

Should Great Lakes City Build a New Power Plant? How Youth Navigate Socioscientific Issues

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Abstract: There is a growing consensus that simply learning enough science to decipher public debates on socioscientific issues will not make citizens better equipped to handle the complex and ill-structured problems these controversial issues present. This study highlights the interaction and complex interplay between youth authored and appropriated frames for making sense of socioscientific issues. To do so, we analyze how two middle-school aged youth, in an after-school program focused on green energy technologies, made sense of and took a stance on whether their city should build a new hybrid power plant over the course of a 13-week unit. Using critical sociocultural perspectives on learning and qualitative case study, we examined how the two youth navigated the issue and the resources, scientific and otherwise, they leveraged in defining the problem spaces involved in whether their city should build a new power plant. Our findings indicate that the scientific knowledge youth brought with them and acquired over the course of the investigation influenced how they made sense of the issue, but their knowledge was deeply connected to a range of personal and public discourses that influenced how they defined the issue and why it mattered to them. In particular, it was through how they framed their range of knowledge and experiences that they were able to recognize the multi-dimensional nature of the problem and propose complex solutions resonant with the science they understood. Our study offers conceptual tools for teaching and learning socioscientific issues. © 2012 Wiley Periodicals, Inc. *J Res Sci Teach*

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Many societal issues require some level of scientific understanding in order to make sense of them and to decipher the many positions that surround them. Science is often brought to the fore in efforts to resolve such pressing disputes, such as the highly contentious debates about genetically modified foods, nuclear power, stem cell research, and climate change, to name a few. Increasingly, the public has been called upon to take a stance on these complex socioscientific issues, either in support of or in opposition to government regulations and policies. Many scientists and science educators believe that educating citizens on the science underlying these issues will lead to better decisions and less conflict.

While there exists much research that focuses on the deficits in citizens' scientific understanding of issues (Bauer, 2008), there is little evidence that suggests such understandings have made much of a difference in how citizens make decisions. Compelling evidence suggests that that conceptual understanding of scientific topics actually bears little impact on the

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actual decisions the public make on real world issues (Allum, Sturgis, Tabourazi, & Brunton-Smith, 2008; Nisbet & Scheufele, 2009). Similarly, in classroom settings, students typically make few connections between the content and their decisions (Sadler, 2004; Zohar & Nemet, 2002).

Our understanding of the nature of socioscientific issues and how the public engages in them in the context of making real-world decisions points to a more multifaceted approach. Such issues inherently require balancing social complexities, including the economic, ethical, and political effects of various courses of action (Sadler & Zeidler, 2009). Family, relationships, personal experiences, and societal discourses have all been shown to be important factors affecting students' thinking about socioscientific issues (Brotman, Mensah, & Lesko, 2010; Kolstø, 2006). Given this multifaceted nature of decision making, Sadler and Zeidler (2009) argue for a more complex view of instruction that incorporates the social, political, ethical, and economic dimensions of real-world socioscientific issues. Such a stance aligns with efforts to promote scientific literacy that combine a range of understandings and practices pertinent to science-related situations (e.g., PISA assessments).

Despite these efforts, we know little about how or why youth might position themselves in relation to socioscientific issues, and its implications for science learning. Science subject areas, such as environmental studies, which often center on societal challenges and concerns, still emphasize the content without fully considering political, economic, or social dimensions of issues and students' connections to them (Bowers, 2002). Even when instruction includes action-oriented goals and activities such as implementing recycling programs, there is often little consideration for how or why youth might engage such problems (Stevenson, 2007). In this manuscript, we investigate how two youth, ages 10 and 12, in an after-school program, made sense of and took a stance on one particular urgent real-world, real-time socioscientific issue—that of whether their community should build a new hybrid power plant. Our purpose in looking over time at two youth, as we describe later, is to understand the ways in which youth navigate such complex issues, including the resources they leveraged in defining the problem, why the problem mattered to them, and the stances towards the new power plant they ultimately took.

Framing Socioscientific Issues in Context

In this study, we draw upon critical sociocultural perspectives of learning to understand how students make sense of a local issue. In particular, we draw upon studies that examine the process of framing, or how people make sense of the problems and situations they encounter, and why it matters to them across the multiple contexts of their lives (Entman, 1993; Goffman, 1974; Lakoff, 2009). We also draw upon social practice theory to situate the process of framing within sociocultural context, paying attention to how power and positioning shape this process.

Authoring and Setting Frames

The process of framing represents the ways by which individuals bring coherence to the bits and pieces of information and experience that comprise their social world. In doing so, they highlight certain dimensions of an issue that reflect their concerns and understandings in relation to the contexts in which they find themselves. They attend to some aspects of the issue, while deemphasizing others. They ask questions that grow out of their desire to see how particular policies and practices respond to the ways they have framed the issues for themselves. It is, as Bruner (1990) puts it, a means of constructing the world.

We can recognize the frames individuals author to make sense of an issue through the narratives they tell to represent the product of the process of their meaning-making (Bruner, 1990). People's experiences provide them with a range of resources for making sense of why an issue might matter to them and their communities (Nisbet & Scheufele, 2009). It is important to note, however, that these experiences are deeply embedded in social, cultural, historical, and political contexts. Concerns and values do not exist in the abstract, but rather grow out of the contexts that give rise to them. Societal discourses intersect with people's experiences, providing them with a broader context within which to interpret their personal experiences. They bring these interpretations to how they make sense of local policy issues as they identify which dimensions of an issue matter to them and why.

Across a range of studies that investigate students' learning about socioscientific issues, Sadler (2004) and others have noted that personal experience, values, and beliefs play integral roles. In fact, recent studies have shown that "value dispositions" play a far greater role in how the public forms their views on science-related policy issues than scientific knowledge (Allum et al., 2008; Nisbet, 2005; Scheufele, Corley, Shih, Dalrymple, & Ho, 2009). This last point underscores the importance of understanding how individuals *frame* what science they do know (or care about) through their experiences, values, and beliefs.

At the same time that people author their own frames in order to make sense of issues (as they bring coherence to bits and pieces), they also rely upon set frames (Lakoff, 2009). Set frames, or dominant societal/cultural frames, are usually deployed by special interest groups, the media, and political projects to organize and convey complex ideas in ways that create common-sense and compelling storylines for the public about an issue. Set frames gain traction because of the ways in which they connect with people's values, interests, and experiences. They also gain traction because of how they are made salient to national concerns. Set frames for socio-scientific issues are not always grounded deeply in science, even when they may reference science to give them an aura of authority. As Nisbet and Scheufele (2009) point out, there is no such thing as an unframed science-related policy issue. As Entman (1993) explains, stakeholders frame issues by "Select[ing] some aspects of perceived reality and mak[ing] them more salient in a communicating text, in such a way to promote a particular problem definition, causal interpretation, moral evaluation, and or treatment recommendation" (p. 52).

There are many examples that illustrate the power of set frames. Energy sustainability has been framed by politicians as an issue of national security, allowing movements for increasing domestic production of oil through controversial processes such as off-shore drilling to be carried forward uncritically through slogans like "Drill Baby Drill!" Stem cell research has been framed by advocates as medical promise and progress, while foes have framed the issue as one of "right to life." Nisbet and Mooney (2007) illustrate how "intelligent design" has been a powerful antievolutionist response to evolution, despite the fact that evolution has been an accepted theory within the sciences for many decades. They argue that framing anti-evolution stances through intelligent design have played well with audiences who may tend to "tune out technical messages" or feel "belittled" and "insulted" for their religious beliefs (p. 56). With potentially little attention to the scientific dimensions of contemporary socioscientific problems, the public is encouraged to take a stance through their interaction with dominant set frames in a way that may be uncritically commensurate with their experiences, beliefs and values.

