anything either today with this United States Africa less developed more developed country discussion and problems or in your group project, in which you guys had a little bit more time to collaborate or work together, specifically to discuss, was there anything that you thought of contributing but you didn't because maybe it wasn't the right time or the place or it just didn't,
- 2680 anything that want to add or share with me that  
 J: That maybe I didn't include in the project?  
 I: Yea, for whatever reason.  
 J: Hmm, I think I just might with more details to explain more the problem. In this case, one of the things I just left out was um first in some way explain say the

- 2685 world 'over-population'. What does it mean to be overpopulated? So this, maybe that's the part that I just, maybe it's that I just didn't want to um take that much longer, because it would take a little bit.  
I: yea  
J: So I think that's the part I would say it was that I couldn't put it because of
- 2690 timing.  
I: Do you know, in your own mind, do you have your own understanding of what it means to be overpopulated?  
J: Mmm, kind of sort of. Um because I didn't put that much attention because I was thinking of time and other facts, so I just kind of just came over and get the
- 2695 idea. And the overall was um having lots of people, like say we got a hundred people, that's just an idea, a hundred people, and you have enough sources for ninety people.  
I: oh, ok  
J: So that's overpopulated.
- 2700 I: 'Cause you can't feed everybody and clothe-  
J: On the other hand, exactly, on the other hand if you have ninety or a hundred people and you have a hundred and ten resources, any- food, whatever it is, then you're ok. So that's the bit that I ... there are some more details to it, but that's the basic idea of overpopulation.
- 2705 I: Not enough resources for the number of people.  
J: Exactly.  
I: Ok, is it only relevant to humans? Or is it relevant to animals or  
J: I think for everybody. Any human being.  
I: Any living thing?
- 2710 J: Yea, any living thing, exactly. Yea, that's, yea.  
I: Ok, um now today's class was kind of different because you did a project and you were preparing for the project and you missed some.  
J: (laughs) yea  
I: But what was your favorite part of class today?
- 2715 J: Uh, the presentation, it was fun.  
I: The presentation?  
J: Yea, it was fun.  
I: Why?
- 2720 J: I don't know, I was anxious to the presentation. I was worrying about, when we first got here, the projector was not working, so I was kind of I don't know sad, not sad but um. I don't know since I was anxious to do the presentation and then we find out there's a problem with the plug or something and then the teacher wanted us to come back on next week I guess.  
I: Oh to postpone it for a week.
- 2725 J: Yea, postpone it. So I just wasn't  
I: You really wanted to get it over with.  
J: Yea, plus yea, I just wanted to teach other people that what we got.  
I: 'Cause you were proud of what you guys had?  
J: Yea, yea.
- 2730 I: You think it was a good presentation?

- J: Yea, I think it was. I think it was. I put a lot of effort into that one. But I pretty much designed the powerpoint presentation. I'm kind of putting facts and everything like that so I wanted to  
I: Oh that's nice.
- 2735 J: yea  
I: That's nice to have a sense of pride about what you're doing, your work.  
J: Actually yea, not always yea, but something like this.  
I: Do you think um the other two are as, do you think they're thinking 'yea, Juan did a lot of work.'
- 2740 J: No, well I don't think so. I kind of did pretty much the um overall project. They they had their part, a pretty big part, yea they had a big part, so  
I: yea  
J: They did their part. I did my part so it's  
I: You guys work well together, huh?
- 2745 J: yea  
I: That's good.  
J: yep  
I: You said that last time too.  
J: um-hmm
- 2750 I: Anything that you want to add either about today's lesson, the problems, or your presentation. Anything about how you felt about it or that you've learned about it or that you think about it or?  
J: Mmm, not really, I would say we just what um (inaudible).  
I: yea
- 2755 J: Yea, since the two the two works were related, in some way they help, in this case, overpopulation and what the solutions were about (points to prompts).  
I: Right, right, your presentation and (gestures toward prompts).  
J: Exactly, so  
I: Are other groups doing presentations?
- 2760 J: Yea, we were the last ones.  
I: Oh you were the last ones.  
J: We were the last ones, yea.  
I: Oh interesting.  
J: Yea, we were the last one, so
- 2765 I: Great. Ok, well that was easy today, huh?  
J: yea (laughs)

*Problem #6: A Day in the Life of an Average Joe*

- M: OK, well mine's easy. He's circling around for 10 minutes looking for a parking spot. He could take public transportation and not have to look for a parking spot. Done. (laughing)
- 2770 J: OK. mine is...  
M: Number 2. She throws something away. She knows the cereal box is empty, so she throws it away.  
J: Where's the beginning of this?

- M: As Maria?
- 2775 J: (inaudible reading to self)  
M: She throws it away. She could recycle it. You can recycle cereal boxes if you take the bag out. I think there's actually something you could do with the bag, but you could recycle the cereal box.  
C: 14 is paper, cause you can recycle paper. You can't recycle plastic. You can reuse it...
- 2780 M: 14...after she shops, the bagger asks paper or plastic.  
C: Paper...I had the same thing happen to me.  
M: You can take your plastic bags to grocery stores though.  
C: Really?
- 2785 M: Yeah, like outside of VONS, I know that they have a big huge thing. It's like a big, like, looks like a big trash bag, but you can take all of your bags and put them in there.  
C: What do they do with them?  
M: I think they recycle them. They do something with them.
- 2790 C: I thought you can't recycle plastic bags.  
M: I don't know if you can recycle them, like, I don't know if you can reuse them, but they use them for other stuff. Like you can take them, and they have a big huge bin...like I know the VONS in North Park they have it and there's, like, at Ralph's in Mission Valley...a bunch of grocery stores have them now, where you can take all your plastic bags. 'Cause I always save all my plastic bags and then take them there and shove 'em in there. They do something with them. I don't think they just throw them away.
- 2795 C: I wonder what they do with them. That'd be nice to know. Ask her.  
M: Um, on Carol's, she has to have paper or plastic.
- 2800 I: Mm-hm.  
M: And you know at some grocery stores you can take your plastic bags and put them in like a big thing? Do you know what they do with those?  
I: They...do they recycle the paper bags or are the paper bags made of recycled paper? Do you know? Like is it printed on the paper bag that it's made of recycled paper?
- 2805 Other: No, it says bring your bag in and they recycle them.  
M: We're talking about plastic.  
I: Plastic, um I don't know...  
M: 'Cause they collect them, but I don't know what they do with them.
- 2810 I: They do recycle them. I don't know what they end up making.

