Students' Use of Science in Making Socio-ecological Decisions

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Abstract

A fundamental challenge for science education in a democratic country is preparing citizens to make informed socio-ecological decisions. We offer a framework for analyzing how students approach environmental decisions. The research questions explored include: When presented with a socio-ecological issue, how do students investigate and explain the issue and what consequences do they predict for their possible actions? What decisions do students make and how do they justify those decisions? What values and other resources do they draw on as they make decisions? We developed two interview scenarios, one about purchasing strawberries and one about a proposed water bottling business, and interviewed 22 elementary, middle and high school students in a Midwestern US state. Findings highlight the role that factors other than school science played in students' decision-making practices. Students who had relevant out of school experiences and practices drew on knowledge and values from out of school resources more than school science. This work raises questions for how school science can be designed and implemented to help students connect in and out of school experiences to become more informed and engaged socio-ecological decision-makers.

Introduction and Research Questions

Young people who are in school today will be asked to change their lifestyles on the basis of scientific arguments about the environmental effects of human actions. Most people who have studied the scientific evidence are convinced that if we do not undertake voluntary changes in policies and lifestyles on a massive scale, our children will endure involuntary changes on a much more massive scale, as we encounter the consequences of global warming, loss of biodiversity, and degradation of water resources. This is a fundamental challenge for science education in a democratic country. We must prepare our children to make the decisions that confront them in responsible and well-informed ways. Some of these decisions will have to do with their private conduct as consumers, workers, and owners. Other decisions will concern public policy roles students will take on as they become voters, volunteers, and advocates.

In this paper we propose a framework for analyzing how students approach both public and private environmental decisions. We use this framework to analyze the decision-making practices of students who we interviewed about several socio-ecological issues (one related to water and one related to food). Finally we consider the implications of our results for the school science curriculum. We explore the following questions:

1. When presented with a socio-ecological issue, how did students investigate and explain the issue and what consequences did they predict for their possible actions?
2. What decisions did students make and how did they justify those decisions?
3. What values and other resources did students draw on as they made their decisions?

Framework and Literature Review

We make dozens of socio-ecological decisions every day. For example, when we decide whether to buy organically or conventionally grown produce, or whether to drive to work or take the bus, we are making decisions with environmental consequences. We also participate in decisions about public policies when we vote for a candidate, decide whether to accept rezoning of a parcel of land, or choose to volunteer for a political organization. Most of these decisions we make quickly and seemingly with little thought, relying on heuristics that frame and limit our choices (Tversky & Kahneman, 2000).

In this paper we are concerned about the reasoning that underlies the heuristics. Some of our decisions are indeed as quick and careless as they appear. In other cases, we are aware that not everyone would approve of our decisions, and we have considered different points of view about courses of action before deciding how to act. Thus our daily choices, although made quickly on the basis of habits and heuristics, are often guided by lifestyle and policy choices that we have made more carefully and deliberately. These lifestyle and policy choices are political in nature. That is, they involve reconciling different values and points of view. We normally think of politics as a social process, occurring among different people and groups. In a Vygotskian sense, though, we also internalize those political debates through engaging in inner speech, so the reasoning of individual students that we describe in this paper reflects the internal politics through which they arrive at their decisions (Vygotsky, 1986).

We are especially interested in the role that scientific knowledge and practices play in students' internal politics—their socio-ecological decision-making. It is apparent from our data, though, that students' reasoning is not solely or even primarily scientific. Many other factors such as students' family and personal values, family practices, and economic considerations also affect their decisions. We begin by exploring the interplay between science and some of these other factors with the example of vegetarianism.

The Role of Science in Political Decision-making: Vegetarianism as an Example

Each day, people purchase food for their families. Given that individuals have sufficient funds, their choices about what foods to purchase and consume represent personal, private decisions. Individuals may, for example, decide whether they will eat meat or choose to be a vegetarian. However, citizens also have the opportunity to vote on ballot initiatives or to elect public officials on the basis of their propositions on policies designed to control how food is produced at state and national levels. These policies make food production and consumption a public issue as well. Thus, food production and consumption is an issue that requires both public and private decisions.

In this section, we focus on positions that people take on vegetarianism as a public issue. There are two extreme positions on this issue:

- An extreme animal rights position: People holding this position believe that it is immoral to kill and eat animals, or to use animals in products such as leather. Therefore, people who hold this position feel that consuming animal products is never justified.
- An extreme personal freedom position: People holding this position believe that individuals should have the right to make decisions about production, harvesting and consumption of animal products. An example of this position would be whalers who believe in an inherent right to harvest whales.

Both of these extreme positions render science irrelevant. They advocate laws that defend an absolute right, of the individual or of the animal. Most people, however, find both of these extreme positions untenable; they feel that some balance needs to be found that considers the well being of both individuals who wish to consume animals and of the animals themselves, or at least of populations of certain animal species. For example, most people who consume meat do not support the taking and consumption of endangered species such as tigers or gorillas.

If an individual does not hold either extreme position on the issue, many questions arise that science might help to answer. Some individuals choose to be vegetarian because they want to reduce their ecological footprints. In these cases, relevant scientific questions relate to what resources are needed to produce, package, and transport food; and what impacts food production, packaging and transport have on environmental systems. People who are interested in protecting biodiversity may ask questions about non-domestic animals, such as how abundant and sustainable are the populations of the species in question? Even for people who are interested in animal rights, but who take a non-extreme position, questions of science can have relevance. For example, science can examine how different conditions of food production may affect animals' health and well-being while they are being raised. In general, science can contribute to answering many questions that can help us think about whether or not to follow a vegetarian diet on a private level, and what policies related to food production and harvesting to support on a public level.

Different positions on food production and harvesting policies are associated with different Discourses (Gee, 1990; Gee, 1991) that are embedded in social and cultural contexts. People who strongly hold a given position are likely to associate with other people who share similar knowledge, practices, and values that frame the issue for them and make their position seem clearly correct to them. Some of us frame the issue in ways that require no internal debate while others consider all of the arguments about the issue before reaching a decision. Our decisions about what foods to eat are examples of socio-ecological decisions. These decisions

require us to resolve conflicts associated with different Discourses and values. Our framing of these issues can render science more or less relevant.

A Framework for Analyzing Socio-Ecological Decision-Making

In this paper we present results from interviews with students about two socio-ecological issues, each involving public and private decisions. In the water-related interviews, we asked students about whether and when they drink bottled water (a private decision) and about how they would vote on a proposal to allow a bottled water company to drill a well in the watershed of a northern Michigan trout stream (a public decision). In the food-related interviews, we asked students about the health benefits (private) and environmental impacts (public) of purchasing and eating different strawberry products.

In our analysis we endeavored to understand the reasoning—internal politics—of students as they arrived at their decisions. The framework we used to guide our data analysis is represented by Figure 1. The framework highlights four *practices*—investigating, explaining, predicting, and deciding—embedded within *Discourses*. The practices all require *knowledge.* Discourse, knowledge, and practice provide the core conceptual framework for our analysis.

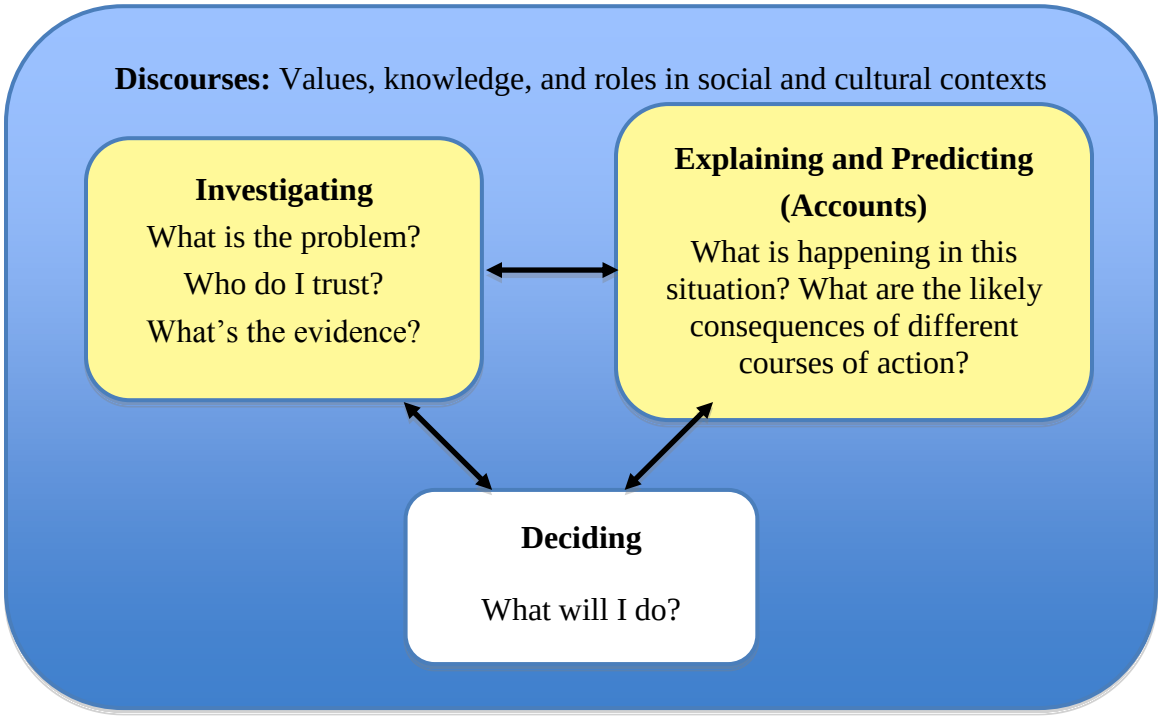

Figure 1: Framework for analyzing students' decision-making practices

Discourses. As noted in the discussion of vegetarianism, our responses to complex issues are generally framed within the social and cultural contexts with which we identify, and their associated Discourses. Gee (1990) defines a Discourse as "a socially accepted association among ways of using language, of thinking, and of acting that can be used to identify oneself as a member of a socially meaningful group" (p. 143). We propose that students' decision-making practices are rooted in the Discourses they participate in. Discourses embody an association of values, knowledge and practices in social and cultural contexts- these values, knowledge, and

practices serve as the resources that students can draw on as they engage in decision-making in various ways and to various extents.

Gee distinguishes between primary Discourses that we acquire in our homes and secondary Discourses that we learn in other social settings:

> All humans … get one form of discourse free, so to speak... This is our socio-culturally determined way of using language in face-to-face communication with intimates… Beyond the primary discourse, however, there are other discourses which crucially involve institutions beyond the family… Let us refer to these institutions as secondary institutions (such as schools, workplaces, stores, government offices, businesses, or churches)… Thus we will refer to them as "secondary discourses". (Gee, 1991, pp. 7-8)

Thus, while considering socio-ecological issues, students may draw on resources (values, knowledge, practices) associated with their primary (family) Discourse and/or their secondary (e.g., school science) Discourses.

In our interviews we asked students to take on citizen roles, including a private role (consumer) and a public role (voter). Playing these roles is in part a matter of knowing social conventions rooted in social Discourses—how to pay for food in a grocery store checkout line, for example, or how to cast a vote in a polling place. As noted above we commonly play these roles without a lot of conscious thought, relying on heuristics or habits (e.g., "I usually vote Democratic." "I buy some bottles of water every week."). In such cases, the deciding practice in Figure 1 does not rely on a lot of investigating, explaining, or predicting practices.