This last point is important, especially with respect to understanding the role that the process of framing socioscientific issues plays in how people engage science. Some studies have shown that people attribute their science knowledge to experiences in informal settings

such as the media, museums, personal interactions, and everyday activity, rather than the science classroom (Falk, Storksdieck, & Dierking, 2007). We believe this leaves people even more open to being deeply persuaded by the ways in which powerful constituencies frame socioscientific issues. It has been argued that those in the sciences (and science education) assume that once one learns enough science, they will view science as scientists do (Groffman et al., 2010). Yet, scientific messages are not always packaged in ways that might obviously account for or productively respond to individuals' experiences, beliefs, and values, and that decisions about socioscientific issues are always laden with subjective judgment, as the previous examples illustrate.

Social Practice Theory and Equity Concerns

Taking an equity lens to decision making on socioscientific issues suggests that part of understanding how or why youth rely upon or challenge set frames is making sense of the cultural practices and funds of knowledge they bring to engaging science in their communities. Research from the learning sciences, and in particular from the perspective of social practice theory, has taught us a great deal about the cultural dimensions of science engagement in everyday life (Bell, Lewenstein, Shouse, & Feder, 2009). As people move through the world, they are exposed to, positioned by, and react to a range of people and institutional and cultural structures and forces (Holland, Lachicotte, Skinner, & Cain, 2001). As people take on new projects or problems, they re-appropriate salient local cultural practices and ways of knowing and being that are from other places, creating new hybrid practices that make sense in time and in place (Holland & Lave, 2009).

However, most contexts in which youth engage are marked by power relations, often along race, gender, and class lines. Scholars have stressed the importance of acknowledging the diverse funds of knowledge and cultural practices that are grounded in students' membership and experiences in the out-of-school worlds that they inhabit (Gonzalez, Moll, & Amanti, 2005), and the roles these practices play in making disciplinary knowledge meaningful and accessible (Calabrese Barton & Tan, 2009). Especially for students for whom science represents different ways of knowing, talking or doing than are prevalent in their life experiences, figuring out how to negotiate the multiple texts, discourses, and knowledge available for science sense making can be a challenging undertaking (Moje et al., 2004; Rosebery, Ogonowski, DiSchino, & Warren, 2010). In a recent manuscript, Zimmerman (2012) suggests that the question of "when is science?," meaning when do youth say that what they are doing is science, is a part of acknowledging the diverse perspectives youth bring to doing science. She argues that when young people perceive their activities as related to science, it shapes how they understand their involvement and the resources they draw upon to do so.

As youth attempt to make sense of any given policy issue, they engage in a process of authoring frames to give meaning to what they know and care about in ways that bridge the science with their own experiences and values and the dominant set frames to which they are exposed. Thus, in our article, we are interested in how youth frame their decision about a power plant, and in how this framing represents dynamic interactions among the science they learn, their own cultural practices and funds of knowledge, and dominant set frames. Part of what is central in understanding how youth make decisions on socioscientific issues is understanding the discourses and funds of knowledge youth draw upon as they define the socioscientific problem of the power plant, when and how they talk about the problem as a scientific issue, and what and how they seek to acquire new information and take a stand in their community. At the same time, it is also important to understand the value that youth ascribe to the various set frames to which they take up or challenge, the scientific (and other

knowledge) they draw upon in doing so, and how they prioritize them and ultimately integrate them in their own authorship of such issues.

Purpose of our Investigation

In focusing on how youth navigate the complex socioscientific issue of a proposed new power plant, we attempt to provide a rich description of the frames they author with and against broader societal narratives, and the relative meaning they ascribe to them. This approach is intended to both supplement and challenge the majority of educational research that has investigated the ways youth engage with socioscientific issues. Much of this research investigates distinct aspects of the decision-making process by emphasizing various attributes of students' informal reasoning (Sadler, 2004; Sadler & Zeidler, 2005; Zohar & Nemet, 2002). Typically, these studies privilege the role that various aspects of science and argumentation skills play in the decision-making process. In addition, these studies often compare and contrast students' informal reasoning with some normative or expert conception of how their decision-making ought to look (Sadler, 2004). This study highlights the interaction between youths' experiences in an after school program, their scientific knowledge, and set frames to which they were exposed. The questions that guide our study include:

- What narratives do youth tell about their evolving stance over the course of the investigation as they made decisions on a socioscientific issue?
- In what ways do youth leverage, prioritize, and integrate set frames with personal experiences and scientific understandings in making decisions on socioscientific issues?
- In what ways are frames important conceptual tools in making sense of how youth make decisions on socioscientific issues?

In answering these questions our goal is to provide explanations for the ways in which frames can serve as important conceptual tools for making sense of the relationship between learning science and the framing of socioscientific issues. Given that the vast majority of research, as noted earlier, on how the public makes decision on socioscientific issues shows that science is almost always eclipsed by values the development of such conceptual tools is critical.

Making a Decision About the Hybrid Power Plant in the Green Club

In the spring of 2009, 20 middle-school age youth in the Green Club [GC] investigated and took a position on whether their local municipal utility company should build a proposed new hybrid biomass power plant (70% coal, 30% biomass). The new power plant was proposed by the municipally owned electric company as a replacement for the city's aging coal plant that was scheduled to be decommissioned in 2015 due to its failure to meet tighter emissions standards. The aging coal plant provided the city with 69% of its electricity. Thus, the city was faced with finding a way of replacing a significant portion of its electrical power. Immediately, prior to the time the GC youth were conducting their investigation, The Electric Company had sent a letter to consumers explaining its preliminary decision and encouraging citizen input in the decision. It was their letter inviting input which prompted the investigation.

Green Club is a year round after school program that meets twice a week in a community-based youth club and engages youth in authentic investigations into green energy. GC adopts a place-based approach that focuses on community issues related to green energy in the urban

center. The program provides opportunities for youth to investigate science in their own community and actively participate in change making processes as “community science experts” (Calabrese Barton & Tan, 2010). A central goal of GC has been to help youth use science as they take action and make decisions on socioscientific issues that impact their lives and the world around them. At the same time, engaging in placed-based investigations makes social, political, and economic concerns an integral part of the curriculum. The hybrid power plant controversy provided an opportunity for youth to grapple with a socioscientific issue of both local and global importance. Thus, we carried out a 13-week unit that focused on whether their city should build a new power plant, and then we studied how they constructed their decisions over time.

Before beginning the power plant unit, GC youth had completed an investigation into how power plants work, examining closely energy transformations, from stored energy in the form of coal to electrical energy in our homes and the byproducts along the way. The power plant investigation was designed to build on that knowledge by exploring arguments for and against new hybrid technologies, while teaching more about the science of renewable energy, and the feasibility of meeting demand through alternative sources. The unit began with an investigation into the actual plan provided by the Electric Company, using materials available on the web, from the Company, and from the youths’ homes (i.e., the letter sent to customers explaining the proposal). The materials explained the rationale for building a hybrid plant, including the need to close the aging power plant and the impact of the plant on consumer costs and the environment. Then, to delve into the construct of hybrid technologies, youth conducted investigations into the forms of alternative energy employed by the Electric Company, including biomass, biogas, wind, and solar, although not all forms investigated were a part of the proposed hybrid plant design. These investigations involved simulating electrical production through small scale models, gathering and analyzing quantitative and qualitative data from these models, taking fieldtrips to local solar power array, wind turbines, and the local coal fired power plant, and surveying local experts and community members on their views of the proposed power plant and the efficacy of other forms of green energy technologies. The unit concluded with a community forum in which the youth presented renewable energy demonstrations and their views on the proposed plant. The youth also participated in a debate between the Electric Company and the citizens’ group, Great Lakes City Can Do Better, who were opposed to building a new coal-fired power plant.

