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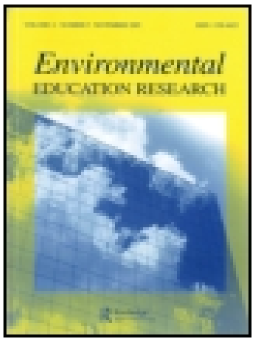

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Compelling evidence: an influence on middle school students' accounts that may impact decision-making about socioscientific issues

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ABSTRACT

This study investigates how middle school students make hypothetical purchasing, consuming, and voting decisions about environmental and science-related issues – a key component of environmental literacy. Fifty-three female students were given a packet containing multiple excerpts of information from conflicting positions from stakeholders and interviewed about how they would make decisions about environmental and science-related issues. We first investigated whether and how information presented as evidence influenced students' accounts that may impact their decision-making (i.e. to make or change decisions). We then investigated how evidence type affected students' decision-making. Findings indicated that most students did not change their stance after reading additional contrasting information presented as evidence. Implications for science teaching and learning are discussed.

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Environmental education; decision-making; environmental issues

Adults and children worldwide choose how to vote and what to buy. Making informed decisions requires that people interpret, evaluate, and use evidence. Unfortunately, much of the public has insufficient understanding of how to evaluate and use evidence to make informed decisions (Collins et al. 2007; Covitt et al. 2009; McBeth and Volk 2009; Miller 2004). Miller (2010) claims that only 28% of people of the United States understand the process of science sufficiently to read and understand the science section of The New York Times, let alone use this information to make informed decisions.

People's voting and purchasing decisions have important implications for the environment. While individuals may verbally commit to responsible environmental behaviors, research indicates that there are many complexities towards pro-environmental behavior (Kollmuss and Agyeman 2002) and their actions do not demonstrate 'critical thinking and decision-making skills that might be useful in helping to resolve environmental issues in their own communities and in society at large' (McBeth and Volk 2009, 63).

Of particular interest in this study are students' understanding of socioscientific issues (SSI), issues that are complex, open-ended and at the interface of science and society, and *how* students evaluate and use information presented as evidence in decision-making. These issues rely not only on an individual's science literacy, but also on their understanding of how humans exist as part of the system. This has been referred to as *environmental science literacy* (Moore 2009) or, similarly, sustainability literacy (Colucci-Gray et al. 2006).

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In this study, we investigated how middle school students made decisions about five scenarios related to SSI. We selected scenarios that were likely to be relevant to California students, either because they were issues in the news at the time (safety of power plants, usefulness of forest thinning) or related to the everyday interactions of students (bottled vs. tap water). The goal was to understand *how* students evaluated and used data to influence accounts that may impact decision-making, rather than what they thought about these particular issues.

Environmental Science Literacy is important because citizens need to be able to understand and evaluate scientific and non-scientific evidence and use it to make informed decisions in their daily lives (e.g. in purchasing, voting, etc.). That is, *environmental science literacy* is a key component of environmental citizenship. In this project, like Anderson (2010) we understand environmental citizenship to mean that 'citizens should be able to understand and evaluate experts' arguments about environmental issues, choose policies and actions that are consistent with their environmental values,' and explain their reasoning about personal decisions with environmental consequences (5). We adapt this understanding to say that middle school students (future adult environmental citizens) should be able to use data and evidence from multiple sources to make informed hypothetical decisions about environmental issues in both public and personal roles.

There is a general gap in students' awareness of the origins of goods purchased and thus, many students do not make connections about how their actions (e.g. their purchasing or voting choices) impact the environment (Hadjichambis et al. 2015; UNESCO 1999). Teaching students skills towards environmental scientific literacy provides them the tools necessary to make sustainable decisions about the environment and their health.

We focus on whether and how data and evidence influence students' decisions about SSI. Using such information for decision-making is a complicated task. To make such decisions requires analyzing reports of scientific findings that are filtered, adapted, and communicated in newspapers, the web, and other media. This means we must help students understand the role of data and evidence in science *and* help them learn to evaluate the source of the information and how to use the evidence for decision-making.

Here, we investigated in what ways data and evidence affect students' decision-making about SSI. We asked,

(1) Did data and evidence influence students' accounts that may impact decisions? If so, how (i.e. to make or change decisions)?
(2) For students who changed their decision after reading information packets, what types of data and evidence did they find most influential?

Literature review

Figure 1 shows an Environmental Science Literacy loop diagram depicting how human decisions and actions impact environmental systems. This framework may be used to direct decision-making research about students' use and non-use of information presented as evidence for decision-making about SSI. In their 2012 paper, Gunckel, Mohan, Covitt, & Anderson adapted the 'loop diagram' from the Long Term Ecological Research Network (Long Term Ecological Research Planning Committee 2007). We adapted it further to focus on the constructs and SSI in our study. This loop diagram depicts the relationship between 'Human Social and Economic Systems' (the left-side box) and 'Environmental Systems' (the right-side box). As shown in Figure 1, human and environmental systems impact one another: (1) decision-making and management practices in human systems impact environmental systems (including human-engineered environmental systems) and (2), environmental systems produce ecosystem services valued by human systems. Human systems include three key practices in which citizens act that impact environmental systems: inquiry (identifying a problem and finding evidence based on science related to the problem), accounts (explaining to oneself the components of the problem and predicting consequences as they connect to ones actions), and decisions (e.g. actions such as voting and purchasing