But there are times that we are asked to justify our habitual decisions, for example when someone questions our choices or when we encounter new issues in our roles. In these cases, our ability to investigate, explain, and predict possible outcomes for an issue becomes important for carrying out our roles. These are the kinds of problems we presented students with in this study.

Citizens in our society participate in multiple socio-cultural contexts associated with different Discourses; in other words, individuals participate in and use both primary and secondary Discourses. While primary Discourses are always accessible to students, secondary Discourses can provide important resources as well (Cobb & Hodge, 2002). One secondary Discourse that is especially important as a goal for science education is scientific Discourse (e.g., Duschl & Osborne, 2002; Rosebery, Warren & Conant, 1992). Scientific Discourse is about investigating, explaining, and predicting, but not deciding. Scientific communities have developed values and standards for judging the quality of investigations, explanations, and predictions, and we hold that these standards and values are critically important for those practices. Scientific values, however, do not tell us what to do about socio-ecological issues. For this purpose we must rely on other Discourses.

Thus our students' interview responses were determined in part by their (generally unconscious) choices of Discourses, including their primary Discourse and possibly some secondary Discourses, including scientific Discourse. They acquired these Discourses through participating in social and cultural contexts, and used these Discourses to frame the problems and their responses.

Knowledge embedded in Discourses. One fundamental resource for decision-making that is embedded within Discourses is knowledge. We are particularly interested in the science-related knowledge that students may draw on as they consider socio-ecological issues. While we acknowledge similarities to the construct of funds of knowledge (Gonzalez, Moll, & Amanti, 2005; Moje et al., 2004; Moll, Amanti, Neff, & Gonzalez, 1992) in our study, we adopt the less

formalized term of informal knowledge to describe the non-canonical scientific ideas that the students in our study often used as they considered the socio-ecological issues we introduced them to. Individuals develop funds of knowledge through participating in everyday family, community, and labor practices (Calabrese Barton & Tan, 2009; Moje et al., 2004). The reason we use the term informal knowledge rather than funds of knowledge is because we are not only interested in the context in which a student constructed knowledge. While we are interested in the sources of students' knowledge (i.e., school science or out of school sources), we are also interested in the alignment or non-alignment of students' ideas with canonical science knowledge. Just as students develop knowledge about science from everyday practices, they also develop knowledge about science through school science experiences. We have found that students' knowledge about science topics developed through out of school experiences may range from informal to canonical in nature. Similarly, students' knowledge developed through school science experiences may also range from informal to canonical in nature. (For further discussion of Discourse transitions from informal to canonical scientific, see for example Gunckel, Mohan, Covitt and Anderson, in press, and Mohan, Chen and Anderson, 2009.) Thus, we use the term informal knowledge to designate students' non-canonical ideas about science, regardless of the context in which these ideas were constructed. In analyzing students' reasoning about the socio-ecological issues, we distinguish between the informal and canonically-aligned scientific knowledge they bring to bear in their decision-making processes.

Practices embedded in Discourses: Investigating, explaining, predicting, and deciding. Practices also represent Discourse-based resources that students may draw on. In the interviews, students made decisions, supported to a greater or lesser extent by practices of investigating, explaining and predicting. In this section we briefly discuss each practice and its possible functions in an overall decision-making process.

Investigating: Learning about the facts of the case. When we judge that we don't already know enough to make an informed decision, we investigate the problem, either by inquiring directly into a situation or by relying on inquiry conducted by others. In the course of our investigations, we must decide what the problem is all about, who to trust and how to judge the strength of the evidence we encounter.

What is the problem? The way we define a problem space can influence the questions we ask to learn more about an issue, the sources we go to for answers, the courses of action we consider, and the extent to which we can envision potential environmental and social consequences of different courses of action (Arvai, Campbell, Baird & Rivers, 2004). Although decisions about socio-ecological issues can be informed by a combination of scientific and social understandings and values, individuals cannot include all possible factors when they frame their problem spaces. Research concerning how students investigate socioscientific issues suggests that they are more likely to consider social rather than scientific information (Fleming, 1986) and immediate factual claims rather than scientific theories and content knowledge learned in school (Kolstø, 2006).

Who do you trust? Because citizens are not able to carry out independent scientific investigations every time they confront a socio-ecological issue, they need guidelines for deciding who to trust if they are to competently use science as a tool in decision-making. Researchers interested in students' capacities to deal with socioscientific issues have explored how students engage in this practice (e.g., Elliott, 2006; Kolstø 2001; Korpan, Bisanz, Bisanz, & Henderson, 1997; Sadler, Barab & Scott, 2007). Kolstø, for example, found that students use four strategies for deciding who and what to trust including, "1) Acceptance of knowledge claim,

2) Evaluation of statements using 'reliability indicators' and through explicitly 'thinking for themselves', 3) Acceptance of researchers or other sources of information as authoritative, 4) Evaluation of sources of information in terms of 'interests', 'neutrality' or 'competence'" (2001, p. 877). Kolstø found that overall, while students were sometimes concerned about empirical evidence provided by sources, they were more often swayed by sources' "superficial contextual information."

What's the evidence? Arguments may be grounded in scientific data that were collected, analyzed and interpreted in ways that correspond to scientific Discourse, or they may be grounded in non-scientific ways of knowing such as reliance on authority or belief biases (Klauer, Musch & Naumer, 2000; Milgram, 1974). It is important for citizens to be able to distinguish between knowledge claims grounded in scientific evidence, and knowledge claims grounded in non-scientific ways of knowing, when engaged in decision-making about socioscientific issues (Bell & Lederman, 2003; Sadler, 2004). Research suggests, however, that most people rely on non-scientific ways of dealing with arguments and evidence. For example, whereas scientists often place value on arguments accompanied by statistical evidence, non-scientists are generally more swayed by arguments accompanied by graphic or personalized information (Arvai et al., 2004; Slovic, 2007).

Research on individuals' epistemological stances informs our understanding of how people adopt different perspectives when deciding what they believe. Studies by Perry (1970) and Belenky, et al. (1986), suggest some of these varied perspectives. Perry found that over time, male college students moved from seeing the world in absolutist terms towards identifying personal commitments among relativistic possibilities. Working with women, Belenky, et al. (1986) found perspectives including silent obedience to authority, valuing personal intuitive understanding, and integration of personal understanding with knowledge gained from others. The stance that an individual adopts influences the way she/he interacts with arguments and evidence of a socioscientific issue.

Explaining: Combining Discourses, models, and data. Informed decision-making requires some explanation of the situation; we must figure out what is happening in the socio-ecological systems we live in, and how those systems can be affected by our actions. Much of our current work on environmental science literacy focuses on how students explain socio-ecological processes. In our research (e.g., Covitt, Gunckel, & Anderson, 2009; Gunckel, Covitt & Anderson, 2009; Mohan, Chen, & Anderson, 2009), we have found that students' explanations about socio-ecological systems often reflect primary Discourses and informal knowledge rooted in family experiences, popular culture, and popular media. As such, their explanations often conflict with scientific explanations. We believe that decisions about socio-ecological issues are generally better informed when individuals' explanations correspond with scientific explanations, which combine general knowledge—theories and models—with specific data about the case at hand.

Predicting: Consequences of different courses of action. Informed decision-making involves a concern for the likely consequences of our actions. As with investigations and explanations, scientific Discourse can inform problem definitions and provide values that lead toward more accurate predictions, but in our everyday lives we commonly rely on approaches based on other Discourses and their problem frames and values.

The process of predicting outcomes is always complicated by limited information and uncertainty. This is true for all Discourses including formal (e.g., scientific and economic Discourses) and informal Discourses. For the most part though, as individuals reason about

likely outcomes of actions, they do so in informal ways. Few people consciously engage in weighing probability, risk or uncertainty (Arvai, et al., 2004). Instead, we generally rely on simplified understanding constructed through the use of heuristic principles (Tversky & Kahneman, 2000). While research from psychology has shown that actively considering uncertainty is not a common informal decision-making practice, recent science education research has demonstrated that, when provided with instructional support, children as young as second grade are capable of conceptualizing multiple types of uncertainty in scientific investigations (Metz, 2004).

Deciding: Applying values and knowledge in a problem space. While science can provide us with some guidance concerning how to estimate risks and uncertainties associated with different courses of action, it cannot provide definitive suggestions concerning which actions to pursue, given any set of scientific facts. Decisions related to socioscientific issues always depend not just on facts but also, and ultimately, on values (Kolstø, 2006). So scientific values cannot determine our decisions, but our decisions can be informed by scientific knowledge and practice. Informed decision-making thus involves all of the practices in Figure 1: investigating, explaining, predicting, and deciding.

As science educators, we place a high value on the role that science can play as a tool for helping us understand and make predictions about the material world. Research related to socioscientific decision-making, however, suggests that individuals tend to draw on personal values more than on scientific evidence in their decision-making processes (Bell & Lederman, 2003; Kolstø, 2006). We are interested in exploring what can be done to support people in making decisions about socioscientific issues that are well-reasoned and informed by scientific knowledge and practice.

Summary: The practices of informed decision-making. This paper reports on a study of students' decision-making practices about socio-ecological issues. These practices can never be purely "scientific;" they inevitably rely on problem frames, knowledge and values influenced by other primary and secondary Discourses. Some students may rely on problem frames and values that include no place for scientific knowledge and practice.

We hold, however, that informed decisions about socio-ecological issues require more than use of informal knowledge and personal values. Informed and responsible citizens also seek to understand and use scientific knowledge as they engage in practices of investigating, explaining, and predicting. Scientific knowledge can help decision makers by providing information about the likely ecological outcomes of different courses of action. Using scientific knowledge that is synthesized with other forms of knowledge (e.g., economic, cultural), citizens can draw on their personal values to make more informed decisions about socio-ecological issues. We seek to understand what resources students use and how they engage in practices of socio-ecological decision-making.

Methods

Design and Procedure

We conducted 30 to 45-minute interviews with a total of 22 students. Six students were interviewed for the strawberry scenario: 3 high school and 3 middle school students. For the water interview, we interviewed 16 students: 8 high school, 4 middle school, and 4 upper elementary school students. Interviewed students attended schools in rural, suburban and urban districts, all in one Midwestern state.

Interviews were transcribed and analyzed primarily through a modified grounded theory approach (Corbin & Strauss, 1997; Glaser & Strauss, 1967). Data were analyzed by the first three authors and all four authors met weekly to discuss the data. We adopted an iterative approach for data analysis and creating the decision-making framework (Figure 1). Our analyses represent a modified grounded theory approach in that we examined the data both with an openness to emergent categories as well as a beginning sense that we were interested in how students used their Discourse based knowledge and resources to reason about socio-ecological issues.

To begin, our analyses focused on questions including: What resources did students draw on in the interviews? What knowledge did students' talk reveal? How did students frame the socio-ecological issues that we presented to them? How did the students make decisions about courses of action? Over time, we developed and compared descriptions of students' Discourse resources and their knowledge and practices through iteratively writing and refining multiple student cases using agreed upon formats (e.g., each case should describe the student, their consideration of the evidence, their account of the issue, their decision with regard to the issue, and the resources such as family experience or values that the student drew on in talking about the issue). This iterative work of writing and comparing cases, refining case formats, and rewriting and comparing cases, led to the development of the framework in Figure 1 and the corresponding structure for describing the student cases. This approach allowed us to identify patterns of similarities and differences in how students engaged with considering and making decisions about socio-ecological issues. We chose three student cases representative of diverse Discourses, knowledge and practices to report as results. In addition, we drew on patterns in cases to create a cross-case analysis of six students (the three reported case students, plus three additional students chosen because they too represented diverse patterns).