Methodology

To build generalized claims about the youths’ decision making we employed longitudinal qualitative case study. Case studies are preferred when examining events in naturalistic settings (Yin, 2009) and are relevant to examination of an environment where the boundaries between the phenomenon of interest and context are not clearly evident, and where problems are multi-issued, multi-partied, ill-figured, or complex (Scholz and Tietje, 2002). A case study approach also allows for the collection of multiple forms of data using different strategies such that the corpus of data results in complementary strengths and non-overlapping weaknesses, which is useful in expanding understanding and informing theory and practice (Johnson and Onwuegbuzie, 2004). The longitudinal component maximizes opportunities to refine theory related to how decisions developed overtime by assuring a steady stream of data at different time points in the process.

This study focuses on case studies of two youth, Jana and Jeremy. We opted to write about our examination of two youth in order to present an in-depth analysis of their decisions, allowing us to describe and explain the nuances in how scientific, personal and societal

discourses matter to youth in their decisions. We did, however, analyze the general decision-making patterns of all of the GC participants.

At the time of this investigation, Jeremy was a 7th grader, and had been participating in GC for 1.5 years. Jeremy's mother was a nurse and his father a construction worker. Jeremy typically received A's in school science. He often volunteered or was called upon to explain a range of science related concepts in GC. At the same time, Jeremy placed value on seeming cool with his peers, making sure his hair was just right, that he had cool desktop images on his computer, and that he cracked the latest firewalls so that he could play music videos from Youtube.com. Jeremy attended GC regularly, although he missed sessions in the fall due to football practice.

Jana was a smart, vivacious 6th grader. She attended the local magnet school for the performing arts where she was a member of the student council. Jana displayed a curiosity and willingness to work with others. Outspoken and never shy, she was a leader in GC even though she was one of the younger participants. Jana often enthusiastically demonstrated her science knowledge. An eager participant, she always had questions to ask or comments to make about the content. Jana's sister was in GC the year before and had won an award for the multimodal public service announcement she crafted on the Energy Crisis (and which had been shown on the local CBS-affiliate television station). Jana had an opportunity to attend GC forums the year before where she watched her sister and other GC youths' public service announcements. She joined GC already familiar with the focus on energy related issues and the kinds of action-related activities in which GC youth engaged.

Our findings are not generalizable in the traditional sense. Some might argue that as a case study our findings will lack representativeness. We believe it is precisely the "irreducible quality of good case study" which supports the kind of in-depth work needed to really understand how issues get framed by youth, why and for what purposes (Flyvbjerg, 2006, p. 237). We believe that Jana and Jeremy's stories offer rich insight into how youth frame complex socioscientific problems at a particular moment in time and place. Our investigation is also unique in that we studied youth making decisions about real-time real-world problems in their community. This is likely to be different from students studying broader socioscientific problems for which there is no real immediate or urgent problem that their families face. The connection they made to their lives in their families and communities were immediate and highly salient. Thus, while we certainly cannot make empirical claims beyond these two youth in this article, we use these findings to build claims about how and why framing matters, and the tools others may use to conduct similar kind of work.

Thus, as case study, we intend for these results to yield the kind of context-dependent knowledge necessary for understanding the nuanced ways in which individuals make sense of and make decisions about socioscientific issues. We took great care in our selection of these two youth for this presentation because we wanted to tease out the intricate ways in which these youth engaged in the process of framing the power plant, while they were, at the same time, living lives permeated by set frames. We further intend for our analysis to yield theoretical insights into how frames and framing matters in science learning and in the decisions and actions one might take.

Thus, our decisions for selecting these two youth were based on the following criteria. First, we desired to analyze in-depth and over time, the data from youth who have a history in doing well in science in traditional terms (i.e., good grades in school) and who appeared to us to be strong science students because of the extent of their participation in science in both school and out of school programs. This was important to us as we wanted to work to build an understanding of how youth navigate their decisions under the best possible circumstances,

where a potential “lack” of scientific knowledge might prohibit how or why scientific thinking weighs into decision making. Given the research literature which indicates that the general public lacks the scientific knowledge needed to engage deeply in socioscientific issues, this criterion was of utmost importance. Jana and Jeremy were both “A” students at school, and exhibited strong capability in science in their previous work in GC (Calabrese Barton & Tan, 2010). Second, we desired to analyze the data from youth who demonstrated intellectual leadership among their peers. This was also an important factor as we wanted to understand how youth who were really invested in and knowledgeable about the science took on the issues with some intellectual independence and authority. Jana and Jeremy both stood out to us as youth who actively raised ideas, volunteered information, and asked questions without being prodded or following the lead of others. Our third criterion was that we desired to select cases where there was consistent and on-going participation and engagement in GC. In other words, which youth regularly attended sessions? Which youth completed project activities and assignments, for both the unit under investigation and previous units? As a result of this last criterion, we had a rich and consistent body of longitudinal data on both youth.

Data Sources

Below we describe five data types that inform our analysis: Taking a position surveys, weekly thinking prompts, student artifacts, interviews, and video transcript of GC sessions.

Taking a Position. As part of the regular instruction, GC youth were asked to take a position on the proposed power plant at three times over the course of the investigation—before we began the unit (January 29, 2009), after investigating the Electric Company’s proposed design (February 5, 2009), and at the conclusion of the unit in preparation for the Community Forum debate (April 23, 2009). In each of these instances, we asked youth to explain, in writing, the reasons for their position. At the outset, we asked youth whether they knew about their city’s plans to build a new power plant and what reasons there might be to build or not build a new power plant. We then asked them to take an initial position and to give at least two reasons in support of their response. We also asked them which reasons were most important to them. After investigating the Electric Company’s proposed design, we asked them if they had changed their minds and if so, why. On the final survey, we asked again whether they thought the Electric Company should build a hybrid power plant and why, what additional information they might need, and what they would tell community members about why they should care about this issue.

Weekly Thinking Prompts. Each week at the start of GC students responded to either open-ended content related questions (i.e., What do you think are the main problems associated with using coal to create electricity? What is your evidence? Have you heard of biomass before? What do you think it is?), and opinion or other general questions (i.e., What do you need to know about the proposed power plant to be better informed? How would you like to learn it? What did you hear in the news this week about the power plant, if anything?). While most of these questions were asked in an on-line question environment intended to support student thinking, sometimes these questions were posed as initial discussion questions at the start of the session. These questions were initially intended as pedagogical tools to scaffold learning, but for our analysis serve as critical indicators of how student thinking developed over time.

Student Work. We collected the artifacts youth generated as they investigated various green energy alternatives, and that they prepared to educate the community (i.e., posters on

solar energy, PowerPoint presentations on wind energy, and key data representations used in support of these, such as GIS wind maps and coal maps, and their written explanations, etc.). We also drew from student work created in previous GC units that emerged in youth talk about the power plant (i.e., public service announcements and video shorts prepared by the youth and brought up in class discussions). Finally, periodically students posted blog entries updating the community on their progress in their investigation, which we also collected for this analysis.

Interviews. Interviews were not conducted specifically for this particular analysis primarily because the role and importance of frames and framing emerged after we spent significant time making sense of the data. At that juncture we felt we were too far removed to interview the students about frames and framing. However, to further supplement our data sources, we used interview transcripts for each youth that had been conducted in the Fall 2008 and in late Spring 2009, which focused on why green energy technologies matter to them and their community, and think aloud questions related to core content issues covered during the year.

Transcripts of GC Sessions. Each week, GC was video and audio taped and sessions were transcribed. We turned to these transcripts to situate and to make sense of students developing understandings and decisions.