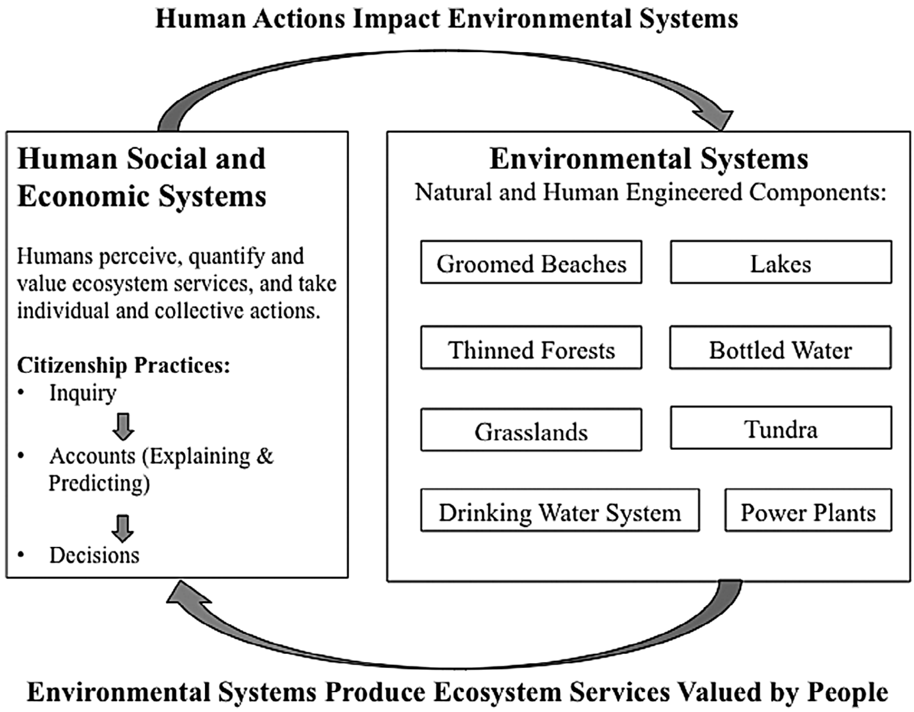

Figure 1. Environmental Science Literacy Loop Diagram. Source: Adapted from Gunckel et al. (2012).
Notes: Model for how human decisions impact environmental systems and how environmental systems (and their related human engineered components) produce ecosystem services that are valued by people. In this study, students were presented with five environmental scenarios (including human-engineered environmental systems): Groomed Beaches, Thinned Forests, Bottled Water, Power Plants and Drinking Water System.

decisions) (Covitt et al. 2009). Inquiry in citizenship practices differs from scientific inquiry in that the former identifies a problem and typically uses secondary evidence and personal experience (e.g. news reports, magazine articles, websites) to better understand the issue; scientific inquiry involves hypothesis development and testing to generate original data that inform the problem. Similarly, the citizenship practice of accounts does not necessarily employ the scientific methods of statistical or similar analyses for explanatory purposes, but rather builds a narrative from the secondary data that has been uncovered. Finally, citizens make decisions through their actions based on their narratives, and while some scientists engage in conversations with policy-makers on scientific issues, the goal is often to provide data-based information for other's decision-making. In this study, we focused on decisions: whether and how evidence influenced accounts that may impact decision-making.

Ecosystem services are benefits provided by environmental systems that people want and need over long periods of time and are affected by management decisions (Abramson et al. 2010). As stated by the LTER Network Planning Committee (2007),

> We must recognize that our actions affect the material world – the environmental systems on which we and our descendants depend – and find ways to use scientific knowledge as a vehicle for considering the environmental implications of the decisions we make as citizens. (67)

For example, prosperity, part of our human system, depends on the responsible management of our environmental systems (Lubchenco 1998).

Defining evidence

Erduran, Simon, and Osborne (2004) discuss how students use evidence to support claims using Toulmin's argument structure of 'an interconnected set of a claim; data that support that claim; warrants that provide a link between the data and the claim; backings that strengthen the warrants; and finally, rebuttals which point to the circumstances under which the claim would not hold true' (918). We use Toulmin's argument structure to help us think about data and its relationship to claims. We define data as observations, statistics and other pieces of information that are not directly connected to a claim through an argument structure and define evidence as data that supports a claim and is connected to the claim through a warrant. It is important to note that while evidence may support a claim, it cannot 'prove' a scientific claim (Popper 1963).

Socioscientific issues

SSI are complex open-ended problems which relate to science and have a socially relevant dimension, generally require a degree of moral reasoning in the process of arriving at decisions, and have multiple solutions, (Sadler 2004; Zeidler and Nichols 2009). Asking students to respond to SSI has been established as a productive means of eliciting students' ideas about decision-making and a tool for improving students' scientific literacy (Albe 2008; Kolstø 2001a, 2006; Ratcliffe 1997; Yang 2004). SSI require the layperson to make science-related decisions about personal health or environmental issues, that relate to general public interest, or are political in nature (Rudolph and Horibe 2015). As stated by Sadler (2004), 'In response to socioscientific dilemmas, valid, yet opposing, arguments can be constructed from multiple perspectives' (514). Examples include embryonic stem cell research (Shea 2015) and maintaining clean water supplies (Emery et al. 2015).