Interviews

Making Decisions about Purchasing Strawberries (Strawberry Interview*).* In this interview, students were asked to complete two ordering tasks of eight different strawberry products, which included locally-grown Michigan strawberries, California-grown strawberries, organic strawberries, yogurt (a large and small container of same type of yogurt), locally-grown jam, California-grown jam, and Pop-Tarts. First, students were asked to order various products from what they deemed most nutritious to least nutritious. This task positioned students in the role of consumer. Next, they were asked to order the same products from most environmentally friendly to least environmentally friendly. In both ordering tasks, students were asked to explain why they ordered each product as they did. The products had labels with pertinent information, as shown in Appendix 1.

Informed accounts for the strawberry scenario. Each of the ordering tasks for the strawberry interview required students to construct accounts—explanations of where the strawberry products came from and predictions of how they would affect the environment.

1. Nutritional ordering – which product is the most nutritious to eat? With regard to nutrition, students need to consider what is desirable for a healthy diet. Characteristics of packaging and transportation are not relevant. We would expect scientifically literate students to consider issues such as degree of food processing and nutritional content of the products. The nutrition labels on products are a source of relevant information.

2. Environmentally – friendly ordering. We would expect environmentally literate students to construct scientific accounts that include multiple aspects of a product's life cycle

that can impact the environment. A scientific account could include consideration of how food is grown, processed, transported, and packaged. A sophisticated scientific account requires an understanding of the connections between social and economic systems and environmental systems, and how each is affected by human actions. Due to the complexity of these connected systems and the limited information available in the interview, it would be possible for two students who both have relatively sophisticated scientific knowledge to describe and justify different environmentally-friendly orderings for the strawberry products. For example, one student might prioritize the impact of long distance transportation over the impact of pesticide application, while another student might take the opposite stance.

Making Decisions about a Proposed Water Bottling Venture (Water Interview). In the water interview, students were first asked general questions about their knowledge and use of water. Then, students were introduced to a real-life scenario in which the Nestle Company sought permission to drill a well near a trout stream in northern Michigan to produce Ice Mountain bottled water. The interview focused on whether the company should be allowed to drill the well. First students were asked questions to find out how they understood the science of the scenario. Next, they were asked questions about how, as citizens, they would respond to the issue. During the interviews, the students were presented with additional information from stakeholders including the Nestle Company, West Michigan Trout Unlimited, Michigan Citizens for Water Conservation, and Michigan Department of Environmental Quality. Students could use the additional information to inform their decisions. The additional stakeholder information presented to middle school students was abridged from the information provided to high school students.

***Informed decision-making for the water scenario*.** In considering whether or not to support the building of a well to provide water to a bottling venture, we would expect an informed citizen to develop accounts based on both general scientific knowledge about human and environmental systems and specific information about the particular scenario.

Relevant general scientific knowledge includes an understanding of how watersheds and groundwater function in relation to one another. Water to be tapped in the well will have arrived underground after first falling as precipitation within a given watershed. Some water that falls as precipitation infiltrates into the ground and enters the groundwater system. Groundwater can also discharge from an underground system back to the surface water system through contiguity with a body of water such as a river or a lake. When water is removed from a groundwater system through a well, there will be an impact on the amount of water in contiguous water systems such as rivers and lakes. The impact of well water removal on a contiguous surface water system will depend on the volume of water that is removed relative to the total volume of water in the system; the greater proportion of overall water in the system that is removed, the larger the impact.

An informed citizen would also have knowledge of other issues related to bottled water such as the fact that there are monetary costs and environmental impacts associated with producing plastic bottles, bottling water, transporting water and disposing of bottles. In addition, a knowledgeable citizen should have some understanding of how scientists develop accounts and make predictions, including, for example, an understanding of validity in scientific studies, uncertainty, and risk.

In addition to this general knowledge, an informed citizen would need some specific knowledge of the case of Ice Mountain Water building a well near Evart, Michigan. For example: How much water flows through this watershed (with a margin for dry, normal and wet

years) and groundwater system? How much water is proposed to be removed? What species live in the potentially affected streams and how much water flow do they need to maintain a healthy population? How many people live in this water system and how might the well impact their water supplies? What other impacts associated with building the well and the water bottling plant are likely? What other water systems may be dependent on this system (e.g., the Muskegon River) and what potential impacts may occur?

There is no one ideal decision for the Ice Mountain Water scenario. Rather, an informed citizen would be able to integrate his or her understanding of the general science of water systems, the specific science and data associated with this case, and personal values relevant to the case. Thus, two well-informed citizens may construct similar accounts of this case, and yet come to different decisions based on differing values – such as valuing recreational opportunities, valuing local economic growth, or valuing conservation of natural areas.

Results

We found a wide range of approaches to investigating, predicting, explaining, and deciding in the 22 interviews, with many students having interesting individual ideas and practices. Since we cannot represent the full set of results within the space limits of this article, we have chosen a subset of interviews that are representative of the range of approaches. We first present three student cases (two water interviews and one strawberry interview). In each case, we provide:

1. A brief description of the student;
2. A description of his/her investigating, explaining, predicting, and deciding practices; and
3. A description of the values and other resources the students drew on in the decision-making process.

Following the three student cases, we present a six student cross-case analysis in which we discuss the Discourses-based resources students used in their decision-making including informal and scientific knowledge, practices, and values.

Three Student Case Studies

The case studies of Michael, Mark, and Selena were chosen because they are representative of the range of knowledge and practices of the students we interviewed. Findings from three additional interviews are integrated into the summary cross-case analysis.

Michael (A Water Interview). Michael was an 11th grade, male student who attended high school in a community that was undergoing a transition from a rural to a suburban profile. At the time of the interview, Michael was taking an environmental science course. During the interview, Michael frequently referred to personal and familial experiences and practices related to environmentally responsible actions, recreation in nature, and especially fishing. Overall, Michael demonstrated relatively sophisticated scientific knowledge and practices as he reasoned about the water scenario. Figure 2 provides a synthesis representation of Michael's decision-making resources and practices.

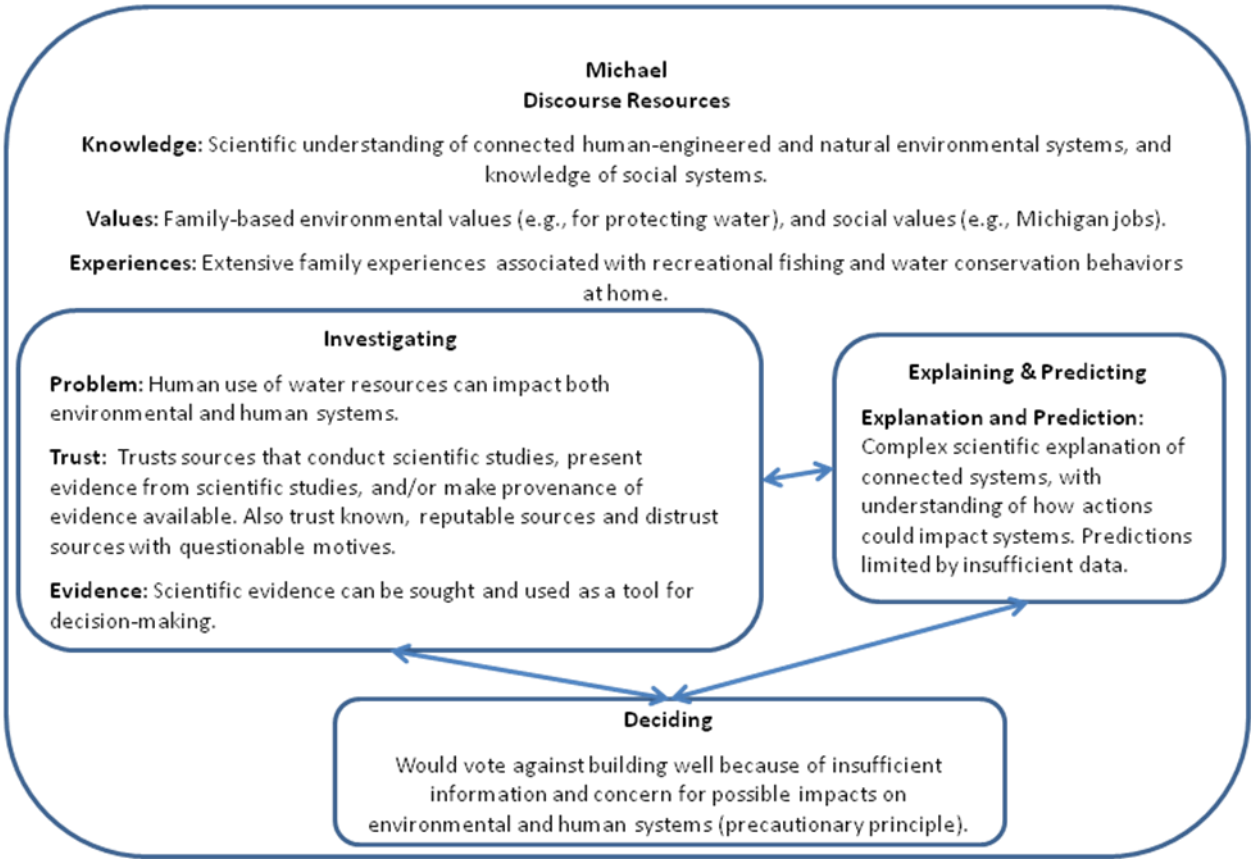

Figure 2: Michael's Discourse-based Resources for Decision-Making about Water

Investigating: Among the interviewed students, Michael was the most active investigator of the issue presented to him. He was highly interested in seeking information about the Ice Mountain bottled water venture, largely because of his personal and family practices of fishing, including taking fishing trips near the site of the proposed well. After being presented with initial information about the scenario, students were asked what else they would like to know to help them make a decision. Michael offered several questions that he felt could help him decide including, *"If they had like smokestacks and stuff to make air pollution? That could make it so that we wouldn't go down there. I know it takes in a lot of jobs but it also has a negative effect on the citizens."* And, *"How much water exactly is going through and coming back into the creeks and the rivers and how much is, well I know how much is being taken out but I want to know how much of a percentage is being taken out?"* In posing these questions, Michael demonstrated awareness of multiple types of environmental impacts (i.e., impacts on air quality and water quantity) and awareness of social impacts as well (i.e., positive and negative impacts on tourism and jobs).

Michael was the only student who pursued the implications of the scenario beyond the hypothetical context. At the end of the interview, Michael asked the interviewer how to find more information about the case. For Michael, the import of the Ice Mountain case transcended the interview context because it had potentially direct impacts on his important family practice of fishing in the area where the well was to be built.

In addition to his information seeking practices, Michael also had several elaborated ideas about deciding whom to trust. In the interview, he offered several criteria for deciding who

to trust and what constitutes a good scientific study. For example, Michael trusted sources that had evidence to back up their information and he trusted sources that provide references for information. In addition, Michael trusted sources he had heard of and respected, and he had less trust in sources whose motives he questioned, as seen in the transcript excerpt below:

Michael: Yeah, I trust the Dept. of Environmental Quality more than I would the citizens because they actually do all the tests and they evaluate what happens over a period of time. With the [Michigan] Citizens [for Water Conservation] they're just, I don't know if they research their information or not but if they didn't that would influence what I think about them and if they actually had like a bibliography on where they got their information from I would trust them more.