Methods of Analysis

In part one of our analysis, we examined GC transcripts and student work (including Jana, Jeremy, and their peers' responses to the power plant survey) to trace out, macroscopically, the problems youth identified in the proposed new power plant, what they viewed as causing those problems and why those problems mattered to them. Data were initially categorized by one researcher both individually for Jana and Jeremy, and chronologically including pre, during and post unit data for the larger group of youth. We drew primarily from the taking a position surveys, weekly thinking prompts, GC video transcripts, and student work artifacts for this analysis. Over the period of several months, 2 hours a week was devoted to group meeting where four researchers discussed the data, tested out, and argued for different interpretations. Specific questions discussed included: What scientific evidence does each youth draw upon to explain their decisions at each time point? What other kinds of data or experiences does each youth draw upon to explain their decision at each time point? How do these types change over time? What kind of content storyline does each youth present in explaining their decision? How do these storylines change over time? In the intervening GC sessions, as evidenced by session transcripts, weekly thinking prompts and student work, how do the questions that each youth ask change? How do the ideas that come in GC become a part of (or not) their decision rationale? After each weekly meeting one researcher would write an analytic memo to capture the ideas, disagreements, and outcomes of the discussions.

After these series of discussions two researchers (the authors of the article) generated "decision making maps" specifically for both Jana and Jeremy, to organize and synthesize the patterns and ideas that emerged over the discussions and as evidenced in the analytic memos. These were created in PowerPoint to allow for multiple temporal dimensions to emerge on the map (decision time 1, decision time 2, and decision time 3), with data sources hyperlinked to each emergent claim. Data layers on these maps included information and claims about: (i) naming the problem space and its causes and solutions, (ii) scientific understandings, (iii) values and concerns that appeared to underlie their positions, and (iv) local experiences used to position the issue. We then analyzed the maps for how and why each youth viewed the possibility of building a new power plant as both a problem and a solution

simultaneously depending upon which concerns they were focusing upon. We noted references youth made to dominant set frames and examined how they connected to the personal concerns they raised. The maps were then shared with the larger research team over two meetings and debated, then revised, and shared again with a larger and more objectively positioned group of science education faculty and graduate students in a program seminar for feedback and review.

The second part of our analysis focused on understanding how Jana and Jeremy's framing of the issue evolved throughout the investigation and how this developing frame incorporated and/or was responsive to set frames that appeared a part of their experience. Here, the two main researchers were tasked with reviewing previous interviews and student work from previous units (primarily the unit on energy transformations and how power plants work, which immediately preceded the unit under investigation) and coding instances that connected to our analysis, such as evidence of relevant content understanding and engagement, or evidence of values or stances that appeared to help to explain and/or challenge our interpretations of the youths' decisions, especially at the initial decision time point.

By engaging in this multi-leveled contextual analysis we hope to reveal the complexity of youths' decision making and the relationship and interaction among their experiences in GC, scientific knowledge, set frames, and the stories they constructed about the power plant.

Findings

We present our findings in two parts. In Part One, we offer an analysis of Jana and Jeremy's decisions regarding the power plant and how they changed over time. As part of this analysis we present how they ultimately framed the issue of the proposed new power plant, and how they leveraged "bits and pieces of information and experiences" to do so. In Part Two, we turn our attention to how this process of authoring a frame sits in dialectic with dominant set frames.

Part 1: Constructing Narratives: How the Youth Framed the Decision about the Proposed Hybrid Power Plant

In this section, we overview the evolution of the decisions that Jana and Jeremy made with respect to whether their city should build a new power plant starting from prior to their investigation of the plant's design through the end of the unit (13 weeks). We describe the reasons they offered in support of their positions, highlighting how and why their positions shifted over time. As Table 1 indicates, both Jana and Jeremy began the unit opposed to the idea of building a new power plant in their city. By the end of the investigation, they both supported the Electric Company's plans, although to different degrees and for different reasons.

Jana's Story: A Story of Compromise. January 29th: "The coal plant would be bad so they should veto it!" At the outset of our investigation, Jana had a strong negative reaction to the possibility that the city might build a new power plant. She argued that the Electric Company should not build the plant because "It will cause carbon dioxide and it will pollute the air and kids could [get] asthma from breathing those horrible chemicals" (Survey, January 29, 2009). She explained the reasons that the Electric Company might want to build a new power plant "might be that the Electric Company wants more energy." Jana asserted that while some people might think it is a good idea, "The truth is the coal plant would be bad." She believed that the plans should be stopped and that "if the government is going to have a meeting about this, they should VETO it!" (Survey, January 29, 2009). In light of her strong

Table 1
Overview of Jana and Jeremy's decisions during the power plant unit

Time point	Jana		Jeremy	
	Decision	Reasons	Decision	Reasons
January 29, 2009	No	Burning more coal will produce CO ₂ and pollution	No	Burning more coal will produce CO ₂ and pollution
February 5, 2009	Maybe	Burning more coal will produce CO ₂ and pollution Create jobs	Yes	Biomass is a step up Biomass is cleaner and greener Create jobs
April 16, 2009	Tentative Yes	Control energy costs No realistic alternatives: Wind and solar are not reliable in her geographic region, and cost prohibitive New technologies will prevent non-CO ₂ pollution Biomass is not carbon neutral, but it is local and renewable 30% renewables is too low Faith in technological advance Provides jobs and affordable/reliable energy	Yes	Biomass is a step up—exceeds standards 30% less coal helps to reduce CO ₂ and pollution Biomass is cleaner (carbon neutral) and greener (local and renewable) Biomass is more effective than wind or solar in his city Construction jobs
Final frame		Power plant as problem and solution: A story of <i>compromise</i>		Power plant as solution: A story of <i>progress</i>

stance toward burning coal, Jana was left wondering “why do [they] want to build a coal plant?”

February 5th: How come it can't be 70% and 30%? After investigating the proposal for the new 70% coal and 30% biomass power plant and the Electric Company's reasons for it, Jana tentatively decided that she might support the proposal. In defense of her shift in position, Jana highlighted the Electric Company's point that the price of electricity would jump from “\$60 to \$90 per month for the average customer” if the Electric Company purchased electricity on the “volatile open market” instead of building a new hybrid power plant. In addition, Jana raised an issue not addressed by the Electric Company's explanations. She wrote, “Now that I have thought about it, it could be good because the coal plant could give people jobs.” Highlighting her ambivalence, she added that, “it could still pollute the air” because it would rely primarily on coal. She wanted to know “Why you guys want to burn more coal than biomass? How come it can't be 70% and 30%? Or how come we can't just burn biomass instead of coal?” (Survey, February 5, 2009).

April 16th: Still seeking solutions. At the end of the investigation, despite Jana's continued reservations about the proposed plant, she found no other realistic alternatives to the proposed plant. She wrote:

Yes. I think that they should consider that we can not have wind because there's not a lot of wind in our city. We really can not have sun because we in Great Lakes City do not have a lot of sunlight. We have a lot of cloudy days in our city. Since we don't have those resources, if there are other sources of energy that are healthier for the environment than we should use those resources. (Survey, April 16, 2009)

Given the lack of seemingly viable options, Jana feared that the city would not have the energy it needed. She wanted to know “how people are going to get electricity in their houses and how are going to feed their families (because if they have no power all their food will go bad), how they are going to work without working in the dark?” (Survey, April 16, 2009). In her final response, she highlighted the importance of biomass as a renewable source of energy: “The proposed plant is going to use renewable energy (biomass) to help [her community] be cleaner and help reduce global warming” (Survey, April 16, 2009). However, she questioned whether biomass was the best choice for moving forward. She consistently referenced the outcomes of the biomass expert survey to remind us that “biomass still releases CO₂” when it is burned, and that she agreed with the experts who indicated that it was not carbon neutral due to the farming practices used to generate it¹. That she questioned the Electric Company's meanings of the terms green and clean seemed to be due, in part, to the controversy around carbon neutrality.