One advantage of using SSI in science instruction is to address uncertain and conflicting information in the context of science-based issues students will encounter in daily life. The variety of data, evidence, and opinions that students encounter (e.g. in the news, on the Internet, and through social media) often includes uncertain and conflicting information. Many examples including conflicting information in science do not require citizens to act in any way. And, textbooks typically do not provide lessons or tasks to teach skills related to how to deal with uncertain and contradictory information. Using SSI to augment existing curriculum can help students learn these skills.

Recent studies provide insights about how students deal with uncertainty and contradictions in data and evidence. For example, when faced with uncertainty or contradictions in information, people rely on common sense rules to make decisions (Tversky and Kahneman 2000), assume that conflicting results mean that the scientists have not yet gathered enough information (Albe 2008), or simply do not recognize ambiguity in evidence (Emery et al. 2015). Media and teachers can motivate students to think about when it may be better to make a decision based on best available (and even ambiguous) information and when, in the face of uncertainty, to encourage new scientific work instead.

Factors that affect students' decision-making

As stated by Nielsen (2013), 'scientific information alone is not enough to render even an informed socioscientific decision acceptable or not – science cannot be the sole arbiter when it comes to decisions such as embryonic stem cell research and maintaining clean water supplies' (277). Studies provide insights about factors other than evidence and the ability to understand and use evidence that impact students' decision-making: their values and how much they care about a topic (Jang 2013; Slovic 2007), prior judgments and personal experiences (Albe 2008; Kahneman 2011), religious views and perceived knowledge (Jang 2013), attitudes about source and trust (Arvai et al. 2004; Covitt et al. 2009; Kolstø 2001a), and ideas about the nature of science (Sadler, Chambers, and Zeidler 2004). When making decisions about a SSI, one interprets the statements and factual claims offered. Interpretations depend on their general knowledge, affected by their awareness of the nature of science and scientific knowledge (Kolstø 2001b). In fact, Kim, Anthony, and Blades (2014) found that when a topic was highly controversial with opposing views, and there was doubt in public discourse, participants adhered to their preexisting and personal beliefs about the issue, did not agree on a conclusion, and left the decision regarding the topic unresolved. On the other hand, when the topic and evidence were less controversial, participants were able to agree on conclusions and make action plans about the SSI. Kim, Anthony, and Blades (2014) note that further work is needed to better understand students' lack of critical questions about evidence and that it would be worthwhile to research how students evaluate the trustworthiness of scientific knowledge.

In a study of how high school students evaluated two conflicting reports (i.e. 'science briefs') about global warming, Sadler, Chambers, and Zeidler (2004) asked students which report had the most scientific merit and which was most persuasive (i.e. convincing), criteria that are 'potentially significant considerations for the process of socioscientific decision-making' (400). Students' assessments of scientific merit were based on four categories of criteria: personal relevance, better data and information, better explanation, and equally meritorious. Students' assessments of the articles' persuasiveness were based on three categories of criteria: personal relevance, information quality, and previous personal beliefs. Many students reported that the most convincing article was the one that supported their prior beliefs and that personal relevance was important in evaluating the scientific merit and persuasiveness. Forty percent of students said the article that they considered had the most scientific merit was the least persuasive. In contrast, in their analysis of participants with two years of college, Brem and Rips (2000) found that participants claimed that the arguments that were most scientific, were most convincing.

When making decisions about whether or not power lines increase the risk of childhood leukemia, Kolstø (2001a) identified four main kinds of 'resolution strategies' used by high school students to decide who and what to trust when judging information encountered about a SSI:

> (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, and (4) evaluation of sources of information in terms of 'interests', 'neutrality' or 'competence'. (877)

Kolstø (2001a) found that some pupils used all these strategies, while others used only one or two, that students are critical of researchers, but have an underlying trust in their authority, and that they are frustrated with disagreement among scientists.

In an investigation of how middle and high school students made hypothetical decisions for or against a bottled water company building a well near a local stream, Covitt et al. (2009) found that students rarely used knowledge learned in school, rarely judged the scientific quality of evidence or arguments, and often trusted evidence that did not appear biased.

Investigations about how students interpret and evaluate conflicting information regarding SSI are increasing (Albe 2008; Jang 2013; Rudsberg, Öhman, and Östman 2013; Sadler, Chambers, and Zeidler 2004), and yet, a gap remains in research about how students use conflicting information for argumentation and decision-making. Argumentation in science education, through teaching about SSI in the classroom, is critical to science education: students learn to think critically, make thoughtful decisions, and take active parts in democratic society (Driver, Newton, and Osborne 2000; Rudsberg, Öhman, and Östman 2013). In an analysis of how high school students in Sweden discussed and evaluated different statements made by the teacher about SSI, Rudsberg, Öhman, and Östman (2013) found that through classroom discussions, students developed more complex insights into SSI and improved the quality of their arguments. Building upon Rudsberg, Öhman, and Östman's (2013) study, after we asked students to evaluate conflicting positions from stakeholders about SSI, we investigated whether and how they used that information to make (or change) their decisions.