Interviewer: What are some things that go into whether or not you think info is trustworthy?

Michael: Where they get it from. The Michigan Departmental of Environmental Quality, I've heard of them, and they're like the DNR. I'd trust them more than I would the Nestle Company because Nestle could be just switching information to make it seem like it's good and leaving stuff out about what would negatively impact the environment.

Interviewer: What about Trout Unlimited?

Michael: I'd still like a bibliography and if they had showed where they got the information from it would be better and if we had information on the Muskegon River that would be good. I don't exactly know what Trout Unlimited is. If they could tell us what they do and how this affects them this would be good. Because if it doesn't affect them, why should they care.

Overall, Michael displayed relatively sophisticated investigating practices, with some awareness of values of scientific inquiry (e.g., collecting evidence over time and making the provenance of evidence public), along with some complementary reliance on non-scientific criteria (e.g., trust based on social judgments about bias and self-interest).

Explaining and Predicting: Michael's accounts of water systems and the scenario issue demonstrated understanding of both scientific and social scientific factors including economics, values, impacts humans have on environmental systems, processes that take place within environmental systems, and ecosystem services. There were some weaknesses in his understanding. For example, Michael believed the bottled water he drinks comes from glaciers, which is unlikely in Michigan. In many respects though, Michael had a complex scientific understanding of water systems that he applied to his account of the Ice Mountain Water well proposal.

Michael understood what a watershed is and knew that water that falls within a watershed can run over the surface of the land or infiltrate into the groundwater system. Michael also understood that removing water from the well could impact the flow of water in a stream. He stated, *"It depends on how much water they take out and how much water is in the creek."* Michael could further explain how removing water through the well could impact flow of water in the creek. *"It would take the water going that would seep in and go to the creek and it would take it in and they would take most of it and push it back out, or something."*

In addition, Michael provided an elaborate explanation when asked whether the well could affect trout that live in the creek:

Michael: It depends on how much water is going in but it could if they took too much and maybe the water wouldn't flow fast enough to make ripples that cause oxygen in the water and they might not be able to live there. And, it could draw the rivers in and then the trees wouldn't be able to drop leaves in and then bacteria wouldn't eat that which, the fish eat, and then they could end up losing different food sources.
Interviewer: How does that second thing work?
Michael: Yeah, if nobody lived on this river, and the water level went down and the trees were on the side of the river and they were dropping leaves in, it would cause the bacteria to come in to eat the leaves. If the leaves drop and they don't go into the river the bacteria wouldn't eat the leaves and break them down. And then the zooplankton wouldn't eat the fish and then the fish wouldn't be able to eat the zooplankton.

Michael's account of the scenario was not limited to scientific considerations. When asked if the well could have any other impacts, Michael's response indicated awareness of connections between natural systems and human social and economic systems. For example, Michael was aware that because of Ice Mountain's removal of water, "*maybe people who live around there could have to dig their wells lower just so they could get water."* Michael further referenced the possible impact on the recreational economy, "*Some people have businesses where they go out and take people fishing and they might get less business because of water going down and maybe they'd go out of business and go bankrupt or something."*

Deciding: When asked to make a decision about supporting or not supporting the well, Michael said, *"I would vote against it because I don't know where all the information came from and I wouldn't want to affect the environment in a bad way even if I don't live there because I believe fresh water is a great resource in Michigan so I'd vote against it."* He drew on both scientific understanding (i.e., he felt he did not have enough information to create a sufficiently certain account and prediction of what might happen) and values (i.e., he valued fresh water resources in Michigan) together in this one sentence response, demonstrating how he combined these two aspects in his decision.

Values and resources. Michael expressed a diverse set of values through the course of the interview. For example during the initial questions about water and water use, Michael expressed a personal willingness to invest time in preserving water quality. When asked if he took any actions to protect water quality, Michael talked about what his family did, including, *"we don't, like some people if they don't have enough money they just dump their oil in the yard, but we don't do that, we take it to the recycling center."*

Michael also expressed related values for maintaining water quality and environmental quality. Michael did not like the idea of removing water from the Great Lakes water system. Michael believed that, *"fresh water is a great resource in Michigan."* On a more personal level, Michael was a fisherman (often fishing with his father) who valued recreational water resources in Michigan. Talking about information provided in the scenario, Michael stated that, *"We've been there [the Muskegon River] before; it's a great river. Has a lot of fish. We actually had a lot of fun. I wouldn't like to see anything happen to it."*

Michael also expressed human social and economic values. He thought about the potential effects on people of the well being built. He considered both positive effects (e.g., it might create job opportunities) and negative impacts (e.g., it might affect people's water supply and fishing opportunities).

In considering the scenario, Michael seemed to emphasize his family-based Discourse resources and knowledge more so than his school science resources and knowledge. When talking about fishing and environmentally-friendly practices, Michael often mentioned his actions in terms of collective behaviors he engaged in with his family. When asked if he did anything to protect water, Michael used the collective "we" to describe his participation and also mentioned his father as his source of knowledge. *"Well, we don't use the laundry detergent with, my Dad told me about it, it had some chemical in it which you're not supposed to use because it can pollute the water."* In contrast, the one time Michael mentioned school science in the interview, he suggested that he couldn't remember the details of what he had learned. When asked if he knew the source of his tap water, Michael stated, *"I know it's an aquifer. We talked about it in science class, but I forgot about it."*

Overall, Michael expressed a fairly diverse set of values through the interview, including valuing water quality and quantity in Michigan, conservation of recreation areas, social goods such as access to water and jobs, and scientific information needed to inform decisions. While he appeared to be interested in school science, his talk suggested that his family experiences provided much richer resources of values, practices and knowledge than did his school science experiences.

Mark (A Strawberry Interview). Mark was a 10th grade student who attended high school in an urban community. At the time of the interview, he was enrolled in a Biology course. Mark was a student athlete, specifically a wrestler. His participation in wrestling played a significant role in the interview, and particularly in Mark's ideas and values about the nutritional ordering of the strawberry products. In contrast, as he reasoned about the environmental ordering of the products, Mark made fewer references to Discourse-based resources of knowledge, values and practices that were important in his own life. Overall, Mark drew on a mixture of informal and scientific ideas and practices during the interview. Figure 3 provides a synthesis representation of Mark's decision-making resources and practices.

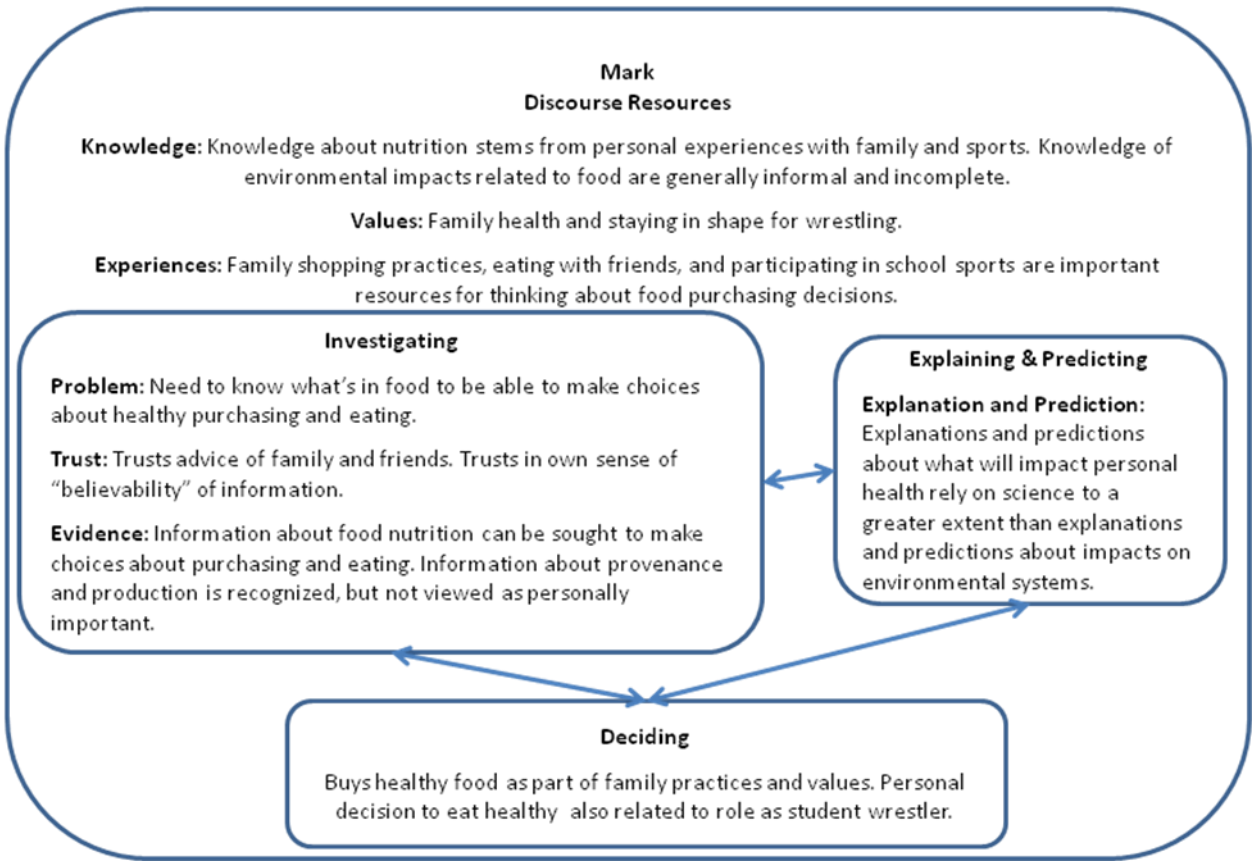

Figure 3: Mark's Discourse-based Resources for Decision-Making about Food Purchasing

Investigating: Mark investigated the nutritional characteristics of food products more actively than he investigated their environmental characteristics. For example, when considering the nutritional value of yogurt, Mark suggested that "carbs" are nutritious and wondered aloud whether the yogurt had "carbs" in it. When the interviewer provided an indeterminate response of "hmm," Mark proceeded to look at the label on the yogurt carton and state that, *"Yeah, it does have 'carbs' in it."* In contrast, Mark was less curious about investigating characteristics related to environmental-friendliness. For example, when asked, he told the interviewer that while he acknowledged it is important, he did not really think about where his food comes from.

In considering the trustworthiness of potential sources of information at the grocery store, Mark suggested he would rely on his personal assessment of believability. He stated, *"Well, I guess if they're [the store worker] saying something that's really bologna or something. Like you know… Honestly, I don't know. I probably would believe them if they worked there. They actually, if they actually say stuff that's believable, but I guess it would be a feeling like if I believed them or not."*

Mark suggested that he relied on his family and friends for information and advice. His mother shopped at organic food stores and looked for foods with low calories and foods that would not increase a person's cholesterol. He indicated that her choices influenced his own. Mark also listened to his friends when he went out to eat with them and they told him to eat certain foods because they were healthier. Thus, Mark's information seeking and trusting practices appeared to be largely personal (i.e., trusting his own beliefs and the suggestions of people who are close to him) with scientific evidence playing a smaller but sometimes significant

role (i.e., trusting food labels to provide important information about things like calories, fat and "carbs").

Explaining and Predicting: Mark's approaches to the nutritional and environmental ordering tasks are summarized below.

Nutritional ordering task. Mark ordered the products from most nutritious to least nutritious as follows: Organic strawberries, yogurt (both large and small containers given equal ranks), local strawberries, industrial California strawberries, local jam, California jam, Pop-Tarts.