*Stimulated-recall Interview: Carol*

- I: So today was the last day of class? You come back for a final or how's it work?  
C: Um, we come back for a final I believe on mmm Tuesday and then Thursday we have a field trip. I'm not sure, but we come back next week, definitely.
- I: Today was the last like lecture day, information day?
- 2815 C: (nodds) um-hmm  
I: Cool, yea. That's so exciting

- C: I know it's almost over.  
 I: That's so exciting. Cool. Well let's watch this part of the tape that she's queued up for us. And um, let's see what's today, Thursday, May 25th.
- 2820 C: 25th  
 I: Alright, great. And um tell me what's going and what you guys are working on as we watch it.  
 C: There's not much going on today, so  
 I: No?
- 2825 C: not much  
 I: So it should be (laughs) should be straight-forward?  
 (both watch video)  
 C: So she gave us this handout of scenarios of things happening, and we're supposed to and she gave us each like a scenario. And we're supposed to come up with um like something that'll help the environment.
- 2830 I: oh  
 C: And the one that was assigned to me was ok, so Maria goes to the supermarket and then the bagger asks "Do you want paper or plastic?"  
 I: Oooohhh. Ooo that's a great question.
- 2835 C: So um, it's funny 'cause the same question happened to me when I went to Trader Joe's.  
 I: oh yea?  
 C: Not a lot of stores ask you that now.  
 I: right
- 2840 C: So um I'm thinking about it, so ok what would be better for the environment?  
 I: Yea!  
 C: And um then boyfriend automatically goes 'paper!' He's into recycling and stuff like that, right? And so I was like, "Why? What makes you say paper?" He's goes "'Cause you can recycle it and paper you can't recycle." I mean "plastic you can't recycle it." And me and Meg we were talking about that and she said that certain places um collect plastic bags and recycle them, but I don't know what for and we asked Bekky and she didn't know either. So um they recycle it for something but it's not common.
- 2845 I: Not as common as recycling paper.  
 C: um-hmm (nodds)  
 I: But each of you three, you and Meg and Juan, you each got different (gestures the size of a strip of paper)  
 C: uh-huh  
 I: little scenarios? Is that right?
- 2855 C: uh-huh (watching video)  
 I: And so you each read your own and then you, did you guys talk about them as a small group afterwards?  
 C: Mmm (watching video). We had to share the same paper, so like  
 I: Oh I see, they're all on that paper together.
- 2860 C: yea  
 (C watching video)



- C: I'm trying to remember what Juan's is. So basically Juan's is um yea, she ate the cereal so she throws away the cereal box
- I: oh
- 2865 C: And so instead of that, Juan comes up with, she could you know recycle the box.
- I: Oh the, just the box.
- C: instead of throwing it away.
- I: Cool.
- 2870 (watch video when Meg is explaining there are bins outside of grocery stores where plastic bags can be recycled)
- I: Um-hmm. I've actually seen that at a Ralph's. I've never seen that at a Vons but I hardly go to Vons anymore so maybe that's why, but what Meg's talking about, I've seen that at Ralph's before too.
- 2875 C: Do you know what they use it for?
- I: I don't but there's I was wondering that actually. I was talking with my husband about that actually. And I saw that there's a 1-800 number on the little sign that says "Put your recy- put your dry, plastic grocery bags in here for recycling" and then it has a number that's like the company that comes and picks them up. I don't
- 2880 think the grocery store picks them up. I don't think. But I haven't called the number yet. I'd like to. It'd be interesting to know.
- C: Yea, I don't shop at Vons or
- I: Yea? Me either. We only go there to drop off our bags. (laughs)
- C: (laughs)
- 2885 I: We just park and then drop them off and then leave. Um, so that you guys were working on, were they important?
- C: Yea. 'Cause-
- I: Why?
- C: um they deal with our everyday life
- 2890 I: uh-huh
- C: like all those.
- I: Let me try and stop this for a sec. Important because why?
- C: 'Cause we go through those scenarios in our everyday life.
- I: (nodds) Alright nice. And um if these were problems, well you kind of already
- 2895 answered this. If you knew about this problem outside of class instead of learning about it inside of class, would it still be important to you?
- C: Outside of class? Mmm, no because you know it's um, by being in this class, I've been taught about the problems that occur when you don't recycle. And of you know the process that that we all have to go through or these companies have
- 2900 to go through to get those resources and we're just throwing them away when we can recycle them.
- I: Um, nice. So if you had not learned that in the class already, then you wouldn't be thinking that way.
- C: (shakes head)
- 2905 I: Oh, I see. But what about what you were just telling me were you with your boyfriend you said at Trader Joe's? So how did, tell me how that scenario happened, like what, did he answer first or tell me about how that happened again.