Study design

We choose to follow a qualitative research design because, rather than test a hypothesis, we were attempting to understand a phenomena. Students' understanding of evidence and how to use it to make decisions about complex problems like SSI, is a result, not only of their school learning, but of prior experiences, morals, and other factors. Qualitative data can help researchers better understand complex phenomenon (e.g. Strauss and Corbin 1990) and interviews can be used to elicit how people understand an experience (e.g. Seidman 2013). Our primary method of collecting data was through qualitative interviews, using SSI tasks to prompt student's talk. We followed a standardized, open-ended approach where each participant was provided with the same questions (Patton 1990). This facilitated analysis and comparison.

Study participants and context

Fifty-three female middle school students (12–14 years old) were randomly selected as participants from a population of 146 girls who were enrolled in a week-long summer science, math, engineering and technology camp for girls, held at a large research university in California. Students came from diverse ethnic and socioeconomic backgrounds. All the students had finished seventh grade and were entering eighth grade. Students in the camp were above average in their interest and/or aptitude about the topics. We focused on middle school students because they study science at school, are surrounded by the opinions of peers, parents and teachers, and will soon become independent decision makers eligible to vote and responsible for making their own purchases.

In this study, we did not define evidence, nor the criteria for how to evaluate evidence strength. In fact, we investigated what criteria they thought should be used and what criteria they actually used to evaluate evidence. In a companion paper to this study (Emery et al. forthcoming), we focused on how middle school girls defined the word evidence and how they interpreted and evaluated information presented as potential evidence about environmental issues. Prior to giving the students information to assess, we asked them 'What counts as evidence to you?' We found that students described evidence as something associated with proof and that, in the context of decision-making, students evaluated information presented as evidence according to three main criteria: presence of new information, presentation style, and relevance to issue.

Data collection and analysis

We provided students with five environmental scenarios. We call these scenarios (1) Bottled Water, (2) Water Bond, (3) Power Plant, (4) Forest Thinning and (5) Beach Grooming. See Table 1 for full questions asked for each scenario.

For each scenario, we provided students with a packet containing five excerpts (see 'inquiry' in Figure 1) from stakeholders to read, interpret and evaluate (See Table 2). To ensure an appropriate reading level and constrain the amount of time students spent reading the packet of information, we selected parts of each excerpt and highlighted key points in bold. For each scenario, we selected real excerpts from two stakeholders who were in favor of the proposed issue, two who were against, as well as one who presented both sides of the argument. This is typical of the types of evidence students will encounter in the media. Most excerpts and articles only present one side, especially if it is within advertisements or political campaigns – the two things that are designed to influence purchasing and voting decisions. This resulted in a total of five excerpts for each scenario. We purposely designed these packets so that they were similar in that excerpts for each scenario collectively provided a range of representations (graphical or tabular, numerical, or text based) and sources (peer-reviewed journals, newspapers, environmental non-profit groups, businesses, blogs, and other online information sources), and used multiple presentations of information (question and answer format, quotes, bulleted information, and photos). (See Figure 2 and Emery 2013, for more details). The variety in information sources, presentations, and perspectives was intentionally designed to mimic the variety of information one might encounter and attempt to make sense of when making a decision on a complex issue.

Each student participated in a task-based interview focused on the scenario packets. The initial design of the interview was informed by prior work (Covitt et al. 2009; Tsurusaki et al. 2008) and a pilot study (Emery 2013). Final versions were informed by feedback on the interview items given by teachers, science educators, and environmental literacy researchers.

In each interview, students were first asked to describe what the word 'evidence' meant to them and to discuss criteria for judging the strength of evidence. We then presented students with summaries

Table 1. Questions and initial information provided to middle school students for each scenario.

Scenario	Question
Bottled water	People debate whether it is better to drink bottled water or tap water (water from the faucet, such as from water fountains). Some people think that bottled water is of higher quality, has fewer contaminants, and is healthier. Other people claim that it is better for the environment and people's health to drink highly regulated tap water Question: Would you prefer to drink tap water, bottled water or do you not have a preference? Why?
Water bond	On the 2012 California ballot there will be a water bond proposition called the Safe, Clean, and Reliable Drinking Water Supply Act of 2012 that voters will vote 'for' or vote 'against'. Some people think that the bond is needed to protect California's water, environment, and economy. Other people think that the bond shouldn't be passed because the money would hurt the environment Would you vote for the water bond?
Power plant	Diablo Canyon nuclear power plant in San Luis Obispo, California, is trying to renew its licenses to operate for 20 more years. Some people state that nuclear power plants are better for the environment than other energy sources because they produce no carbon dioxide or air pollution and are safer. Other people state that nuclear power produces radioactive waste that can remain radioactive and dangerous to human health for many years Would you vote to renew their license for 20 years?
Forest thinning	A current debate in California and across the United States is whether or not to 'thin' forests. Forests are 'thinned' by cutting down or burning trees and brush. Some people think that it is better for the environment to thin forests because it decreases forest fires. Other people think that forest thinning actually causes fires to spread because it reduces shade and moisture in forests Would you vote to allow 'forest thinning'?
Beach grooming	Many beaches in California are groomed or raked using trucks to remove trash and beach wrack (seaweed). People debate whether it's better to remove beach wrack or leave it. Some people state benefits of beach grooming such as improved scenery, decreased smell of rotting seaweed, and fewer flies. Other people state disadvantages of beach grooming such as hurting the local ecology by removing homes and food important to small animals at the base of the food chain Would you vote to allow beach grooming?