Mark used the labels to help him with the nutritional ordering task. He used three criteria to order the products. The first criterion Mark used was whether or not the products were organic. Mark believed that organic products were healthy because they did not contain pesticides. He ranked the organically grown strawberries as most nutritious, because they were grown without pesticides. He ranked the local strawberries third because he assumed that they were grown using pesticides.

A second criterion he used was number of ingredients. He said, *"Ah, pretty much because it's just purely made and you know, fruits is always good for you"* as a rationale for ranking the organic strawberries as most nutritious. Thus, the strawberries were ranked higher than the jams that contained sugar and other ingredients.

Along with his idea that having more ingredients that could be unhealthy, Mark considered the amount of processing involved in the jam products. He thought that the local jam was more nutritious than the jam made in California because it was less processed. He said:

> *And I put this one before this [local before CA jam] 'cause I think this is a brand [touching CA jam] so they probably make it at a factory. And this [touching local jam] is probably healthier because they probably are doing it themselves without a machine.*

Mark ranked both sized containers of yogurt as second most nutritious because they were non-fat and contained dairy and protein. With the exception of considering whether or not the products were organic or non-organic, Mark did not take into account how the provenance of the products affected nutrition. He seemed to have an informal, unelaborated understanding that organic products were better than non-organic products. He believed that products with more ingredients were less healthy because they had the potential to contain more sugar and also believed that processing could be unhealthy.

Environmental ordering task. Mark ranked the products from most environmentally friendly to least environmentally friendly: Organic strawberries, yogurt (both sized containers given equal weight), local and California jam (given equal weight), Pop-Tarts, and local strawberries and industrial California strawberries (given equal weight).

Mark did not mention the impact of transportation or packaging of the products in the environmental ordering task. While few students took the packaging of the products into account, most students mentioned pollution related to the transportation and processing of the products as a factor for the environmental ordering.

Mark used two criteria in the environmentally friendly ordering task. Similar to his nutritional ordering, the first criterion Mark applied was whether or not the food product was organic or non-organic. He immediately placed the industrially grown strawberries from California as least environmentally friendly and the organically grown strawberries as most environmentally friendly. He said, *"So it's [pesticide] also affecting bugs, it's also probably affecting plants and the soil."*

The second criterion Mark used in his environmental ordering was the number of ingredients in each product and the degree of processing. For the yogurt, he considered the

impact of milk and strawberries. He believed that because milk came from cows, there was not a negative environmental impact related to obtaining milk. He stated, *"… 'cause all you're doing is milking the cows to get the milk and you probably have strawberries so they probably just factorize that and I guess it's not really polluting anything making yogurt."* While Mark mentioned that the yogurt products were processed in a factory, he did not consider any environmental impact of the "factorizing" process.

When Mark discussed the negative environmental impact of pesticides, he recognized that the pesticides affected not only insects, but also plants and soil. He demonstrated a partial understanding of the impacts of human actions on environmental systems. However, as Mark considered the environmental impact of yogurt ingredients, milk and strawberries, he did not show a deep understanding of supply and waste disposal chains. For example, he did not consider the environmental impact of raising milk cows, such as the food the cows eat, treatment with growth hormones, or the wastes cows produce.

Mark demonstrated an incomplete understanding of the connections between natural and human-engineered systems. He traced the supply chain of the food products back only as far as the ingredient. For example, he did not think that producing jam products impacts the environment, *"Just because once they've already got the strawberries, they make the jam, that's not really gonna hurt anything bad for that."* Additionally, he said, *"Since the Pop-Tart is industrial and you already have the materials then it's not really affecting anything too."* Thus, Mark placed the Pop-Tarts as more environmentally friendly than the locally grown and industrially grown strawberries from California that used pesticides even though they contained more ingredients and underwent more processing than the strawberries. Mark did not trace the ingredients back to their origins; he only took into account the environmental impact of creating the products once the ingredients were obtained. When probed about tracing the ingredients back further in the supply chain, the following conversation ensued:

Mark:	*I know strawberry and bread is in Pop-Tarts but I'm not sure where they get it or how they're making the bread or not.*
Interviewer:	*Are you concerned at all about where they're getting it or like where they're getting the strawberry or bread?*
Mark:	*Um, I may be concerned if I knew how they were getting it but I'm not really, I'm not really like oh, no Pop-Tarts are doing something bad. Like it's not really on my mind right now.*
Interviewer:	*So do you think it's important to know where they came from? Or where they're getting the strawberries from or where they're getting the sugar or whatnot that they're using in it?*
Mark:	*Um, well, yeah, I guess it's important. But I never really ask myself that question when I, when I'm eating a Pop-Tart. I'm gonna be like, oh where's this from?*

Deciding: In talking about his food buying decisions, Mark contextualized his practices within his family and athletic experiences. Mark's Mom did much of the food purchasing for the family, and he described her practices as, *"Whatever's cheaper we get. Or like also, my Mom's really like, trying to stick with healthy foods. So also what's healthier. She always checks about that. So yeah, usually healthy we try to head for."* Also, *"she actually shops at like organic stores. So she's usually looking at calories first of all and ah, she tries to, she has high cholesterol so she likes to try to see stuff that helps lower your cholesterol."* In contrast with food, which was primarily purchased by his mother, Mark talked about how he bought drink

products for himself. When the interview asked why Mark drank water and Fruit2O, Mark stated, *"Well, I usually do that for myself because… I'm a wrestler so I try to watch my calories too and like Fruit2O has zero calories so I just drink that a lot. And I also have bottles of water too…I try to stick with water. It's like zero calories."* Overall, Mark's talk about his food buying decision reflected his family and sports-related orientations to food purchasing and consumption.

Values and resources. Mark valued foods that were nutritious and talked about how eating healthy food was important to him because he's an athlete. During his interview Mark also said that he thought science was important because you learn about how your body works. Nutrition as a value seemed to be embedded within Mark's family food-related Discourse as well as within his secondary student athlete Discourse. Thus, family and wrestling related resources (i.e., practices of shopping; knowledge about "carbs," calories, and fat; and values related to eating healthy) seemed to be those that Mark drew on most heavily during the interview. In contrast, Mark's talk during the interview suggested that he had fewer personally relevant resources related to considering the environmentally friendly nature of foods. Mark stated that protecting the environment was important, but his knowledge about environmental impacts of food production and purchasing were generally shallow, and his commitment to learning more about this topic was not enthusiastic.

Selena (A Water Interview). Selena was a 7th grade student attending an urban middle school. Her science class had been engaging in a study of groundwater prior to the time the interview took place. During the interview, Selena did not explicitly draw on many out of school experiences and resources. She relied on her personal ideas to reason about and respond to the interviewer's questions. In general, Selena displayed mostly informal knowledge and practices as she talked about the water scenario. Figure 4 provides a synthesis representation of Selena's decision-making resources and practices.

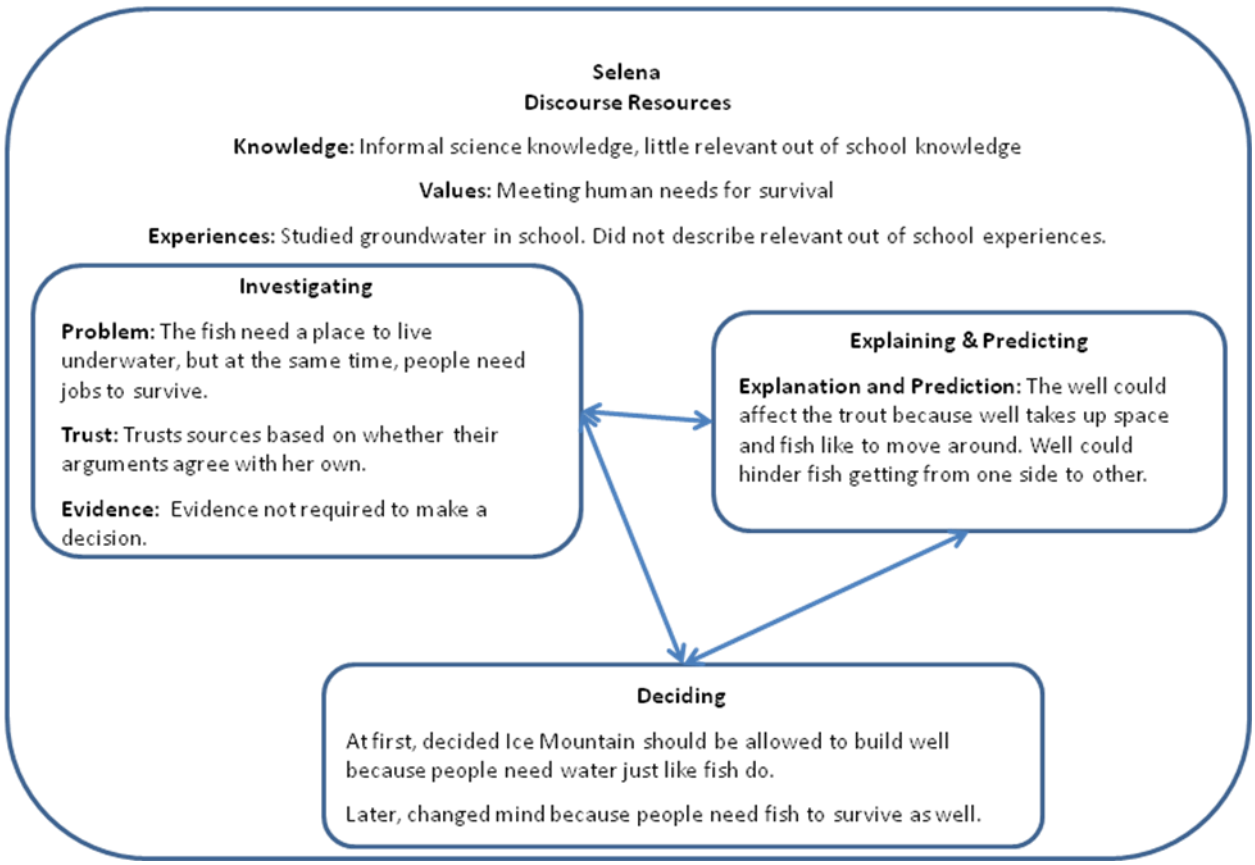

Figure 2: Selena's Discourse-based Resources for Decision-Making about Water

Investigating: After hearing an introduction to the scenario, Selena did not see a need to investigate the case further. After being introduced to the scenario, she felt that she had enough information to decide how she would vote. However, when offered four excerpts of information from different stakeholders, she read and considered several of them. Selena used the information provided to confirm beliefs that matched her own ideas. When asked which information she trusted, Selena stated:

Selena: *I think these [Trout Unlimited and Michigan Citizens for Water Conservation] are more trustworthy because they have the information that I was talking about mainly.*
Interviewer: *So they kind of match your own ideas?*
Selena: *Mhm.*
Interviewer: *So you think that makes them trustworthy?*
Selena: *Yes.*

For Selena, trustworthy sources offered information that seemed reasonable or right to her based on her own experiences with the world.