C: Oh ok. This is our first time at Trader Joe's. Bekky told us, told the class about it and I was like you know I want to check it out. And so um we were over there  
2910 in that area, and so we stopped by and we bought some stuff and the dude asked us, "paper or plastic?" And I was standing here thinking. I was like 'wait a minute'. I'm thinking. And then my boyfriend goes "Paper!" automatically. And then you know after we got out of the store, he's like, "What took you so long?" I was thinking you know what's going to make a a bigger impact, you know? And  
2915 he goes, "Well, duh. You can recycle paper and plastic you can't." And I mean it's San Diego. We can only recycle ones and twos, not the others.

I: Right, right.

C: And um his family is into recycling and stuff like that so he already knows. Like when I was growing up, we were never told to recycle anything. We threw  
2920 everything away so

I: Did you grow up here in San Diego?

C: I grew up in Amarillo, Texas.

I: Oh, ok. Oh wow.

C: It's a really small community and not a big population so I guess um I don't  
2925 know. We were never taught about um the environment in school, at least I don't remember. We were taught about car pollution and stuff like that but nothing about recycling and stuff. Not much at least.

I: So have you, have you and your boyfriend talked about other things, not just plastic or paper but have you talked about-

2930 C: Oh yea!

I: What else?

C: Like um the other day we were talking about hydrogen cars.

I: Oh cool. Yea.

C: 'Cause I saw it on TV. And I was like so, you know, "If you could would you  
2935 buy a hydrogen or an ethanol car?"

I: Oh, huh

C: 'Cause at least well when we were talking about it he was like "Well I don't really know because there's not that many hydrogens". I can't afford one of those electrical cars or one that runs out of ethanol. You know, but we heard that  
2940 ethanol, you actually mix it in gas, like in gasoline.

I: Oh right. Ok.

C: Is that right?

I: It could be. I learned about that a few years ago and I don't remember the details.

C: Yea, there's different um I believe different ways of using it. But I was trying  
2945 to ask him because I learned something the other day while doing an assignment that was given to us, that ethanol is actually kind of like goes through the same process the way gasoline is made. It costs about the same price.

I: Oh interesting.

2950 C: But um, basically, it's made out of corn or something like that.

I: Um-hmm.

- C: And it's actually bad for us. So we should that's why I think hydrogen or electric cars would be better because you know one (inaudible) is running out of ethanol. So
- 2955 I: Nice, oh that's cool. So what if you you know come across something in the paper or see something on TV or have a conversation with your boyfriend in the future, like after now that you've taken this class? Do you think you'd have a different perspective or would you think about things differently?  
C: Oh yea.
- 2960 I: Yea? You think so?  
C: I do now. Like when I see something or when I read something or when I hear something over the news, I actually think about it, whereas before I'd just like turn the channel. (laughs)  
I: (laughs)
- 2965 C: It was boring, turn it. No, now that I have the information, I can actually think about it.  
I: That's awesome. That's really awesome. That's cool. Um, so when you were working through just your three little scenarios in your group, was there anything that helped you solve the problem or that you found useful to solve the problem?
- 2970 Any information or anything anyone said?  
C: Well, I didn't know about the whole plastic recycle thing andum yea, I was thought pretty um useful. I mean I'll drop my bags off there now because my dad shops at Albertsons and stuff like that and we have a bunch of bags. But we have to reuse it, but we end up throwing it away at the end anyways.
- 2975 I: So you use it as like a trashbag or something?  
C: Um-hmm, trashbag, or using it to carry things and stuff.  
I: Oh yea. That's a good idea.  
C: We actually after we shop, just like gather them all and stick them in one bag so we can use it for later. But it ends up getting thrown away. So you know, might
- 2980 was well recycle it.  
I: Yea, it was useful knowing that there was that option for plastic bags, somewhere that you know of now where you can take them and drop them off if you're done using them.  
C: um-hmm
- 2985 I: Oh that's cool. That's good. Um, did you feel like you could effectively or did you have a good way to help solve these scenarios. Do you feel like you had kind of the knowledge that you felt comfortable enough talking and solving them.  
C: Yea, we all had the knowledge 'cause they were everyday scenarios of what happened to us so we were pretty comfortable with it. We just got the answer
- 2990 right away.  
I: Yea?  
C: It was pretty easy.  
I: It was easy to talk about those?  
C: um-hmm
- 2995 I: Well that's good, that helps you that helps you, well I don't know I would think that would help you see that when you come to those decisions again and again,

you know when you shop at the grocery store next time and someone asks you paper or plastic, you might already know what you want to tell them.

C: um-hmm

3000 I: I don't know. Little things like that can make life easier.

C: yep

I: It doesn't have to be a huge decision every time. You can just say, "paper" or if you need some plastic bags at home, "plastic" or something like that.

C: (nodds)

3005 I: Oh, that's cool. So um, and did you feel, yea I think you've already told me this, but did you feel like what the three of you were talking about that your comments and your ideas would be taken seriously by your group mates?

C: um-hmm

I: Why? Why did you feel that way?

3010 C: We just work well as a group. We listen to each other's ideas and stuff without just disregarding right away. And we talk about it like this one Meg brought up the fact that well you can recycle plastic. I was like "Really I didn't know that. No way!" So we actually asked Bekky about it.

I: Um, nice. That's cool. It's nice that you have that-

3015 C: It's easier when everyone is open to new ideas instead of just being narrowminded.

I: Yea, I agree, definitely. Was there anything else that you wanted to talk about or that you wanted to contribute to your group but you didn't say anything because it thought it might be out of place?

3020 C: hm-mm (shakes head)

I: No? Nice. That's good. So what was your favorite part of class today?