She also acknowledged that the new technologies in the plant would reduce other forms of pollution, such as technologies that would “get rid of those nasty particles” that cause smog and asthma. However, she demanded more information that might help her decide if the proposed plant could adequately address her concerns about carbon emissions and its relationship to global warming. She further wrote: “I want to know about the pollution factor. They say it will be cleaner but I want to know what they mean. Is there still going to be pollution? If they are going to get rid of smog, can they invent an invisible ray to get rid of the carbon dioxide because that causes global warming?” (Survey, April 16, 2009). Having learned that technology could reduce particulate emissions, she wondered whether “an invisible ray” might “get rid of” the CO₂ emissions caused by both the biomass and the coal. In the end, Jana left the door open to other possible solutions adding that “[I]f there are other sources of energy that are healthier for the environment than we should use those resources” (Survey, April 16, 2009). In light of the limited choices presented to her, Jana reluctantly supported building the plant.

A tale of compromise. Jana told a tale of compromise in which some of her concerns would be addressed by the new plant, but not others. She identified the competing problems of burning coal and biomass (which would release CO₂ and other pollutants into the atmosphere) alongside the clearly felt need in her community for jobs and affordable energy. Each time she spoke of her decision to support the new plant she expressed ambivalence, highlighting the tension she felt between her seemingly conflicting priorities and her scientific understandings. In some instances, she emphasized the conflict between job creation and the role the plant would play in creating CO₂ emissions. In other instances, she focused on the need to find an affordable source of energy and her desire to use “healthier” options. In the end, Jana settled for the only ostensible viable option that would provide her city with reliable and affordable energy. Jana's ambivalence toward the hybrid plant hinged on her desire to find a solution to the city's energy needs that addressed her concerns about global warming. Her story focused on the way the power plant solved some problems, but would continue to contribute to others. Based on her faith in technology (e.g., using an invisible ray to eliminate CO₂ emissions) she held out the hopes of finding a “healthier” choice.

Jeremy: A Story of Progress. January 29th: “This will bring a lot more pollution and global warming!” Like Jana, Jeremy initially stated that the Electric Company should not build a new power plant “because this will bring a lot more pollution and global warming.” In offering a reason why the Electric Company might build a new power plant, he presumed that it might be “because we might not get renewable energy for a long time” (Survey, January 29, 2009). Although Jeremy contemplated a reasonable explanation for the Electric Company’s plan, he was also left wondering why they would want to build a power plant that burned coal.

February 5th: “A step up”. After investigating the proposed design of the power plant—that it would include 30% biomass—and the Electric Company’s reasons for it, Jeremy went from being fairly negative about the prospect of building a new plant to being enthusiastic about the possibility of a hybrid plant. In support of this position, he highlighted that the proposed plant would be “cleaner and more efficient” (Student Handout, February 5, 2009). As a result, he concluded that they “should build it” and that it would be “a step up for Great Lakes City” (Survey, February 5, 2009). Jeremy also raised the prospect that the new power plant might bring more jobs to his city. He wondered whether the new plant “[w]ill take more jobs to build it?”

April 16th: “A good step forward for all renewable energy.” At the end of the investigation, Jeremy reiterated the reasons he offered in support of the proposed hybrid plant, referring to it as a “a good step forward for all renewable energy, it would be a good step forward, there will be more jobs needed to build it” (Survey, April 15, 2009). He contrasted the old power plant that needed to shut down because it is “very old and it is not really up to date anymore...and because it makes too much pollution also” with his view that the proposed plant would be “cleaner” than the old one. He argued that it would be “cleaner because there won’t be so much of CO₂ produced because of the 30% biomass” (Survey, April 16, 2009). Jeremy grouped biomass with other alternative energy sources that “don’t produce bad things that will heat up the earth” (Survey, May 14, 2009). He also leveraged the expert survey to support his position by noting “most experts agree that biomass does not contribute to carbon emissions.” By using the pronoun “we” in describing the city’s efforts to move ahead with the new plant, Jeremy aligned himself as a partner with the Electric Company’s efforts. As he says, “If they say they want less coal, then I will say we are working toward it” (Survey, April 16, 2009).

Like Jana, Jeremy also identified the important role that the proposed plant would play in replacing the energy their city would lose when the old plant shut down. He stressed the need to find energy sources that would replace the energy lost when the old plant closed down. He argued that people “should care [about this issue] because [the old plant] produces 69% of the power for Great Lakes City.” On the final content assessment, he wrote that he would not advise relying on wind energy because “we don’t get as much wind as by the [shores of the] Great Lakes” (Survey, May 14, 2009). In the end, Jeremy was satisfied with his decision and felt that he did not “really need to know anything else” about the issue (Survey, April 15, 2009).

A story of progress. Over the course of the power plant investigation, Jeremy constructed a story about the power plant that cast it in terms of the progress it represented in terms of several of the problems he identified, namely global warming (climate change), pollution, and jobs. He repeatedly evoked images of small steps in the right direction that could realistically be accomplished. He referred to the new power plant as a “step up,” “a step forward,” and a “move in the right direction.” He assured customers that “we are working toward” using less coal. In the end, Jeremy incorporated both of his primary concerns (and the concerns that he

saw as being central to his community members) into his story of progress. He viewed the plant as being “a step forward” regarding the use of “green energy” and job creation in his city.

At the end of the investigation, both Jana and Jeremy each concluded that the hybrid plant represented the only way to replace the energy the city would lose when the Electric Company shut down their city’s aging power plant. Despite many of the similarities in their experiences and knowledge, their response to the Electric Company’s plan to use biomass and their engagement in investigating possible alternative energy sources looked different.

Part 2: A Critical Dialectic Between Authored and Set Frames

Over the course of the investigation Jeremy and Jana identified multiple reasons that mattered to them in support of and opposition to the new power plant (i.e., CO₂, electricity costs, jobs, and renewable energy sources), highlighting the complexity of the issue. In some instances, their concerns led them to see the proposed power plant as a problem that needed to be addressed. In other instances, they viewed the power plant as a solution to a variety of societal problems. It was through their range of knowledge and experiences that they were able to recognize the multi-dimensional nature of the problem and propose complex solutions. They understood that building the power plant might affect their community in a variety of ways, both positive and negative.

How Jana and Jeremy ultimately framed the issue of the proposed new hybrid power plant—compromise and progress—reflects the process by which they made meaning across science and their lives, and named their particular realities. As evident in the stories they told, their own process of framing the issue reflected a dialectic between their experiences and dominant set narratives on energy related issues. When and how Jana and Jeremy leveraged scientific understandings was deeply connected to the multiple contexts in which those understandings developed. When Jana and Jeremy drew upon scientific knowledge, they both did so in the service of understanding how the new plant either created a problem they cared about or helped solve a problem they had identified.

We now look across Jana and Jeremy’s stories to make sense of how their framing of the power plant issue (as either a story of compromise or of progress) was both a reflection of their experiences and a response to (both critical and acritical) the dominant set frames that shape energy and the environment. Four cross cutting themes emerge: (i) global warming and its dire impacts, (ii) energy demands and rising costs, (iii) unemployment and the economy, and (iv) pollution as a public health threat. As we explain each of these below, we show that what appeared to be more important than any of the dominant set frames, was how the two youth viewed these frames as in tension with each other, with their own experiences and with the science they knew (both their understanding and as a process of advancement). In doing so we work towards the claim that supporting youth in thoughtfully drawing upon and integrating scientific knowledge and practice with personal experiences, values and beliefs in making sense of socioscientific issues requires an awareness of and critical response to dominant frames.