of the five voting scenarios for them to read. We asked each student to identify the issue she cared most about and the scenario she cared least about. The rest of interview then focused on these two scenarios. Although this approach resulted in students working with different scenarios, it allowed for students to work on the two scenarios in which they had the strongest and least interest. For each of these two scenarios, we asked each student whether they thought they had enough information to make a decision (voting or purchasing, depending on the scenario) and to explain their reasoning (See 'accounts' in Figure 1). If students claimed not to have enough information we asked what else they would need to know. The students then read, interpreted and evaluated the five excerpts for these two scenarios (the one she cared most about and the one she cared least about). After reading each set of excerpts for that scenario, we asked the student if she had changed her stance.

Following this initial task, after the student read all excerpts for this scenario, we asked the following questions (1) 'Which excerpt do you think is strongest and which do you find the weakest?' and 'Why?', (2) 'Which evidence has the most scientific merit?' and 'Why?', (3) 'Which evidence do you think is most persuasive/compelling?' and 'Why?', and (4) 'When you read the information, what factor is most important to you? (Source, information, way information is presented, or another factor)' and 'Why?' This

Table 2. Excerpts provided to middle school students.

Scenario	Excerpt	Argument	Type
Bottled water	What is bottled water?	For	Text
	Updated groundbreaking report	For	Numbers
	Frequently asked questions (FAQ's)	Against	Numbers
	Bottled water quality investigation	Against	Graph
	Santa Barbara's CEC	Both Sides	Newspaper
Water bond	Water bond needed	For	Newspaper
	Safe, clean, and reliable	For	Numbers
	Sierra Club California	Against	Numbers
	California water bond	Against	Table
	Proposed sites	Both Sides	Quote
Power plant	About Diablo	For	Numbers
	Diablo Canyon	For	Numbers, blog
	Capps testifies	Against	Quote
	Mothers for peace	Against	Text
	Energy production costs	Both Sides	Graph
Forest thinning	Benefits of prescribed	For	Text
	Effects of thinning	For	Graph
	Thinning forests	Against	Text
	Forest thinning myths	Against	Text
	Bioenergy	Both Sides	Numbers, quote
Beach Grooming	Ken Gill Construction	For	Advertisement
	Coastal systems	For	Numbers
	Loss of coastal strand	Against	Graph
	Kelp wrack hopping	Against	Text
	Beach grooming	Both Sides	Numbers

Loss of Coastal Strand Habitat in Southern California: The Role of Beach Grooming
Dr. Jenifer Dugan & Dr. David Hubbard, Estuaries and Coasts, Journal of the Coastal and Estuarine Research Federation, 2010

Results from our study **indicate that beach grooming or raking can have negative impacts** on coastal dune and strand habitats and vegetation through direct and indirect effects.

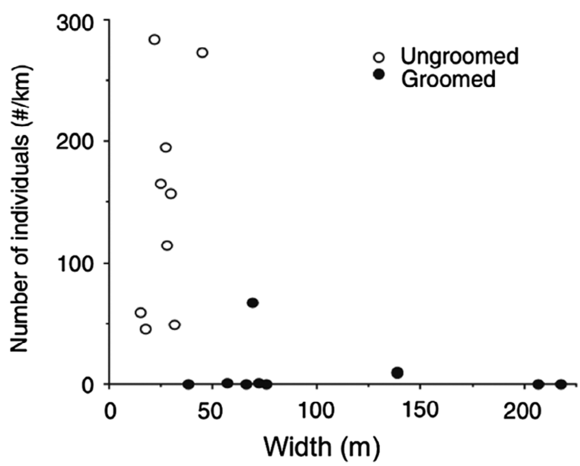

Figure: Abundance of native coastal strand and dune plants present seaward of the crest of the primary foredune as a function of width of the unvegetated zone measured at groomed and ungroomed beaches between Goleta and San Diego, California sampled in the summers of 2001–2003.

Figure 2. Example of a graphical excerpt about Beach Grooming that helped students make a decision. Source: Dugan and Hubbard 2010. Reprinted with permission from Dr. Jenny Dugan.

allowed us to identify the specific excerpts that students claimed to find most compelling in developing their accounts that influence their decision-making.

We conducted 53 interviews during summer camp activity hours. Each lasted 25–35 min. Two researchers conducted and digitally recorded each of the interviews. Interviews were conducted with one student at a time. Complete transcripts were produced for analysis. Participants were assigned pseudonyms for analysis and reporting of data.