Explaining and Predicting: While describing her understanding of science related to the scenario, Selena shared some informal accounts. For example, when asked what the source of her tap water was, she thought that it came from the ocean or one of the Great Lakes. Selena also held some informal ideas about protecting water. When asked what kinds of things people can do to protect water, she said:

Selena: *Stop dumping their wastes in the lakes and rivers.*

Interviewer: *What kinds of things do people dump that's bad?*
Selena: *Like chemicals, um food sometimes, 'cause it has a lot of calories in it. And I want to say sugar, but that might be wrong.*
Interviewer: *So why would it be bad to put calories in the water?*
Selena: *Having too much calories can affect your body.*
Interviewer: *So that's bad for the water then?*
Selena: *Mhm.*

Selena revealed a few informal ideas here. First, chemicals for Selena were not materials with individual identities, but rather, generic bad stuff that people dump into water. Also, her ideas about calories may reflect inaccurately reconciled learning about nutrient overload in water. If she had heard about nutrients polluting water, but did not understand where the nutrients came from and how they impacted water quality, she may have drawn on her own ideas to complete the story. Thus, the nutrients, instead of coming from overuse of fertilizers or from insufficient sewage treatment, were transformed by Selena into calories that come from people putting food in water. Further, Selena interpreted the impact of the nutrients through a lens of having too many calories being bad for peoples' bodies. Selena may have sought to make sense of what she had learned, perhaps in science class, through calling on her past experiences and ideas of how the world works.

Selena also held some informal ideas about groundwater. For example, when asked if she had ever heard of a well, Selena replied, *"they put the well in, they run the bucket down and get the water."* Selena had an iconic vision of a well, which she may have picked up from children's stories. In other comments, Selena revealed additional informal ideas including that direction of water flow is related to the orientation of the paper (flowing down on the paper is how water will flow), and that a watershed is a, *"little shed, like a house."*

One concept that Selena did understand when prompted to (like many other students), was that human actions that impact the environment have tradeoffs. When asked if the debate about Ice Mountain water made sense to her, Selena responded, *"it makes sense because, it will hurt the fish because they need a place to live and they breathe underwater. But at the same time it will give people jobs and make us survive."* Selena's assessment of the scenario acknowledged both human impacts on environmental systems and ecosystem services that support the needs of humans and other species.

Given her informal idea about an iconic well and limited sense of how groundwater and surface water are connected, Selena imagined how the well could affect trout that live in the streams.

Selena: *It will affect them because they need a place to live just like we do. And they breathe underwater. And they could die on land.*
Interviewer: *How would the well change the place they live?*
Selena: *The fish, they like to move around, it might affect them trying to get from one side to the other.*
Interviewer: *How come they couldn't get around anymore?*
Selena: *Because sometimes the well takes up space.*

For Selena, the impact of the well on the fish was not about removing water from the system, but rather about the physical structure of the well blocking the fishes' ability to travel in their habitat. Overall, Selena had an informal understanding of science concepts. She focused on human and visible aspects of systems (e.g., iconic well and watershed as a house-like structure) and sometimes on ideas about materials (e.g., chemicals as vague, bad substances).

Deciding: Selena was one of very few students who stated that she had enough information to make a decision after hearing the initial description. Selena said that learning the initial information about the well would not impact her decision about whether or not to buy Ice Mountain water, and when asked how she would vote, she stated, *"I think I might agree with them to build the well … because we need water just like the fish does."* When again asked if there was any more information about the scenario she would like to learn, Selena said no.

Subsequently, the interviewer did offer additional information for Selena, even though she did not request it. After Selena read and considered some additional information, she changed her mind, and decided the well should not be built. Thus, in the course of the interview, Selena changed her mind on the issue based on reading information that she did not solicit. At first, she thought the well should be built because people need water. Then, she decided the well should not be built because it might harm fish, and people also need fish to survive.

Values and resources. Selena shared some of her values through the interview, but did not express highly consistent values. For example, Selena told us that she values science, though her reasoning about why suggested a novice understanding of the nature of science (i.e., science is inventing "stuff").

Selena did not talk much about her personal and family experiences, but she did share a few ideas. For example, when asked if she did any things to protect water in her community, she said, *"I try to, cuz my Mom works at a factory. I tell her to tell her people not to dump some of the chemicals in the water. And when they throw food away to make sure that you eat it all sometimes."* Thus, Selena described herself as adopting a familial role where she shared what she knows about protecting the environment with her mother. It is not clear where Selena learned her ideas about chemicals and foods as having negative impacts on water quality. It seems likely that these ideas did not come from her mother because Selena positions herself as the person with knowledge to share when she talks about her mother. Perhaps her ideas came from the popular media, and or from school.

At the end of the interview, when asked if she had studied a lot of science in school, Selena described having a deep interest in science. Selena said that she would like to be a scientist, but her talk indicated that she may not have had deep knowledge about what that means. She associated science with invention, and found the idea appealing, but could not suggest details beyond the initial idea of wanting to *"invent some type of stuff."*

When considering how Selena may have arrived at her decision about the Ice Mountain scenario, we see that she drew on some informal accounts of how the world works. Selena actively tried to make sense of her world, and put faith in her ability to understand. Thus, Selena trusted the information from the sources that agreed with her own ideas. She was not eager to seek additional information, perhaps counting her own ideas about the world as sufficient.

Selena initially indicated that the well should be built because people need water to survive. She did not consider tap water. In her science account, Selena indicated that the only way the well would impact the trout would be to prevent them from moving around (i.e., by providing a structural barrier to the fish). She did not see the well as an element that would remove water from a system connecting the groundwater and the surface water in the streams. This understanding may have led her to judge the impact of the well (i.e., just a structural barrier) as relatively small. Although we do not know much about Selena's particular sources of knowledge, she seemed to have some of the general ideas shared by many others students who participated in our water research (Covitt, Gunckel, & Anderson, 2009). Examples for Selena

included the iconic well; the unspecific notion of chemicals as vague, bad substances; and the idea that the source of tap water is the ocean.

It is interesting that Selena had been studying groundwater and building groundwater models in her science class, yet she retained many of her informal ideas about how the groundwater system works. Perhaps because her particular notions about how water systems work were not addressed during her school experiences, Selena had to try to synthesize her experiences in science class with her previous ideas. The result may have been that her informal ideas continued to be strongly held.

Cross-Case Comparisons

In this section we compare the students in terms of Discourses and practices. First, we discuss Discourses in terms of the resources they provide for decision-making practices. Second, we compare decision-making practices in terms of their complexity and use of scientific knowledge. Table 1 summarizes Discourses and decision-making practices for six of the interviewed students, including the three detailed cases presented above.

Table 1. Six Cases: Decision-making practices and Discourses that informed practices

Student	Discourse-based resources	Accounts (Investigating, Explaining and Predicting)	Deciding
James (Middle School, Strawberry)	• Relied on family experiences, such as organic gardening. • Valued natural environment (e.g., did not use pesticides, which harm natural environment).	• Trusted labels on food products. • Made well-developed connections between human and natural systems (e.g., pesticide runoff harmful to plant and animal life). • Examined how food was grown; amount of processing, packaging, and transport; and their impacts on natural systems.	• Decisions rooted in family values (e.g., growing organic produce)
Mark (High School, Strawberry)	• Relied on family and personal experiences (e.g., Mom shopped at natural food stores and looked for foods that helped lower cholesterol. Mark paid attention to calories to make weight for wrestling.). • Valued food that is healthy (e.g., low calories, low fat, low carbohydrates).	• Trusted labels on food products, family, friends, and own sense of "believability." • Missing some connections between human and natural systems (e.g., did not trace environmental impact of food from origin – only took into account what happened once food ingredients arrived at factory). • Examined how food was grown (but did not take into account effects of pesticides on wildlife) and amount of processing.	• Decisions rooted in family values (e.g., organic foods, food that lower cholesterol); and in experience as a wrestler.
Tom (High School, Strawberry)	• Relied on school science experience learning about germs. • Valued packaging for foods that prevented food from spoiling or releasing germs into environment.	• Trusted own ideas gained from school science germ experiment. • Made some connections between human and natural systems, but relied on informal perceptions and personal experiences rather than scientific accounts. • Focused on origin of products (e.g., Michigan or California as producing better foods) and whether or not products would spoil due to germs (e.g., good packaging keeps germs out).	• Decisions rooted in one germ-related experience in school science class; applied informal rather than canonical scientific reasoning.
Michael (High School, Water)	• Relied on family experiences with fishing and environmentally responsible behaviors, as well as some school science. • Strongly held environmental and social values such as protecting Michigan water and jobs.	• Trusted information with references and reputation of source. Actively sought information from multiple sources. • Made scientifically accurate connections between human and natural systems (e.g., ecological, social and economic impacts). • Used scientific understanding to predict negative impacts on wildlife (fish) and ecological system.	• Drew on scientific Discourse and family-related values for water and fish to decide to use precautionary principle.
Valery (Middle School, Water)	• Relied on understanding of water based on school science experience. • Valued fairness, science and scientific studies.	• Trusted scientific studies. Considered multiple sources. • Held mixture of scientific and informal ideas. Considered connected human and natural systems. • Used informal ideas to predict that moving well further away would solve problem and meet needs of multiple stakeholders.	• Drew on informal ideas and value for fairness to try to solve problem for all stakeholders. • Little mention of family practices.
Selena (Middle School, Water)	• Relied on personal experiences to understand world. • Valued meeting human needs (e.g., people need water, fish to survive).	• Trusted information that matched her ideas • Held informal ideas about science (e.g., iconic well). Focused on aspects of systems connected to human needs. • Predicted that fish would not be affected much.	• Drew on her informal ideas and value of meeting human needs to decide.

Discourse-based resources for decision-making practices. Students drew on multiple Discourses for decision-making. In particular, we identify their knowledge, values and experiences from one primary Discourse community (family), and two secondary Discourse communities (peer and popular culture and school science). Each of these Discourse communities afforded students with a range of sufficiency of resources that they applied in their interviews. Below, we briefly discuss each of the Discourses and the roles they played in students' engagement with the scenarios.

Family Discourse communities. Family-based knowledge, values and experiences were important resources for students. For example, Mark and his family were careful to buy healthy and organic foods. This practice was linked to his family's values (mother's concern about health) and his personal experience as an athlete. His mother shopped at organic food stores and looked at the nutritional information on products. She tried to find products to help lower her cholesterol. Mark stated that his family was most influential in his food choices, but his experience as a wrestler also played a role in the food choices he made because he needed to maintain a certain weight for wrestling.

Michael also relied on family experiences and values when he reasoned about the Ice Mountain issue. He talked about actions he took to protect water quality in terms of collective family behaviors. *"We don't use the laundry detergent with some chemical you're not supposed to use in it. We don't dump our oil."* Perhaps most importantly, Michael and his dad were recreational fishermen. When asked about whether the initial information would influence his decision about whether to buy Nestle Water, Michael responded, "*Yes, because if that interferes, if the fish in the lake, I'm a big fisherman, so is my father. If that made the fish population go down we probably wouldn't buy Ice Mountain."*

James (see Table 1) was also influenced by family values of conservation and sustainability, as reflected in family practices of organic farming. Both James's family and his grandmother practiced organic farming with composting. This family practice was probably informed by their stance against pesticides, a point James talked about in detail during the interview. James's family-based experiences with organic gardening positioned him to discuss with some expertise, issues of nutrition and environmental impact of growing foods.

Peer, Popular Culture and Media. Discourses associated with peer and popular culture also provided resources for students. For example, Mark cited his friends as a source of information on healthy food and what is good nutrition for a wrestler. Tom (see Table 1), a high school student who participated in the strawberry interview, expressed his opinion that more well-known and popular brands produce higher quality food. He explained how he and his friends made sure to choose reputable snacks like Cheetos and Doritos, whose advertisements feature prominently on television. Another middle school student who participated in the strawberry interview, James, suggested that his interest and appreciation of animals and wildlife were drawn from television. James shared his concern for polar bears being endangered by global warming, something he had learned from watching the Discovery Channel, which he cited as one of his favorite pastimes.