C: Um, the discussion part.

I: This part right here?

3025 C: Yea, yea. I guess 'cause we were able to interact. Um, the presentation was like cool. I like the pictures and everything but um I forgot her name. I didn't even catch her name because I came in a little late but she was like talking really really quick, and like Bekky said, she was talking about genetics, like you know we've gotten into you know just a little bit into that but not a whole lot. And I mean the pictures were cool, and the studies that she did was pretty interesting.

3030 I: What was she showing you pictures of?

C: Like um different places that she went to like in un probably she showed pictures like of Baja California, and Puerto Rico and a different um (lights go out; get them back on)

I: Ok, so pictures of Baja California

3035 C: And um, the springs and stuff and she talked a little-

I: Mmm, did she tell you about the bugs?

C: Yea, the little water bugs

I: Saucer bugs, um-hmm

3040 C: And she also talked about um, actually we were talking about um, she got into Borrego Springs and that was something we already did. We went on a hike.

I: Oh, you've been there. You went there with the class?

C: um-hmm

- I: Oh that's cool.
- C: So that was cool.
- 3045 I: Did it give you more information about a place, now that you've already visited it? Was it a little easier to understand what she was talking about there?
- C: Um, yea, a lot of it, she was talking about like well she went into talking about introducing like different species into a place where you know it normally wouldn't be existing. Like um like she was talking about Borrego Springs and she
- 3050 was talking about palm like palm trees, like I believe palm dates is how they're called?
- I: Ok, yea, date palms.
- C: Yea, date palms. And she said that most of them don't like occur there. Like people actually bring them there. And we actually hiked to a sp- a um part of the
- 3055 um the spring where there were palm trees.
- I: Yea
- C: And we were questioning whether or not they were like native or not. And most likely, she said most likely they weren't.
- I: I see, interesting. Wow. Nice. Huh. That's really interesting. But you like the
- 3060 discussion part better because you could talk and interact with each other you said?
- C: um-hmm
- I: Ok, that's cool. Was it just a short part at the end?
- C: Yea, it was kind of short.
- 3065 I: When your discussion happened? Nice.
- C: It was like about 20 minutes at the end of class.
- I: Yea, that's good. Did you after you discuss with each other, did you share your ideas with the larger group?
- C: Yea, we did.
- 3070 I: You did?
- C: And we got to hear what other people, other people's scenario was and what they thought about it.
- I: Were there any comments that you made about other people's scenarios? Or any ideas you had about-
- 3075 C: No, it was pretty much straight-forward.
- I: Kind of like the ones you got?
- C: Stuff that we've learned in class too.
- I: That's cool. What were some of them? Were they things that you've thought about before yourself?
- 3080 C: I don't know. They were really common things. One was like um, what was it, something about using the AC in the car or something like that.
- I: Oh
- C: And like rolling down your windows. Like when you're on a freeway you shouldn't roll down your windows 'cause it messes with the way the wind flows or
- 3085 something like that and it slows down your car. I guess um it eats up the gas.
- I: Oh interesting. So would it eat up more gas than if you just closed your windows and turned on your air conditioner?
- C: Um yea, um-hmm.

- I: Is that what you guys were talking about? Oh wow.
- 3090 C: If it's a new car.
- I: Then it's a better usage of gas to close the windows.
- C: Yes.
- I: And use the air conditioner.
- C: Um-hmm.
- 3095 I: Interesting. Well that's cool to know. You taught me something new today. I never knew about that. I never thought about that before. About the drag of the air or the air resistance or whatever. Oh that's really cool.
- I: Was that something that you had heard before or that you have wondered when you were driving around or anything?
- 3100 C: Yea, I knew that because my boyfriend told me about it.
- I: Oh he did.
- C: I don't know. He's not really into like um. I can't explain him, like I don't see him as an environmentalist but he does a lot of things to like you know preserve resources. He's cheap.
- 3105 I: He's cheap? (laughs)
- C: (laughs) He's cheap.
- I: Well it can save money too, can't it?
- C: Yea.
- I: Yea, that's neat. How did he learn all the stuff that he does, or how did he learn
- 3110 to make the choices that he does?
- C: His parents recycle. His parents recycle a lot. They recycle cardboard boxes and um also um he's into cars. And um he used to race when he was like younger and like he knows all these things about aerodynamics and how things work and stuff. He likes to like save up on his gas mileage too.
- 3115 I: Um-hmm, oh that's really cool. So he learned some stuff from home and some stuff from being really into cars.
- C: um-hmm
- I: Oh neat. That's really cool. So are you uh sharing any of the information you learn in here with your family or any of your friends and stuff?
- 3120 C: Um-hmm. My little sister. All the time, just like. I guess when you're at that age you don't really care but when you get older you're like you know.
- I: How old is she?
- C: She's sixteen. Yea, at that age. (laughs)
- I: So you tell her stuff and what does she say?
- 3125 C: Recycle stuff. She doesn't really care, but I make her do it. Especially, well especially when she trashes my car with like her cans and stuff. I'm like go throw it in a bin, you know, a recycling bin. Don't throw it in my car.
- I: Good. Yea, there you go. Don't recycle in my car. Recycle in the recycle bin.
- C: And like you know she likes to like eat and just stu- like litter. And I'm like,
- 3130 'No, don't do that.' So
- I: Good. You're good at being an older sister.
- C: It's getting there. It's getting there, you know. If she gets tired of me nagging her, she'll just do it, so