We analyzed transcripts iteratively to identify initial patterns in students' use and non-use of evidence for decision-making. Our analysis included counting the number of times students made initial decisions without reading additional excerpts and the number of times those students changed or made their decisions after reading additional excerpts. We also identified factors that influenced students' initial decisions and additional information students wanted to make decisions. Our first pass of coding was on a subset of the responses. We read each response and assigned it a code. These codes were emergent and driven by the data. These initial codes were revised and collapsed until a stable set of codes were established and inter-rater reliability between two independent coders was consistently above 80%. Discrepancies were identified and reconciled through discussion until consensus was reached.

Results

Below we present results about (1) whether and how middle school students used the excerpts to influence accounts to impact decision-making (i.e. to make or change decisions), and (2) for students who changed their decision after reading information packets and for students who made a decision only after reading additional information, what types of data and evidence they found most influential.

Analysis 1: stage at which decisions are made and changed

Recall that we first asked students to make initial purchasing or voting decisions about the scenarios after reading a summary of the issue, but before reading any arguments in favor of or against the proposal. We asked students to make a decision before reading the additional excerpts to be able to later analyze whether and how they used the additional information presented as evidence to change or make decisions. Each student was asked to make a decision for two scenarios for a total of 106 decisions. For this analysis, the unit of analysis is a decision. Of the 106 decision instances, 67 (63%) decisions were made after only reading a summary of the issue and without consideration of the additional excerpts. In these cases, students relied on prior knowledge from firsthand experience (e.g. having opinions about forest thinning based on forest fire experience) or from what they had heard to make decisions (e.g. that tap water was 'bad').

For the remaining 39 (37%) decisions, when students were asked to make an initial decision, they claimed they were not able to decide without additional information. For example, to make an informed decision, Sarah said,

> [I would need to know] why [the nuclear power plant] would want to keep their license going for 20 more years; why do we have so many nuclear plants; and why do we rely on the nuclear energy so much.

This indicates that just over a third of our students sought out additional information and evidence *prior* to making any decision.

We then provided all students with excerpts to read and evaluate, and asked if the information changed their stance (or allowed them to make a decision). Results showed that the excerpts were helpful in making a decision if one had not been made, but they did not tend to change a decision that had been made. In the 39 instances where students asked for additional information, the students indicated that the excerpts were sufficient to allow them to make a decision in all but two instances. In contrast, of those decisions made at the onset, less than one fifth of decisions (18%) changed after students read additional excerpts. There are several reasons for this result, including variation in students' prior knowledge or differing views of evidence, which we investigate below. Figure 3 depicts the flow of decision-making and percentage of decisions made, changed, or remain undecided at each stage.

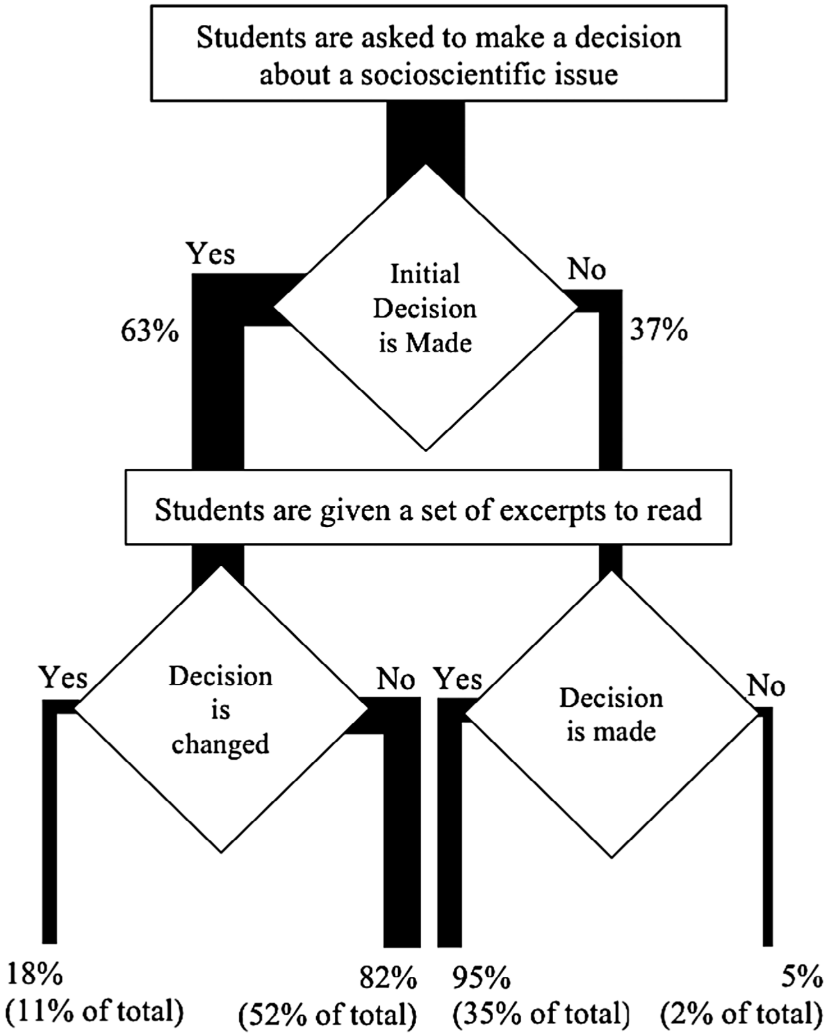

Figure 3. Decision-making flow chart.