Reliance on media-based information was also evident in many of the students' ideas about bottled water. Students talked about bottled water being particularly fresh and pure compared with tap water, and about idealized sources of bottled water including fresh springs and mountain glaciers. For example, when Valery was asked how she decided which bottled water to purchase, she stated, *"the one that has been purified. Like fresh spring water. And they ain't got nothing swimming in it, Pure Life [brand]."* (Table 1) Selena stated that Ice Mountain

water came from "the mountain." And even Michael, who was quite knowledgeable about water systems in Michigan, believed that the Dannon brand water that he purchased and drank in Michigan came from "glacier streams."

School Science. School science was also invoked as a resource by some students. Michael drew on what he learned in science class during the interview, though with less certainty than he drew on his family-based resources. For example, when asked if he knew the source of his tap water, Michael responded, *"I know it's an aquifer. We talked about it in science class but I forgot about it."*

Another student who participated in the water interview, Valery (see Table 1), also mentioned school science learning and worked to apply it in the water scenario situation – with mixed success. For example, Valery knew that the groundwater and surface water systems were connected, but predicted that the negative impacts of building the well could be mitigated by moving the well further away from the creek. Though she had studied water systems in science class, Valery did not understand that moving the well further away, but keeping it within the watershed, would not appreciably change the impact on the water flow in the creek.

When considering the strawberry scenario, Tom's criteria for both nutrition and degree of environmental friendliness of the products depended solely on whether the strawberry products had a long shelf life and if their packaging prevented the entry or release of germs. Tom based his germ-centered theory on a particular science experiment he had conducted in school – investigating how clean the drinking fountain in school was by swabbing it with Q-tips. That experiment left a deep impression on Tom, which was evident in his emphasis on food spoilage and cross contamination of germs between food products and the environment.

Nature of students' decision-making practices. Students' decision-making practices are embedded in Discourses that provide them with experiences, values and knowledge. The students we interviewed displayed a range of competency across the practices of investigating, explaining, predicting and deciding. The variation in competency appears to be related to the Discourse-based resources students had to draw from. We illustrate this observation below, with three water students and three strawberry students. Each pair of students shares commonalities in their level of sophistication when making decisions.

Michael and James constructed the most scientifically robust accounts and were the most sophisticated in their decision-making practices. Michael in particular, considered multiple perspectives when he was investigating the situation. He considered the pros and cons of building a water bottling plant for different groups of people as well as the possible consequences to the trout population. In the end, Michael decided he did not have enough information to make a decision, and expressed a desire to seek additional information from reputable sources to learn more about the situation.

James brought a very particular point of view grounded in a family-based repertoire of knowledge relevant to the strawberry scenario. James was able to consider many factors that could contribute to the impact a food product has on the environment, displaying sophistication in his explaining and predicting practices. Compared to Michael, who was open to all perspectives before making a decision, James filtered the construction of his account through personal values, resulting sometimes in narrow scientific accounts. He used personal values to decide which aspects of the situation were important or relevant. For example, while he could articulate the different factors that contribute to a food product's life-cycle cost (such as degree of processing, transportation, and how food is grown), James prioritized how food is grown as the most important factor. He favored organic farming practices because they eliminate the

consequences of chemical pesticide runoff. As a result, James deemed the organic strawberries more environmentally friendly than the locally grown strawberries (which were not labeled organic), even though he did not ask or know about the origin of the organic strawberries (did not consider possible transportation impacts). James's prioritizing organic farming was related to his personal value for protecting ecosystems and animals from the harmful effects of pesticide runoff.

Both James and Michael showed that they could describe the relationships between human social systems and environmental systems. Both students also grounded their sophisticated decision-making practices in robust scientific knowledge relevant to their scenarios.

Mark and Valery displayed less sophistication in their decision-making practices and resources. Valery had some interesting strengths including a high value for fairness, an empathetic concern for the perspective of diverse groups, and a value for and interest in science. She considered multiple perspectives and was interested in seeking out information related to the scenario, but she could not provide accurate scientific accounts in her explaining and predicting due to a limited knowledge base. What limited her reasoning was not a narrow perspective of what was involved, but rather an unsophisticated knowledge of science in the environmental systems. This led her to the idea of moving the well further away from the river, which fits with many of Valery's criteria for a good decision, and she believed she was relying on science and values.

Mark's interest in the strawberry scenario was limited to his personal experience as an athlete and nutrition concerns stemming from that role. Mark applied his personal values to the scenario. While he could articulate which strawberry products were more beneficial for health, he could not discuss which strawberry items were more environmentally friendly with the same facility, resulting in a more informal account of environmental friendliness. Also unlike his interest in the nutrition of the strawberry products, Mark was not interested in seeking more information about how food production affects the environment. Mark's experience as an athlete and his more robust knowledge related to nutrition positioned him to be more sophisticated in engaging with the nutrition portion, but not the environmental impact portion, of the strawberry scenario.

Tom and Selena exhibited the least sophisticated decision-making practices. Neither seemed particularly interested in investigating their scenario thoroughly, nor did they construct robust accounts in their explanations and predictions. With his germ-centered theory, Tom adopted a relatively superficial approach to investigating, explaining, predicating and deciding; applying his informal understanding that germs are just bad. While he understood correctly that food spoilage could contaminate the immediate environment especially if packaging was compromised, he applied this understanding rigidly to the strawberry scenario. Tom limited the concept of "environmental friendliness" to the immediate physical space surrounding the food product, rather than the impact that creating and transporting the food product has on connected environmental systems. In general, Tom construed environmental friendliness in terms of protecting humans from food contamination.

Selena was satisfied with the information initially presented and felt that she could make a decision right away about the water bottling plant. She accepted provided information and trusted sources of information that agreed with her own ideas without asking more questions. Her decision-making practices were based on naïve notions she held about the science content

relevant to the scenario, even though she was studying groundwater in school science at the time of the interview.

Summary of decision-making practices. Overall, the students who were most successful in engaging deeply with the scenarios were the ones with sophisticated decision-making practices who were able to both investigate the scenario by seeking new information as well as use the information in explaining and predicting. Moreover, students' success in these practices was related to how much they could draw from their Discourse-based resources of knowledge, experiences and values relevant to the scenario. Michael and James possessed the most robust scientific knowledge as well as sophisticated investigating, explaining and predicting practices. Among the students interviewed, Michael and James most actively sought information related to the scenarios, used scientific values to evaluate information and sources, used scientific knowledge to explain and predict, and considered their explanations and predictions while making decisions. Interestingly, while Michael and James were most successful among the students at accessing and participating in scientific Discourse while reasoning about their decisions, they also had among the richest primary family Discourses to draw on during the interviews. Their families' knowledge, practices, experiences and values were relevant and useful for reasoning about the particular socio-ecological issues presented to them. We hypothesize that the capacity to engage in decision-making practices that make productive use of scientific Discourse involves seeking out multiple perspectives and having a solid scientific framework within which the student can make sense of different pieces of information and consider constructed accounts in light of his or her own Discourse based values.

Discussion & Implications

In conclusion, we share some final thoughts about the students we interviewed and the implications of these interviews for K-12 science education.

Reliance on Out of School Discourse Resources

Our data show the prominent role that factors other than school science played in students' socio-ecological decision-making. Students' out of school Discourse-based resources including knowledge, values, practices and experiences provided entry points that influenced how they engaged in a scenario. The students who engaged in relevant everyday practices, such as being a fisherman or a gardener, had an interest in the scenarios and usually drew on knowledge and values from these practices more than school science.

For example, James and Michael were the students who came closest to our conception of informed decision-making. They constructed accounts that reflected an understanding of the interactions between the human and environmental systems. Both students were able to weave coherent narratives in explaining their decisions. Both students also drew predominantly from family experiences such as recreational fishing or organic gardening. While Michael invoked school science briefly, it did not play an explicit central role in his account. James did not invoke school science at all. Thus, the two students who displayed the most robust understanding of these socio-ecological issues drew not from school science resources, but from family and personal knowledge, values, experiences and practices.

What is the role of school science? This raises a question about the role school science can and should play in helping students develop the capacity to make informed socio-ecological decisions. School science did not provide a core resource base of knowledge, values, experiences or practices for many of the students. Water scenario students tended to invoke school science

more often than the strawberry scenario students did. This may be due partly to the way the two scenarios were structured. Water students were asked to construct a narrative of water science before they were presented with questions, while strawberry students constructed narratives after they had ordered the products as explanations for their decisions. Also, many of the students interviewed for the water scenario had just completed or were currently engaged in a science unit about groundwater and/or watersheds in school. Even for those students who did not learn about water systems in science class just before engaging in the water interviews, the water cycle is typically a part of the science curriculum in the United States that is taught more than once in the K-12 curriculum.

Hence, it is interesting and potentially problematic that the students did not more successfully draw on school learning to construct scientific accounts of the water scenario. For example, Selena had been studying groundwater and building groundwater models in her science class, yet she retained many of her informal ideas about how the systems work, as evident in her description of an iconic storybook well.

While students learn about concepts such as food webs and food chains, teaching about food supply chains and waste disposal chains and the impact of these on natural systems is not a common part of the K-12 curriculum. Of all the students who engaged with the strawberry scenario, only one student invoked school science directly. Tom, the student who constructed a germ-centered theory, based it primarily on a school science experience where he investigated the presence of germs on school surfaces (e.g., drinking fountains). This science experiment clearly left a strong impression with him. However, his application of this science experiment to the interview seemed to act as a constraint; he did not explore other factors when ordering the strawberry products. While it is encouraging that Tom leveraged school science, he did not do so in a way that provided him with productive resources for engaging with the issue. Tom's leveraging of his school science experiment did not position him well to consider multiple important factors relevant to the scenario, i.e., benefits and disadvantages of organic and pesticide farming, pesticide runoff consequences, transportation and packaging impacts of a product, etc.

For the students who engaged most deeply with the issues, school science was less useful as a resource than family and personal knowledge, values, experiences and practices previously described. Thus, our data suggests that school science often plays a minimal role in informing students' decision-making processes about socio-ecological issues. Our study raises questions about the role school science could and should play in equipping students to make informed socio-ecological decisions. Future work in this area could include investigating:

- How can school science help students think critically about socio-ecological issues?
- What sort of science content should be taught in school that is relevant to the everyday socio-ecological decisions students have to make?
- How should content be taught so that it resonates with students' out of school Discourse-based resources, as James and Michael's cases have illustrated to be so pertinent?

These questions have implications for decisions about the K-12 science curriculum and the kinds of science curricular materials and pedagogical strategies that will best serve the purposes of teaching science for socio-ecological literacy in K-12 science education.

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Appendix A

Citizenship and Strawberries Interview Protocol

Baseline Questions:

	Question	Target Role
1.	How often does your family go to the grocery store to buy food?	Consumer
2.	Do you go to the store to buy food yourself?	Consumer
3.	What product do you usually buy? (e.g. cookies)	Consumer
4.	How do you choose among all the varieties of that product? For example, how do you choose what types of peanut butter to buy? What criteria do you use?	Consumer/ Learner
5.	What resources do you use to make decisions on what to buy? (for example, family experience, what you learnt in class) (probe – is it based on taste, brand name, family tradition, nutritional information etc.)	Learner/ Consumer
6.	Do you have any other ideas about this issue that you'd like to share?	
7.	Have you studied a lot of science in school? What kinds of things have you learned about (what courses have you taken)?	Learner
8.	Are you interested in a career in science? If so, what kind of job?	Student identity
9.	Do you think that everyone should know some things about science even if they aren't going to be scientists?	
10.	What kinds of things do you think people should know about science?	
11.	Why do you think it's important for everyone to know these things?	