Connecting to and Challenging Dominant Set Frames. Global warming, dire impacts, and the future of the planet. Jeremy and Jana came to the unit with the basic understanding that burning coal generates CO₂ emissions and that CO₂ emissions are a contributing greenhouse gas, thereby impacting the earth’s climate as evidenced in their initial decisions. As we saw in the evolution of their decisions, each time either youth offered a reason in support of or against building the new power plant, they referred to its impact on “global warming.”

Global warming carried negative meanings for the two youth, who described it as “bad,” “deadly,” “causing droughts and famines,” “causing glaciers to melt and making polar bears die,” and “killing all of the animals, even us!”

While the relationship between CO₂ emissions and global warming was more remote than the immediate and visible impact of smog, both youth had come to associate global warming with dire consequences for the planet. They repeatedly conveyed this connection throughout their participation in GC prior to and during this unit. For example, in a documentary Jeremy crafted on urban heat islands the year prior to the unit, he connected carbon emissions to global warming by including a picture of a polar bear jumping into the water off a tiny iceberg accompanied by the caption, “Polar Bears are drowning because the arctic ice is melting.” In a letter to the editor also in that prior year, Jeremy warned that “global warming is destroying our earth” (Jeremy’s letter to Great Lakes State Journal, April 22, 2008). Jana wrote that global warming “heats up our earth and that causes animals to die and lose their homes” (Survey, October 18, 2008). Jana also conveyed her negative association with coal in a rap created in the unit on energy transformation immediately preceding the power plant unit, in which she equated “burning coal” with a “bad day” because it “releases CO₂” that is “heating up the earth:”

- Today was a bad day/We are burning coal.
- Too much greenhouse gases/Heating up the earth.
- And that releases carbon dioxide/And that causes global warming.
- The sun is renewable energy/And that helps global warming.
- Today was good day.
- Word (Rap, October 18, 2008).

Nisbet and Scheufele (2009) refer to this linking of negative impacts with climate change as a “looming crisis frame,” a prevalent set frame on climate change. Even when people do not believe that climate change is happening, most buy into the idea that if it were to happen the earth would suffer dire consequences. This looming crisis frame has garnered international attention, as evidenced by films such as “An Inconvenient Truth” or through Google Image searches of “climate change” “global warming” and “CO₂ emissions” (an activity that youth did in GC as they worked on multimodal artifacts). Shortly after this unit, the Intergovernmental Panel on Climate Change released its fourth report in which it strengthened its claims regarding the anthropogenic nature of climate warming. Politicians and environmental groups redoubled their efforts to mobilize the public in support of policies aimed at reducing greenhouse gas emissions by framing climate change in terms of its dire consequences for the future.

Jeremy and Jana were hooked into the “looming crisis” frame in multiple ways that reflected the degree to which it had also entered the culture and discourse of GC. The subtext of Jana and Jeremy’s concern about the power plant reflected their shared meanings about the implications for the future they associated with the global warming. They saw images of polar bears and the burning earth in artifacts created by GC peers. In a previous unit, GC instructors had used a set of public service announcements sponsored by the Environmental Defense Ad Council that contained imagery and phrases associated with this frame to foster dialog on effective multimodal communication. The public service announcement, “Tick,” for example, featured children repeating the refrain “Tick” as if a bomb is about to go off while they delineated the possible impacts of global warming. The announcement ends by having a child tell adults “Our future is up to you.” Finally, GC instructors themselves incorporated aspects

of the looming crisis frame into classroom activities aimed at helping youth understand the potential negative consequences of energy-related actions.

Jeremy and Jana's appeared to use this dominant frame to help explain why CO₂ emissions mattered. Further, their negative associations with global warming provided a context for them to leverage some of the science they understood while caring for the future of their community. Jana and Jeremy used their knowledge of CO₂ emissions as an on-going metric for evaluating and explaining the impact of various sources of energy and whether they would be good choices for their city. They each described renewable or alternative sources as solutions to global warming for their role in reducing carbon emissions in their decisions about the power plant and across their participation in GC. For example, Jeremy urged citizens to support renewable energy portfolio standards, explaining that renewable energy could "fix" global warming, a point echoed in his decision. In Jana's rap she related renewable energy such as the sun with a "good day" because it "helps the global warming."

The rising cost of energy and its impact on people's lives. The rising cost of energy and its relationship to energy demands had been a central thread in the presidential political contest the fall prior to the hybrid power plant unit. How the US might become energy independent was a hot political debate. That Jana identified the rising cost of energy as her family's number one concern in the fall when gas prices had reached a record high of over \$4.00 U.S. per gallon in Great Lakes City was indicative of how much this dominant frame had viscerally connected to the lives of the youth. She shared that her family said, "This is so stupid how gas prices are. It's a shame" (Survey, October 18, 2008). She also reported that she and her peers had to turn the heat off "because the prices and electricity is just way too much to pay" (Survey, October 18, 2008). She heard her friends share stories about being yelled at by their parents "because we leave the lights on all the time," leading to higher energy bills.

Documents provided by The Electric Company to consumers regarding the design of the proposed new power plant had an impact on how Jeremy and Jana relied upon but also challenged this frame. They learned that the current power plant was required to be shut down by 2015 because of its "increasing cost to operate" and the "mounting environmental challenges" of reducing emissions. The problem, for both youth, was no longer whether or not to build a new power plant, but how to replace the city's energy supply when the aging power plant shuts down. Both Jeremy and Jana read the Electric Company's materials knowing that the city, like the rest of the country, received the vast majority of its electricity by burning coal. Based on their investigations in GC and their daily realities, they also both recognized the important role that electricity placed in their modern everyday lives. As noted in her decision, Jana worried that if the Electric Company did not build the power plant people would not be able to meet their most basic needs of providing their families with safe food and the money earned by working at their jobs, as her reference to having to go to work in the dark or food going bad without refrigeration indicate. Jeremy warned that his community should care about the issue because they received most of their energy from the aging power plant, as indicated in his survey responses and in his questions at the forum. To these youth, energy costs mattered, but so did quality access.

Further, in literature provided to customers, the Electric Company described their decision to build a hybrid power plant as a cost saving measure. They did so by emphasizing the rate hikes customers would face if they bought electricity on the "volatile" open market instead of building the hybrid plant. The letter concluded that rates could "jump" 55%, but might "climb far higher." Jana was sensitive to the Electric Company's references to costs and began to view the proposed plant as a potential solution to future rate hikes, but she understood that real technological advances might ultimately cost more. Her question was

about who should pay for these advances: the consumer, the company or the government? She highlighted the amount the average bill would rise if the new plant were not built as a primary reason she might support the new plant. Like CO₂ emissions, over the course of the investigation, Jana wondered how much particular energy sources would cost to develop and implement and who would bear those costs, and used these criteria to evaluate the sources of energy she studied.

Both Jeremy and Jana integrated their concern about affordable and accessible energy with the scientific questions that undergirded the proposed power plant. Their investigations into wind and solar as possible alternatives to 70% coal, included concern over whether these sources could serve as adequate or reliable sources of energy for their city. When Jeremy and Jana investigated wind energy, both noted with concern that their GIS maps indicated that wind is a much more reliable source of energy on their state's coasts rather than inland, where their community is situated. When they visited the Electric Company's new solar power array, they witnessed that on a cloudy winter day all 432 panels would not generate any electricity, leading Jana to comment in an interview that "it was sad. The panels were taking more energy than giving." Neither source, they concluded, could realistically replace the amount of electricity currently generated by the aging coal plant, and would ultimately drive "the cost [of electricity] up" (Survey, April 16, 2009).