Notes: 63% of decisions were made before students read additional set of excerpts; 37% of decisions were not made initially. Of the cases where initial decisions were made, 18% of decisions were changed after students read excerpts (11% of total), 82% of decisions were not changed (52% of total). Of the cases where initial decisions were not made, 95% of decisions were made after students read excerpts (35% of total), 5% of decisions were not made (2% of total). Total number of decisions are proportional to the point size of the lines on the chart.

In summary, results showed that information presented asevidence was influential in helping a student make a decision when an initial decision had not been made. Information presented as evidence was minimally used to change a decision that had already been made.

Analysis 2: types of excerpts that were influential

For the following analysis, we focus only on the students who initially made a decision about a scenario and then changed their mind after reading the excerpts. This included 12 of our study participants. To understand the *type* of evidence that was most influential, we asked them to identify the particular excerpt in the scenario packet that was the strongest, had the most scientific merit, and was most compelling or persuasive to them. They could select the same excerpt for all three questions or choose different excerpts.

Table 3. Responses to the questions 'Which evidence do you think is the strongest?', 'Which evidence do you think has the most scientific merit?', and 'Which evidence do you think is the most compelling?' by students who changed their stance after reading additional excerpts supporting both sides of the issue ($N = 12$).

Student	Scenario	Most/Least	Strongest excerpt (type, argument)	Scientific merit (type, argument)	Most compelling (type, argument)
Carolyn	Bottled water	Most	Santa Barbara's CEC (Newspaper, Both)	Bottled water quality investigation (Graph, Against)	Bottled water quality investigation (Graph, Against)
Oma	Bottled water	Most	Santa Barbara's CEC (Newspaper, Both)	FAQ (Numbers, Against)	FAQ (Numbers, Against)
Paula	Forest thinning	Most	Bioenergy (Quote/Numbers, Both)	Effects of thinning (Graph, For)	Benefits of prescribed (Text, For)
Rebecca	Bottled water	Least	FAQ (Numbers, Against)	Updated ground-breaking report (Numbers, For)	FAQ (Numbers, Against)
Sophia	Bottled water	Least	FAQ (Numbers, Against)	Bottled water quality Investigation (Against, Graph)	Updated ground-breaking report (Numbers, For)
Tabitha	Bottled water	Least	FAQ (Numbers, Against)	Updated ground-breaking report (Numbers, For)	Santa Barbara's CEC (Newspaper, Both)
Yolanda	Bottled water	Least	FAQ (Numbers, Against)	Updated ground-breaking report (Numbers, For)	FAQ (Numbers, Against)
Becca	Bottled water	Least	FAQ (Numbers, Against)	FAQ (Numbers, Against)	FAQ (Numbers, Against)
Darcy	Bottled water	Least	FAQ (Numbers, Against)	Santa Barbara's CEC (Newspaper, Both)	FAQ (Numbers, Against)
Nicole	Water bond	Least	Sierra Club California (Numbers, Against)	Blank	Sierra Club California (Numbers, Against)
Xafina	Water bond	Least	Proposed Sites Reservoir (Quote, Both)	Sierra Club California (Numbers, Against) and Water bond (Newspaper, For)	Water bond (Newspaper, For) and Proposed Sites (Quote, Both)
Catalina	Power plant	Least	About Diablo Canyon (Numbers, For)	Energy production costs (Graph, Both)	About Diablo (Numbers, For)

Strongest evidence

We asked these students, 'Which excerpt do you think is the strongest?' and 'Why?' Students identified excerpts with numbers most often (nine students) followed by excerpts from a newspaper or those including a quote (four students) (See Table 3). Students selected excerpts with numbers at a higher rate than others, but because more numerical excerpts were offered, we cannot be sure whether this finding was *because* these excerpts were numerical or if it was just by chance. None of these students chose a graph/table excerpt as strongest.

When we asked students to explain their reasoning for selecting a particular excerpt as the *strongest*, the most common response was that it contained new information (seven students) particularly when it related to harmful effects on the environment or risk to their personal health. Students also valued presentation style (4 students). For example, Rebecca said, '[the strongest excerpt is] "Frequently Asked Questions" because it is in a nice format that you can read and it bolds out the important parts. So if you're just skimming through, you would understand what they were talking about.'

Most scientific merit

We also asked students who changed their stance after reading additional excerpts, 'Which evidence had the most scientific merit?' All but one selected different excerpts than those they said were strongest. Students specified excerpts with numbers half the time (six students). For example, Rebecca chose the 'Updated Groundbreaking Report' excerpt by Natural Resources Defense Council 'because it has lots percentages and statistics.' Students chose excerpts with tables/graphs as having the most scientific merit one third of the time (four students). In contrast, no student selected a table or graph as the strongest excerpt.