Strawberry Items Think Aloud

Present the student with a selection of foods, from fresh to preserved, simple packaging to elaborate packaging.

	Food	Treatment
1.	Strawberries	Fresh and frozen, organic and non-organic/GM giant strawberries
2.	Strawberry jam	In a jar, sweetened, jellied, cooked
3.	Strawberry pop tart	Sugared, cooked, preserved, cardboard packaging
4.	Large carton of strawberry yogurt	Single large carton with multiple servings
5.	Small cartons of I serving size strawberry yogurt	Small single size servings

	Food	Labels
1.	Strawberries	-Industrially grown, pesticides applied, grown in California at a large strawberry farm -Locally grown, from a farmers market in Lansing (e.g. Okemos or Allen street, small family farm -Organic, no pesticides used.
2.	Strawberry jam	-Grown and packaged in California -Locally grown and packaged
3.	Strawberry pop tart	- Processed and packaged in California
4.	Large carton of strawberry yogurt	- Dannon, packaged in Utah
5.	Small cartons of I serving size strawberry yogurt	-Dannon, packaged in Utah

Ask the student to do the following and justify her choice:

1. arrange the items in order of nutritional benefits
   - gets at how they decide what is the most beneficial to health, what resources they use to make their decisions, what is common in their family with regards to these products (e.g. always eat pop-tarts for breakfast)

   - How do you know where the product comes from i.e. how did it end up on the grocery shelf? Do you think information is important? Who can you ask? How do you find out? (probe – gets at who do you believe/trust; if they are at all concerned about transport/food production process; probe on GM foods/growth process and consequences)

2. arrange the items in terms of most friendly to the environment to least friendly
   - How do they define "friendly to the environment"?
   - What criteria do they use to arrange the stuff?

Additional questions – depending on time

3. Why is our natural environment important?
4. How would you describe the natural environment? Or What do you think of when you think of the natural environment? (probes: forests, lakes, mountains, animals, gardens, yards, parks, etc.)
5. Why do you think it might be important to take care of or protect our environment?
6. What kinds of things do you do that are environmentally friendly/conscious?
7. Are you aware of the environmental impact of turning off the lights in your home? Taking showers?
8. Have you heard anything about what's happening to the polar bears' habitat/home in the news, at school, or from friends/family?

Appendix B

Citizenship and Water Interview Protocol (High School)[1]

Name of Student _____

Name of Interviewer _____

Date _____

Materials

- Interview Protocol
- Map showing Twin and Chippewa Creeks and proposed location for new well
- Water scenario info sheets (bottom of document)
- Bottle of Ice Mountain Water

Introductory questions

1. What are different ways you know of that people use water?
2. Can you think of any ways that taking a shower affects the environment?
3. What kinds of beverages do you usually drink?
4. Do you ever drink bottled water?

If yes,

   a. Why do you drink bottled water?

   b. How do you decide which brand of bottled water to buy?

   c. Do you know where ___ brand of bottled water comes from?

   d. Can you think of any ways that drinking bottled water affects the environment?

5. Do you ever drink tap water?

   a. Do you know what the source of your tap water is?

6. Would you rather drink bottled water or tap water, or do you not care? Why?
7. Do you think tap water is different from bottled water?

   a. If yes, how do you think they're different?

   b. If no, why do you think they're the same?

8. What kinds of things can people do to protect water and make sure there's enough good water in their community?
9. Do you do any of these things to protect water in your community?

[1] There are two water citizenship interview protocols: one for high school students and one for elementary and middle school students. The interview questions are virtually identical. The "Excerpts for Sources" for the elementary and middle school students are simplified to make them more developmentally-appropriate.

Nestle Bottled Water Scenario (show map while talking about this)

I'm going to tell you about a real environmental debate going on in Michigan. The Nestle Company owns a water bottling plant in Stanwood, Michigan. They get groundwater from wells and bottle it as Ice Mountain water. The Stanwood plant bottled 226 million gallons of water last year. Because bottled water is so popular, Nestle wants to drill a new well so they can sell more water. The new well would be located near two trout streams that flow into the Muskegon River. Nestle also wants to build a new water bottling plant nearby in Evart. Some people think Nestle shouldn't drill the well because it would harm the trout in the streams. The Nestle Company says there is a lot of water available so the well would not harm the trout. Opening the bottling plant in Evart could provide some new jobs for people.

Water Science Understanding Questions

Here's a map showing the streams and the proposed location of the well to pump out the groundwater for Ice Mountain water.

1. (Pointing to a spot on the map) If water fell as rain here, where do you think it would go? Why?
2. Can you draw the watershed boundaries for Twin Creek and Chippewa Creek?
3. Do you think that the well could affect the flow of water in the streams? If yes, how? If no, why not?
4. How deep do you think the well would have to be drilled to get groundwater out?
5. Do you think that the well could affect trout that live in the streams? If yes, how? If no, why not?
6. Do you think that drilling the well and pumping out the groundwater could have any other impacts?

Citizenship Questions

Think of yourself in the role of a citizen as you answer these questions. If you're not eighteen, picture ahead a few years and think of yourself as a citizen of the state of Michigan who is old enough to vote.

1. If Nestle built the well and a bottling plant, would knowing what I just talked about affect your decision about whether to buy Ice Mountain water? How?

2. If Michigan voters got to vote about whether or not to let Nestle drill the well and build the new bottling plant, do you feel like right now you'd have enough information to decide how to vote?

If student says they have enough information, ask the following questions.

1. Would you vote for or against Nestle building their new well and a new bottling plant in Evart? Why would you vote that way?
2. Can you think of anything else that you might want to know about this issue?
3. If you wanted to find out more, how would you try to do that?

Provide the info from sources and time to look over. "Here's some additional information from people who are interested in this issue. You can read as few or as many of these as you'd like." (Note which ones student looks at.)

4. Did looking at this information influence your decision at all? If so, explain how?
5. Which information do you trust the most? Why?
6. Which information do you trust the least? Why?
7. Do you think there's a right answer and a wrong answer about whether Nestle should build the well and water bottling plant?
8. If someone organized a march against/for (depending on student) building the plant, would you join the march? Why or why not?
9. If the town of Evart organized a scientific study of water flow in the Muskegon River watershed and they asked people to help, would you volunteer to help? Why or why not? (If student says no because they live far away, ask what if you lived in Evart?)
10. Is there anything more you'd like to know to be able to make a good decision about Nestle's well?

If student says they need more information, ask the following questions.
1. What else would you want to know about this issue to help you make a decision?
2. What could you do to help you decide about this issue?
Follow up probes: Who would you talk to? Where else could you find out information?
3. If you wanted to find out more, how would you try to do that?

Provide the info from sources and time to look over. "Here's some additional information from people who are interested in this issue. You can read as few or as many of these as you'd like." (Note)

4. Did looking at this information influence your decision at all? If so, explain how?
5. Which information do you trust the most? Why?
6. Which information do you trust the least? Why?
7. If you had to decide right now about whether or not you think the water bottling plant should be built what would you say? Why?
8. Do you think there's a right answer and a wrong answer about whether Nestle should build the well and water bottling plant?
9. If someone organized a march against/for (depending on student) building the plant, would you join the march? Why or why not?
10. If the town of Evart organized a scientific study of water flow in the Muskegon River watershed and they asked people to help, would you volunteer to help? Why or why not? (If student says no because they live far away, ask what if you lived in Evart?)
11. Is there anything more you'd like to know to be able to make a good decision about Nestle's well?

If time questions
1. Have you studied a lot of science in school? What kinds of things have you learned about (what courses have you taken)?
2. Are you interested in a career in science? If so, what kind of job?

3. Do you think everyone should know some things about science even if they're not going to be a scientist?
4. What kinds of things should people know about science?
5. Why do you think it's important for everyone to know these things?

Excerpts from Sources for High School Students

Application for Determination of No Adverse Resource Impact

For the White-Cedar-Osceola Site

Prepared for Nestle Waters North America by Malcolm Pirnie, Inc., August 2006

Zorn's 1998 paper predicts that no change in fish populations in Twin and Chippewa Creeks would occur as a result of the decrease in flow in those streams. Much larger changes than those predicted for this groundwater withdrawal would be required to affect the characteristic fish cluster. This conclusion is consistent with the findings of Nufer and Baker (2004) who found in a long-term study in Hunt Creek that brook trout suffered few adverse effects from summer withdrawals.

Letter from David Smith,

President, West Michigan Trout Unlimited

Sent to Michigan Department of Environmental Quality in March 2007

We are opposed to all groundwater withdrawals that negatively impact coldwater streams. After reviewing Nestle's application, other public documents, and our own independent review, we have a few concerns.

1. It is insufficient protection to our coldwater resources to issue a finding of **No Adverse Impact** with an allowed withdrawal amount and expect the resource to be protected under all extremes of natural variation. Specific limits should be established regarding stream flows and water temperatures which would trigger a reduction or suspension of withdrawal during extreme events.

2. Is there any evidence of potential conflict with Evart's wells on Twin Creek which are currently operating at less than full capacity?

3. Information on Muskegon River impact is missing.

Michigan Citizens for Water Conservation - March 2007 Newsletter

Water levels in Lake Superior last year were as low as they've been for 80 years. When water is low in the Great Lakes, it means water is low in lakes and streams. Every gallon of water taken by Nestle is a gallon mined from a Michigan stream, and because it's **spring water** that usually means a trout stream.

Nestle presently takes about 450 gallons per minute from Mecosta and the City of Evart. That's approximately one-quarter billion gallons a year. Nestle's proposed expansion into three more headwaters & trout streams will take another 300 to 400 gallons per minute, which means another quarter billion gallons a year.

Michigan Department of Environmental Quality

Proposed Determination of No Adverse Resource Impact, December 19, 2006

The proposed withdrawal would take groundwater discharging to Twin and Chippewa Creeks. The effect of the withdrawal is measured against the allowable withdrawal from both creeks. Nestle's proposed withdrawal of 150 gallons per minute is well below the allowable withdrawal of 480 gallons per minute. Therefore, we propose to find that Nestle's project is not likely to cause a negative impact.

Excerpts from Sources for Elementary and Middle School Students

Application for New Well Near Evart, MI

by Nestle Company

Scientific studies predict that the well will not affect trout in the streams. Much more water would need to be removed to harm the trout.

Letter from West Michigan Trout Unlimited

Sent to Michigan Department of Environmental Quality

1. Using the Nestle well could be safe for the trout most of the time, but it might harm them during a very dry or hot season.

2. Building the Nestle well might draw water away from Evart's town well, which is nearby.

3. We do not know how the Nestle well could affect the Muskegon River.

Michigan Citizens for Water Conservation - March 2007 Newsletter

Every gallon of spring water taken by Nestle is a gallon taken from a Michigan trout stream.

Michigan Department of Environmental Quality

Proposed Approval for Nestle Well

Nestle's well would remove 150 gallons per minute. We have found that it would be safe to remove up to 480 gallons per minute without affecting the trout.