Unemployment and the need for jobs in their city. Jana and Jeremy live in a city and state where unemployment rates at the time were *the highest in the country* and where the state's economy ranked 50th out of 51 in the US, due in large part to the demise of the auto industry and their subsidiaries. Not a day went by when the economy and unemployment was not front and central in the news. Their city's mayor was locally famous for "taking on" Fox News' presentation on the auto industry bail out. That the building of a new power plant might create jobs and support economic growth contributed to both youth's view that the plant be built.

During the time of our investigation the Speaker of the Great Lakes State House of Representatives wrote a letter to the Governor urging her to approve coal plant permits around the state as a means of job creation. The Speaker explained that jobs had to take precedence over other priorities given the financial crisis the state faced. He explained: "By delaying the permitting process for construction of new base load power plants in the state is in a sense reneging on the process of new construction jobs for Great Lakes State residents. [W]e feel that the urgent need to create jobs in Great Lakes State trumps most all other priorities during this time of economic crisis" (Speaker of the House, Letter to the Governor, dated March 19, 2009). A few months after our investigation several hundred people staged a protest at the state Capitol urging the government to move forward on issuing permits to build new coal plants. The Great Lakes Newspaper reported that the protestors were mainly construction workers who stood to get jobs. Jeremy's father is a construction worker so there is a possibility that he had heard this argument made at home—although he never explicitly said that he had. However, in contrast to the comments made by the Speaker, Jeremy casts the goals of helping the environment and job creation as being compatible rather than in tension with environmental concerns.

Both youth's concerns about jobs had animated their engagement in GC since the fall 2008 and was a clear priority for them. Earlier that year, Jeremy had authored a public service announcement on green jobs and highlighted the role of green energy technologies in bringing economic renewal to his state. In his public service announcement, he identified the decline of the auto industry as the primary source of unemployment in his state, and green jobs as the solution for laid off workers. As he stated in his video:

Any kind of job that contributes to a greener earth is a green job. . .The green jobs program of Great Lakes State is designed to help make sure that emerging industries and green economy have the trained workers they need to grow and prosper. As days go by Great Lakes State trains more and more laid off workers for green jobs. Great Lakes State green jobs are in the near future and the question is: Are you ready to be trained now?

Jana also raised the problem of unemployment associated with auto industry plant closings when she authored a public service announcement on hybrid cars as her response to the new green economy. She listened to the nightly news where she heard her Mayor and others argue for and against the imminent auto bailout (Fieldnotes, October 27, 2008). She expressed that she was “worried that if the car companies fail, a lot of people will lose their jobs” (Letter to GC guest speaker, December 4, 2008).

Both youth drew upon their understanding that plant closings contributed to job losses to conclude that a “plant opening” would lead to job creation. Both youth separately introduced the idea of the plant producing jobs early in the unit, even when the importance of new jobs had not been introduced by either the teachers or the curriculum. Both youth linked the role of emerging green technologies with economic growth. While Jeremy was much more hopeful that this proposed plant reflected a positive step in the right direction (“a step forward for all renewable energy”), Jana worried that the plant, while providing jobs, did not represent adequate change in environmental impact or cost.

Pollution as a Threat to Public Health. Both youth began the power plant investigation having learned in GC that burning coal causes particulate pollution in addition to the CO₂ emissions described above. They applied this knowledge when they initially reacted to the prospect of building a new power plant in their city that would rely primarily upon coal. Both youth had been taught in the previous unit that burning coal generates smog due to the interaction of the particulate emissions and other byproducts (i.e., SO₂). This idea threaded its way into their talk about the proposed power plant, and the potential community health problems that a new coal plant might produce.

This theme does not reflect a dominant set narrative in the same way the other three themes do, although it does reflect an imperative held by environmental justice advocates and the youth’s own lived realities. Many of the youth could see the smoke stacks of the aging coal plant from their homes and had witnessed the billowing smoke polluting the air. These smoke stacks had come to represent a threat to public health for most of the youth in GC, including both Jana and Jeremy, who had siblings and friends who suffered from asthma. In a public service announcement Jana’s sister crafted the year before, for example, (and the one Jana references as the reason she wanted to join GC) a picture of a young child wearing an inhaler mask is centrally placed after pictures of coal plants emitting pollution, with the text, “The air that we breathe are making us get diseases like asthma/Reduce your carbon footprint.” Her sister went on to explore environmental justice in a teen green club the following year when Jana herself joined GC.

These kinds of images connecting burning coal to breathing problems made their way into many of the GC youths’ products that they used to educate the public about the impact of burning coal. Jana explicitly referenced the relationship between pollution and asthma in her initial justification to oppose a new power plant, described earlier. When both youth spoke of pollution throughout the investigation, they did so, in light of the problems that they had come to associate with it. As Jana and Jeremy learned more about the design features of the proposed plant, they found out that the new plant would use technology that would eliminate

most of those “nasty particles.” This technological advancement addressed both of their concerns about the impact of pollution on public health.

Learning within tensions: The dialectic between authored and set frames. Jana and Jeremy’s decision making about the new hybrid power plant reflected tensions among and between dominant set narratives, their scientific understandings and their own cultural experiences. In particular tensions between the urgent economic realities of their shared community (e.g., jobs and affordable energy) and the need to care for the earth and its inhabitants (e.g., global warming and pollution as a threat to public health) and the role of scientific progress in attending to these needs dominated their thinking. For Jana, these tensions were front and central to her decision making. They served as a set of conditions for evaluating the science of alternative energy and a call to action. For Jeremy, these tensions were the evidence for why the hybrid plant should be built.

Jana first identified the tension between the economic reality of the need for a new power plant and the problems it presented at the very start of the unit. In week 3 of the unit, immediately following the investigation into The Electric Company’s proposal, Jana states that after having “thought about it,” she realized the plant might create jobs. At the same time, she also acknowledges that a plant reliant upon coal would still contribute to environmental problems, which would be “bad” for the earth. Rather than focusing on the environmental benefits outlined in The Electric Company’s plans (i.e., new technologies would be “greener” and “cleaner”), Jana focused her thinking on how “hybrid biomass plant” would continue to burn 70% coal. Based on her understanding that 70% coal represented significantly more than 30% biomass, Jana challenged The Electric Company’s assertion that the proposed plant would be “a plus to the environment.” Jana, focusing attention on some of the experts surveyed felt that biomass was not carbon neutral due to intensive production practices, further cemented her stance that the power plant would not be “clean.” As a result, she continued to view the power plant as a problem in terms of the ways in which it would contribute to environmental problems, despite her recognition that it might be the only way to keep the lights on and the refrigerating going in her house.

Indeed, over the course of the investigation, Jana expressed clear interest in making it more widely known that the proposed plant could still contribute to pollution and global warming through carbon emissions. Jana explained that the people in her community needed to know about these issues when she wrote: “Most people are concerned that burning coal will cause pollution and add more to global warming. Some people think that coal is just fine but it’s not and they need to know that about this new coal plant” (Jana’s letter to the Electric Company).