When we asked students to explain their reasoning for selecting a particular excerpt as the having the most scientific merit, the most common response was because of its presentation style (e.g. graphs, statistics, and numbers) (seven students) and because it contained new information (six students). For example, Paula selected an excerpt as having the most scientific merit because they used data and graphed it:

> Because they're using their data and graphing it … because they actually collected the data and obviously they recorded through a number years; so they were trying to find a pattern, which seems very scientific to me. In the other articles they were just explaining, which was off previous data but it doesn't show the actual data.

To Paula, collecting their own data and identifying trends through graphing seemed most scientific.

Most compelling/persuasive

Finally, we asked students who changed their stance after reading additional excerpts, 'Which evidence was most persuasive/compelling?' While eight of the students chose different excerpts than those they said had the most scientific merit, seven of the students chose the same excerpt for being most persuasive/compelling as being strongest. Students specified excerpts with numbers most (eight students), excerpts from a newspaper/quote less (two students), and a graphical excerpt only once.

When asked to explain their reasoning for selecting a particular excerpt as the most compelling/persuasive, students identified factors including that the excerpt contained new information (six students), was argued well (i.e. described both sides of argument) (three students), and backed their prior convictions (three students).

Types of evidence helping students make decisions

Like the students who changed their mind, we asked the students who made decisions only after reading additional excerpts, 'Which evidence do you think is the strongest?' and 'Why?' This included 37 of our study participants. Similar to our earlier findings, students specified excerpts with numbers most (21 students). When students explained why they thought these excerpts were strongest, they claimed that the new information (24 students), presentation style (e.g. numbers, clear and accessible information, and graphs) (nine students), and the way evidence is argued (nine students) mattered most.

For students who needed more information to make a decision, over one half of the students synthesized information from more than one excerpt when describing how the additional information aided decision-making. This finding supports Kolstø's (2001a) finding that students use a variety of 'resolution strategies' when dealing with SSI. Other students combined their prior knowledge and personal sense of right and wrong with the additional information presented as evidence to make decisions. For example, after reading the excerpts, Wei said that she would vote against Forest Thinning:

> [I would vote] No ['against' Forest Thinning] because if a fire is caused naturally then it was meant to be and it'll actually help the forest because it has its own cycle. But if we burn it, then it's taking something out of the forest and not helping any wildlife because we wouldn't like it if somebody came down and took down our house. It's not fair to do that other animals … (Wei)

In this excerpt, Wei combined evidence around how fires maintain forests with her more personal response comparing animals' habitats to her own home.

Discussion

Our study adds new insights to recent literature about people's environmental literacy by increasing science educators and researchers' understanding of whether and how middle school students evaluated and used conflicting evidence to make and change their decisions about SSI.

We first asked whether data and evidence influenced students' accounts to make decisions (to make or change decisions). Results indicate that the majority of students made initial voting and purchasing decisions about the given issues based on prior knowledge and the brief scenario description.

For students who changed their decision after reading information packets, we investigated what types of data and evidence they found most influential. The excerpts that students selected to have the most scientific merit differed from those excerpts they selected as being the strongest. This leads to an implication that students do not necessarily associate scientific merit with being strong evidence when making decisions. For those students who changed their stance after reading the collection of excerpts, they stated that excerpts with numbers were the *strongest* and the *most compelling*. In contrast, students found excerpts that contained graphical and tabular data to have the most *scientific merit*. Our findings are in alignment with existing research on the value of numerical data. The students in our study often cited those excerpts with numerical data as influential, supporting Nicolaidou et al.'s (2011) finding that most students judged information which included details, numbers, and statistics as credible. This may indicate that people pay more attention to data and evidence that contain numbers than to information that is text-based, regardless of the content or statistical significance of the numbers.

For students who made decisions only after reading the additional excerpts, over one half of the students synthesized information from more than one excerpt when describing how the additional information aided decision-making. Kolstø (2001a) suggestion that some students use a variety of 'resolution strategies' to deal with and use the information: (1) Acceptance of claim, (2) Evaluation of statements, (3) Acceptance of researchers or authoritative sources, and (4) Evaluation of sources), may underpin our finding.

These findings have many implications for the ways that we teach students to evaluate and use various types of texts and representations for accounts when making decisions about SSI. For example, we need to teach students critical thinking: how to evaluate (scientific and non scientific) evidence and question what they hear and read in public media, for example. We need to provide opportunities for students to grapple with information that conflicts. We must teach students how to judge the merit of excerpts as evidence regardless of their own current viewpoints and teach them how to make decisions when confronted with such information. Students can then use such evidence to make decisions about SSI, instead of just ignoring conflicting information altogether and solely relying on personal beliefs and family values to make decisions.

This study was limited in that all participants were middle school aged, female, and science/math/engineering camp participants. Thus, participants' responses may reflect these students' interests and aptitude in scientific reasoning and cannot be generalized to other populations. Future studies could expand the demographics of the population as well as consider how demographic variables such as gender, ethnicity, and age impact students' decision-making practices.

Future research that investigates how students are taught to evaluate evidence in classrooms and their use (or non-use) of such skills in real scientific and environmental decision-making scenarios would provide important insight on this complex issue. Critical thinking skills will enable students to make more informed decisions about environmental issues that impact their lives.

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