- I: That's awesome. That's really good, that you're working on that. How about you  
3135 said your dad always gets the plastic bags at the grocery store?  
C: um-hmm  
I: Have you talked to him about what you you've learned about, the bag thing?  
C: I haven't actually talk- no because I don't know. I guess I haven't had the  
3140 chance and I don't know if he'll listen to me 'cause he's already you know, like  
they say you can't teach an old dog new tricks  
I: (laughs)  
C: so I really don't want to bug him. But the best I can do is do it for him. You  
know?  
I: Or maybe even just tell him that you know places that you can recycle plastic  
3145 bags, because he might not have known just like you didn't know. So if he gets  
too many. You know how sometimes it's so easy to collect so many bags and then  
you go "I don't know what to do with these" and then you just throw them all  
away. I used to do that all the time.  
C: Are the only places Vons and Ralphs?  
3150 I: Vons and Ralphs. Do you have any of these nearby?  
C: Yea, we don't. No we don't have any nearby. There aren't any places that  
recycles plastic bags. But I mean like I know for sure, like for him, he'd only go to  
the places that would be more convenient for him. It's just better off for me to do  
it for him instead.  
3155 I: Yea, instead of trying to fight that battle with him.  
C: Yea, and now I know they don't offer paper anyway, so you can't recycle that.  
I: Yea.  
C: It's easy to make plastics.  
I: You mean at his, the Albertson's where he goes?  
3160 C: Um-hmm  
I: They don't offer paper bags?  
C: Well no, they don't.  
I: oh  
C: A lot of supermarkets don't offer paper bags anymore.  
3165 I: don't anymore, mmm. Why do you think?  
C: It's easier to make plastic bags probably and yea, basically that's it. You know,  
they just want profit.  
I: Yea, it's cheaper to make the plastic.  
C: Businesses aren't very environmentally fr-  
3170 I: Yea, it's cheaper and easier. Yea, that's cool. Cool. Well is there anything else  
about the class or anything that you wanted to mention or how it has affected you  
or your opinions about  
C: Oh, well I guess it has affected me a lot. I really liked this class. You know it's  
my last semester here and I'll be transferring, but I've learned so much and I'm  
3175 glad I took this class.  
I: Yeah! Oh that's great.  
C: I mean I ended the last semester with a bang because this is this is going to be  
a part of my life, you know, it's changed me. And I've learned a lot of things that I  
haven't learned before about you know the environment and how you know how

- 3180 industries are getting like our resources by digging into you know, tapping into oil mines, and all sorts of stuff.  
I: So give me one example of how something you've learned in here has changed you like you said.  
C: I think the biggest part would be just recycling.
- 3185 I: Um-hmm  
C: Um, like we're running out of resources and we're just digging into places that we're not supposed to. We're destroying habitats, endangering species, and you know it's not right. Pretty soon we're going to be headed to our destruction because there's going to be nothing left.
- 3190 I: If we use it all up.  
C: You know I've actually talked about this with my dad and he goes "Well why are you worried about it because you're not going to be living long enough to see the destruction." I was all like "Eh, but you could do something about it now, so why just like turn the ch- you know your cheek." And what about your children's children? You know?
- 3195 I: yea  
C: And so on. But I mean it's it's made a big impact on my life, I think.  
I: Did you say that to him?  
C: Hmm?
- 3200 I: You know, what about the people living here in the future, what about them?  
C: Oh yea, I told him. He's just you know just he's an old person. What can I say? (laughs)  
I: (laughs) He's stuck in what he likes to do?  
C: Yea. He's stuck in his ways. So you know.
- 3205 I: Well good for you for you know, at least giving him ideas, your ideas. I think that's a good place to start, you know? And like you said, if you know there's times when you can go pick up bags and recycle them for him, that's great.  
C: (nodds)  
I: That's a good way to be helping out.
- 3210 C: I even told my boyfriend, I'm like, "You know, when we get married, and when we have kids..." Oh and then you know about the whole pollution and population growth and stuff like that?  
I: Oh yea.  
C: You know what? We've even talked about it, like we want to have two kids and then maybe adopt afterward and we were like we're going to teach our kids how to like recycle and all that stuff.
- 3215 I: Wow, that's great!  
C: So even as far as that.  
I: That's fabulous, that you guys are talking about that and that you agree on it
- 3220 too, you know? So it's not like one of you wants to do one thing and the other wants to do something else.  
C: Well, he wants to have a lot more of our own, but I'm like two is all I'm having 'cause I'm the one going to be pregnant, not you. (laughs)  
I: (laughs)
- 3225 C: So it's all up to me.



I: That's awesome. Good, yea. Good for you for for holding to your opinion.  
That's awesome. Cool, well thank you for doing all these interviews. It's been  
really fun talking to you.  
C: You're welcome

*Problem #7: Environmental Careers*

M: OK. Who are our people? Henry.  
3230 J: Henry, and Michael, Glenda, and Julio.  
M: Well, these two go together, 'cause they both have toxicology.  
J: OK.  
M: So now we just need to find the person who likes toxicology.  
C: What do we do?  
3235 M: You have to pick a person, like your friend, and then you pick like what they  
can...  
C: A career?  
M: No, like what school they would go to, and then like what type of programs  
you could do. Like, this one says UC Davis has a department of toxicology, so  
3240 then there's like an environmental toxicology program. So we need to figure out-  
this one right? Margo-  
J: Yeah  
M: -reacts to environment toxins. So she'd want to learn about toxicology. So  
she'd go to UC Davis and do this.  
3245 J: Yeah. It's ready to go.  
M: OK. So now...which one? Let's figure out for Henry or something I guess?  
J: OK  
M: "Henry likes science topics"  
C: Maybe this one? (long pause) ...can specialize in environmental  
3250 communication. They're two different departments.  
J: Maybe doing this one.  
M: What did it say? "He'd rather take science classes, but he prefers reading pop  
science books and just talking to scientists about what they do. Henry also likes  
to write and is known to be a good communicator." So there's like, environmental  
3255 journalism...and then that one then? Would that-?  
C: Yeah. 'Cause this is for journalism also.  
M: Yeah. So Henry's gonna go be a journalist at Fordham University.  
C: I like that one.  
M: Yeah, this one. She wants to protect wildlife, so where's she gonna go to  
3260 school? This one is probably hers, 'cause this is like the department of wildlife...  
C: ...environmentally minded...  
M: Humbolt State? Isn't that here? It's like not that far away. OK. So then Julio  
likes...first he has ----, a farm with kids.  
J: There's no more choices left  
3265 C: So yeah...  
M: Yeah, this is like...you're helping out. OK.  
J: Last one.

## Stimulated-recall Interview: Meg

- 3270 I: So can you tell me what you guys did today. Just kind of give me like the overview of what today's class and what your subject was just so I'm kind of on board.  
M: I left my stuff outside, but that's ok. First we um on Thursday we had she passed out these strategies to every group.
- 3275 I: Yes, I remember. I talked with Juan about that.  
M: Yea and so then we finished up with that. Everybody had to tell their strategy and then like why or why it wouldn't work and the good things about it so that was the first part of class. And then the second part we got these little things where it had like a friend and then what they like to do and then it had a school that said like basically what you could do there and then what kind of um program it would be in. So we had to match everybody up so ... I kept this one because I want to do education. But we have that was kind of what we did today. And then she gave us a bunch of handouts on stuff if you wanted to do look into going into environment for the rest of your education.
- 3280 I: So it was like future stuff how to how to-  
M: It was almost like a career day where if you study this, this is kind of things you can do.  
I: Gotcha.  
M: So it was fun.
- 3290 I: 'Stable job out of college' and then you got Sonoma State which offers Education & Environment.  
M: And then we talked about what plan like what program they'd be in. So he'd be in environmental education where he would be focusing on the environment but teaching elementary age kids.
- 3295 I: And then each of guys shared your little person?  
M: Well it was kind of like a game. Every group got all four of them and we had to match them up. It was like a little game and then-  
I: Oh you got four people.  
M: Yea we each we had four different people and said it like what they liked,
- 3300 and we had to figure out what school we would send them to and then what program they would work on once they got there.  
I: Oh neat.  
M: So it was fun.  
I: So it was four of the people, four of the colleges, and four of the programs.
- 3305 M: Yea, um-hmm.  
I: And it was like a puzzle putting together the pieces.  
M: Yea it was like a little puzzle. Um-hmm.  
I: Ah. Cool. Ok, I have a section of the videotape we're going to watch together. As we watch tell me what you're trying to do with your group. So
- 3310 let's see.

(both watch video)

M: Yea, it looks like we're explaining this (points to game) thing.

(both watch video)

M: And so here we're just doing this game part.

3315 I: Going one by one, ok.

M: Um-hmm

I: So did you feel like solving this problem was important to you, the problem being the puzzle that you had to complete when you were done. Did you feel like this was an important thing to do.

3320 M: Um-hmm. Well I liked it because well last week also had a reflection, part of our reflection notebook was to write about like what you wanted to do like in the future. Like if you were going to plan on transferring, what were you going to essentially major in. So this kind of helped I think with probably a lot of kids in the class who I think are confused about what they want to do. And  
3325 this is supposed to be an environmental class for non-majors but I think that it's changed a lot of our minds and now we're thinking well maybe now we want to switch and do something in environmental or science major.

I: Oh neat.

M: It was a good thing today. I like it a lot.

3330 I: What did you particularly like the most. I know that's a question later, but since you said that.

M: Probably the just figuring out well this sheet is really helpful because it'll tell you it's like the sheet on the environment so it'll tell you like all the schools that are nearby what they offer. So like at Sonoma, they offer the education in planning studies. That's the the one I'm probably going to look into. And then like Humboldt State has a lot of science stuff, so it was just a good fun day learning about what you could do if you wanted to do something with the environment. You don't necessarily have to be like in the lab with the white coat on mixing chemicals. There's other things you could do like park  
3335 ranger or teaching kids about stuff or  
3340 I: working in museums, nature and science centers and stuff

M: Yea, fun stuff. Like doing what Angelo, you know how Angelo he goes and collects all the snakes and frogs and stuff.

I: Right. He sounds like he has a fun job.

3345 M: Yea, that would be a fun job, but I wouldn't be able to pick up snakes and stuff.

I: Oh you don't like all those.

M: Huh-mm

I: So this is important because it relates to your career?

3350 M: um-hmm

I: Any other reason you think this is important or an important thing to do today with the puzzle.

- M: Um, well I think it's important. I don't know if other people in the class would do it or not, but I'm going to go home and talk to my little sister and tell her 'Hey look. This is some of the fun things you can do if you want to do ...' Say for instance if she wants, she wants to be a monkey trainer at the zoo. She wants to like work with the monkeys and train them and teach them sign language and stuff. So I will probably go home today and tell her like 'Well look if you get a degree in some sort of science, then you can work in the zoo and you could work with animals.' So I'm definitely
- 3355
- I: Yea, she can also volunteer at the zoo.
- M: I'm definitely going to be telling like people I know like get interested in science. These are all the things you can do.
- I: And what hold old is your sister?
- 3360
- M: She is going to be 14 in September.
- I: Oh so she's going to be a ninth grader in September. Yea, plan ahead, huh?
- M: Yea.
- I: Ok, as you were working through the problem or the puzzle figuring out the students with the universities and their and the majors, is there anything for example your own knowledge or a group member's comments or your teacher's comments that helped you or that you found useful in solving the puzzle? Is there anything in there that you found particularly useful?
- 3370
- M: Um, well all three of us kind of we each read the friend, like the person we were trying to help out. And then all three of us each like then had an input so like on one of them it said he liked to write, and I noticed that it said he liked to write but the other two didn't. So I noticed like oh well there's one that's environmental journalism, so each of us like ... When you read it you don't necessarily soak up all the information so the three of us each reading the problem, and then we each had a different intake like in one problem. Like in this one I didn't see that he liked to work with children, I just saw that he liked that he was confused about what he wanted to do. He wanted two different things. But Carol I think noticed that he said that he liked to work with children and that he also wanted to do something with the environment. So we got to figure out that he could do Environment & Education.
- 3375
- I: Oh ok, oh cool. Um, it says to fast-forward to that but does is it seem like really need to?
- 3380
- M: No.
- I: Since it was just reading from the slip. Um, did you feel like you could effectively contribute to solving this problem so you each got a slip and some information but do you feel like you particularly, Meg, were particularly helpful in solving this problem and why or why not.
- 3390
- M: Um, just cause we each noticed different things like when you like again when we read something, we each like you'll remember a specific thing, like something will jump out at you so that kind of helps that you remember a specific thing from the person. But ...
- 3395

- I: Do you think that if you fast-forward a little bit to the um let's see.  
 (both mumbling about how to work camera)  
 (both watching video)  
 M: Oh this is the one about journalism.
- 3400 I: Oh the writing one.  
 M: Yea, how I noticed it, it said he liked to write.  
 (both watching video, tapping in video)  
 M: Yea, see. Carol just pointed to the school.  
 (both watching video)
- 3405 M: So each of us, we read it how just immediately figured out the school and I  
 figured out the program and then (gestures hand moving forward) so we each  
 got something both something different out of it.  
 I: Each of you, cool. Um, do you feel like when you made suggestions, like 'I  
 think this student with this college' or 'I think this program within this college,'
- 3410 do you think that um you've been working a long time now with Carol and  
 Juan. Do you feel like they took your suggestions seriously?  
 M: um-hmm (nodds)  
 I: and things that you said were valued?  
 M: (nodds)
- 3415 I: Anything in particular that you can think of?  
 M: Probably with the journalism one because that was the one I noticed where  
 it said he liked to write. Because we were kind of confused about that one so  
 that I noticed oh he likes to write so he's probably going to want to be writing  
 in maybe journalism or something so in a way that one was a good example ...
- 3420 'cause they took it seriously and they were like 'oh yea.'  
 I: I think I asked you this last time, but in general when you're working with  
 your group, do you think in general your opinions or suggestions are taken  
 with a lot of weight or do you think you kind of just feel dismissed or ... do  
 you know what I mean by that?
- 3425 M: I think that each, each of us take each other's opinions like equally. It's not  
 like my opinion is better than Carol or Juan's but if my opinion is treated the  
 same, it's like as if it was their own opinion so it's just equal.  
 I: Like I remember when I was in school. Sometimes I'd be in a group and I  
 knew there was like somebody in the group who kind of always got
- 3430 everything right.  
 M: yea  
 I: It's like no matter what I thought and the suggestions I gave, we always kind  
 of went with him. I keep thinking of this exact person.  
 M: yea
- 3435 I: Do you kind of feel like that happens in your group or not really?  
 M: Mmm, not really. Like some of us are more shy than others so like not  
 saying, this is just an example. Like if Juan knew the answer in his head, he  
 might not necessarily spit it out, but if Carol knows it, she's just going to blurt

- it out right away so. It's not like one of us is smarter than the other. It's just a  
3440 matter do we really want to like spit out what we're thinking in our head like  
...  
I: So Juan is less assertive or Meg might be a little more assertive in the  
circumstance.  
M: yea
- 3445 I: But if the answer doesn't come out at all and you're all just sitting there  
pondering, Juan will contribute?  
M: Yea, um-hmm.  
I: Ok, and you feel comfortable always contributing?  
M: um-hmm
- 3450 I: Do you ever sometimes feel like 'Oh I'm not going to say that because that's  
... I don't want to feel stupid' or anything  
M: No, I think over the semester it's gotten better. Like in the beginning I  
would say weird random things that would not make any sense to anybody.  
But now I'll say them and just see. Usually they'll just laugh and like 'Why do  
3455 you think of those things?' or something.  
I: But you still feel like you have a lot to contribute to the group?  
M: yea  
I: Ok, great. Is there anything today that you wanted to contribute to the group  
or that you wanted to discuss with your group but it just didn't seem like it  
3460 was appropriate or you didn't want to or it seemed like it was out of place for  
some reason? Anything in particular that you can think of?  
M: Not anything I can think of. Today wasn't really about like whether or not  
you were smart and knew anything about it. It was just basically just like Ms.  
Darner was telling us information on careers and stuff so we were kind of like  
3465 I was talking about well we were also talking about the Peace Corps and stuff  
and how you would have to learn another language. So we kind of were  
talking about if we knew another language and we were joking around 'cause I  
know sign language so me and Carol were joking. She was saying "Well I  
don't think they have a country that's only deaf people, so you can't be in the  
3470 Peace Corps." so we were just kind of joking around. I think it's gotten better  
over the semester where we can each kind of say whatever we think and not  
worry about like 'Are these people going to think I'm a weirdo?' or 'Am I  
going to be taken seriously?'  
I: Yea, well that's good.
- 3475 M: yea  
I: Um, uh I should have written it down because I was listening to you and I  
zoned on what I wanted to say. Hang on a second. Oh did you mention to  
them. You're interested a little bit in elementary education it sounds like. Did  
you happen to mention that to your group?
- 3480 M: Mmm, I probably have over the semester. I don't know if necessarily today  
I was like 'Oh this is perfect.' or something. But I was like when we were

3485 talking about this guy, I don't know if I said it or not, but I was thinking it. I was like "Oh that's something that I could look into or something." But I know over the semester I've told them 'cause we've talked about like what do you want to major in and stuff. Like when we do on-campus labs, we talk a lot more than when we're on field trips.

I: oh yea

3490 M: Because on field trips we're usually listening to somebody, but in the on-campus labs we're usually doing like testing water so there's more time to like get to know each other. So like then then we'll talk about like what do you guys want to major in, what are going to do after this. Carol's going to be transferring to SDSU in the fall so we talk about that and how she's going to major in what she wants to major in and stuff like that.

3495 I: And were you interested in environmental studies and science before you came to this class?

3500 M: A little bit. I wouldn't say that I was just like gung-ho let's recycle. Like my sister, it's kind of weird. I have another sister who's like a year younger than me. Last maybe two years ago she was all in to the environment and recycling and everything and I would just get like annoyed. We had this box in our kitchen where we had all the recycle stuff and I would just get annoyed that it was there. And she would not take it to the we have a bin by a park by our house. And I would always complain like 'Why don't you take that over there. Why don't you do something with this.' But now I'm the one. She's like doesn't care anymore. She's kind of over it, and I'm the one running around after them 'Are you going to throw that can in the garbage? No, give it to me. I'll take it to the recycle place.' So I like have a bag in my car to keep cans or soda bottles. I have things in my room. I collect the newspaper now. I'm saving everything now.

3510 I: That's awesome. Do you think (lights go out) ugh.  
(talking about getting lights turned back on)

I: Why do you think, do you think that your your um passion to recycle and care about the environment now, do you think it's going to last or like your sister do you think it will kind of wane?

3515 M: I'd like to think it'll last. Like I hope it will. I'm going to try to keep sticking with it and I'm going to look into some of these programs at the schools 'cause I think is something I think ... This is probably the first thing in school that I've really learned where I just go tell everybody about. Like I go home to my mom and while we're eating dinner I tell her everything I learned today. And so it's kind of the first thing that I'm real gung-ho about and want to just keep going with and so

3520 I: Oh that's cool.

M: I think it'll last.

I: And you came in not that gung-ho, so something happened in this semester.

M: yea

- 3525 I: Do you think it's specifically um Ms. Darner I couldn't remember her last name, or do you think it was the act- the curriculum and the problems that you did or do you think it was just awareness of just the field trips or anything in particular?
- M: Um, well this is one thing that me and Carol were talking about the other
- 3530 day. Is that we think that it has a lot to do with Ms. Darner. And when we went on the all-day field trip we were with the other teacher Gary who we would have theoretically had class with if we hadn't ... if she hadn't been doing this study
- I: right
- 3535 M: this semester. This is like a once-in-a-lifetime thing for her. I don't think she's going to teach another class after this. So kind of feel, we both feel like really lucky and fortunate that we got in this class because we think that we learned a lot more about like recycling, and we also learned about just random stuff like at Target they have the Method brand, which is more
- 3540 environmentally friendly brand. So we just learned like interesting things like Starbucks, they're environmentally friendly
- I: eco-friendly, uh-huh
- M: yea and they have like the organic grown. I think that we learned a lot more like real life situations and I think it was lot more interesting than ... I
- 3545 don't know how Gary teaches but I think Ms. Darner's approach is a lot better. And that's part of like the problems and stuff that we did and the field trips also helped because it showed you in real life like when we went out to the water dam and the recycling and showed you real life things. So I think it had a lot to do with like your teacher 'cause if you're not interested in your teacher
- 3550 than you're just going to zone out in class and fall asleep.
- I: Why do you think the problems were good?
- M: Because they make you interact with a group. Like I also think that in like a class setting it was good that Juan and Carol were my partners everyday, that we didn't rotate around, because we got more comfortable with each other
- 3555 and I think the problems were good because they were all like real life problems like something you could relate to. We did on the ... I don't know what they're called. They're called the Channel Islands, like Catalina.
- I: um-hmm
- M: about some foxes that live there. And they just live on one of the islands
- 3560 and so that was kind of cool to learn about that because when you drive up the coast you see Catalina all the time and all the other islands, so it was kind of just stuff you could relate to and it was fun. So that was good.
- I: Cool. Anything else about today's class that was particularly fun, you said one of your favorite parts was um
- 3565 M: Yea, the environmental careers.



I: and this gave you some insight into potential potential for your future.  
Anything else that you want to share about today's class that you didn't get to share about that you'd like

3570 M: Not really. I just basically like the careers part of it because I always had this picture that if you're majoring in some sort of science, you're going to be stuck in a lab, like dissecting animals or doing something boring or not, like with a bunch of old people with glasses. I had this typical stereotype so this kind of opened your eyes to all the different things you could do. And she told about some of the jobs you could do and then she also told us about like when  
3575 we had guest speakers come in and when we were like interested in their jobs, she told us like what kind of degrees you want to get and that type of thing.

I: Cool. Ok, any other questions or comments.

M: Mmm, not really.

3580 I: Ok, thank you so much. This was your third one right? Did you meet once with Krista?

M: (nodds) I think so, yea in the very beginning.

I: Ok, so I think we're done.

M: yea

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