When Jana analyzed the benefits of a particular energy source, she brought these tensions to bear on her analysis as she searched for a source that was affordable, clean and reliable. For example, when she learned that using more alternative energy sources like wind and solar would likely cost more, on her own time (outside of GC) she emailed a question to a GC instructor highlighting her competing priorities: “It would be good to have renewable energy in Great Lakes City but how come it has to cost costumers more than they are already paying for?” She also drew upon her understanding of the limitations of wind to argue that spending money on developing unreliable energy sources did not make sense. She wrote, “But if we spend all that money on wind turbines we would be wasting money because in Great Lakes City we do not have a lot of wind which means how are the wind turbines going to spin if there is no wind for them to spin?” In this instance, her scientific understanding coupled with her economic concern reinforced her view that developing clean energy sources like wind and solar did not make sense in her city. In the end this left her frustrated and tentative on her

decision. The data that Jana collected about the prospect of using solar and wind in her city offered her no obvious third choice and merely highlighted the limitations of these sources. In the end, Jana ultimately used this tension between economic concerns and environmental health as a call to action. She was dissatisfied with the limited technological options available for the design of a new power plant, and insisted at the end of the unit, that “more work be done.” She noted that Germany was a leader in solar energy, despite having such snowy winters (Fieldnotes, April 16th, 2009).

Unlike Jana who viewed progress as too slow, and incomplete, Jeremy focused on the importance of incremental steps and trusted progress to contribute positively to solutions. Central to how Jeremy filtered his concerns were the trade-offs he felt necessary to move alternative energy forward in society. For Jeremy, a 30% biomass plant that was “cleaner and more efficient” represented progress in relation to the “old” power plant. He referenced his GIS map indicating the local sourcing of biomass (as opposed to the coal transported to his city from a far away state). He evidenced the youths’ surveys of alternative energy experts, which indicated that many experts espoused the carbon neutrality of biomass. He was compelled with how the incorporation of 30% biomass exceeded the state requirement of 10%, and this, alone, reflected progress in the move towards energy sustainability. In his Green Jobs public service announcement from the previous unit, he quoted directly from the Great Lakes State Green Jobs Initiative website explaining the need to simultaneously address economic and environmental problems by promoting renewable energy: “Great Lakes State has gotten the message that we have to switch to renewable energy and other sustainable technologies to remain economically viable and help protect the environment” (Jeremy, Green Jobs Public Service Announcement).

Jeremy’s framing of this tension also seemed to rest on his understanding of biomass as an alternative energy source (as was Jana’s). Jeremy (like Jana) understood biomass to be both a renewable and local energy source, unlike coal. However, different from Jana, Jeremy identified with The Electric Company’s written claim that the new power plant would be “a plus to the environment,” noting that their materials asserted that the new plant would be “cleaner,” “greener,” and “more efficient.” Jeremy was clear in his thinking that biomass, as a source of energy, was carbon neutral, referencing that half the expert panel the youth surveyed indicated as much, as did advertisements for biomass as clean burning, and the Electric Company’s materials.

Jeremy linked building a new power plant as a step ahead with the possibility of job creation and felt that while limitations existed, this was an exciting opportunity not to be missed. In doing so, he drew upon a model for thinking about simultaneously addressing the problems of unemployment and global warming that he had appropriated in the fall when he crafted his public service announcement about green jobs. Jeremy also began to link scientific solutions with economic concerns. The new “cleaner and more efficient” power plant might help his city create jobs and help protect the environment. Over the course of the investigation, Jeremy went from asking whether the new plant might bring jobs to stating it as a central fact in support of his decision. Jeremy’s belief that the new plant would bring jobs to his community mirrored the hopes of people he interviewed at the club and at City Hall on Earth Day. When asked what issues they cared about related to the proposed hybrid plant, 71% of the 28 adults GC youth surveyed selected the “impact of the new plant on the jobs” (Survey, February 10, 2009).

In some ways, the difference in the youth’s decisions can be attributed to their understanding of biomass as a “clean and green” energy source. This understanding contributed to how they framed the new plant as a contributor to global warming and its dire consequences

or not. And yet, their decisions were more complicated than that in how they leveraged and/or pushed back against other dominant set frames through their own experiences. Jana consistently, and on her own, interrogated possible renewable energy sources for their affordability and reliability, which led to her framing the power plant debate as one of compromise. Her concern with jobs and energy affordability, two issues which had greatly and immediately impacted her family, ultimately trumped her concern about the negative consequences of biomass. She was tentative in her decision; dissatisfied with what she felt were limited options in a world where scientific progress moved quickly and powerfully when properly funded. Jeremy believed, as The Electric Company purported, that biomass was a cleaner source for electricity than was coal. And yet, his decision hinged on making progress—on building a plant that would create jobs and would push the community forward as leaders in green energy.

Why Framing Matters: Conceptual Tools for Making Sense of Socioscientific Issues

We live in a society where public discourse on socioscientific issues is constantly renegotiated through the process of framing. Different interest groups, with particular agendas and calls to action, offer their own narratives on socioscientific issues with varying attention to scientific rigor, but nonetheless intended to persuade others. In national debate on energy issues, for example, there is an on-going battle for dominance in how energy sustainability is primarily understood: Energy independence, climate change, and economic vitality reflect just some of the efforts to frame this conversation. Within each of these frames, terms like “clean” and “green” carry different meanings. Without attention to how or why these meanings differ, it becomes particularly easy for some interest groups to control the terms of the debates. Jana and Jeremy had to come to terms with whether and how the new hybrid plant was as clean or green as The Electric Company claimed, and what that meant in their lives and for broader issues of environmental and personal health, jobs and affordability. They not only had to understand what is implied scientifically by such terms, but also how and why that mattered.

If we return to the literature on making decisions on socioscientific issues, we are reminded that individuals rarely draw upon scientific understandings to make these decisions (Sadler, 2004). We are also reminded that few people make connections between the content of socioscientific issues and their decisions (Zohar & Nemet, 2002). We argue that understanding how people author or take up set frames for making sense of socioscientific issues offers a pedagogical pathway for making science matter. Further, we argue that especially important in this process is accounting for how power and positionality play out as people author or take up set frames, a concern not previously considered in the literature on how people make decisions on socioscientific issues. While it has been argued that values and beliefs play a role in such decisions (Nisbet & Scheufele, 2009; Sadler & Zeidler, 2005), little attention has been paid to how these values and beliefs *are practiced* by people in sociocultural context, and the impact this has on how or why they might express a willingness to examine an issue. We believe our study shows how the cultural practices and experiences of youth—as reflected in the funds of knowledge and experiences they bring to the issues—provide pedagogical spaces for critical examination of frames using the tools and knowledge base of science. In the case of Jana and Jeremy, we can begin to see how framing offers an important conceptual tool for how people might better, and more critically and scientifically, make sense of socioscientific issues.

Jana and Jeremy’s stories show us how people are both authors and (critical) consumers of frames as they engage in socioscientific issues. This view recasts how we think about the

role science plays in decision making. Instead of viewing decisions as driven by values and beliefs, we can begin to view if, how and why science might be appropriated within frames, even when these frames may foreground beliefs and values (Allum et al., 2008; Scheufele et al., 2009). As authors of frames, Jana and Jeremy actively constructed stories to justify their support for the hybrid power plant that provided a *scientific rationale-in-context*. By examining their decision making through how they authored frames, we can see how the dialectic formed between their beliefs- and values-in-practice and their scientific understandings supported a more complex decision than might otherwise be visible. Jana's story of compromise stood in contrast to Jeremy's optimistic story of progress. Neither Jana nor Jeremy cast their decision in terms that directly mirrored that of the Electric Company or any dominant frame around energy consumption or production. Both youth authored their own frames in ways that melded dominant narratives with their own concerns, experiences, and knowledge they brought with them and acquired during the investigation (refer back to Table 1).

How Jana and Jeremy understood the controversies surrounding biomass as a form of renewable energy reveals even more about the power of authoring frames. Recall that Jana and Jeremy took different stances on the importance of a hybrid power plant that uses 30% biomass. Like some of the experts the youth surveyed, Jeremy was compelled by the idea that biomass is renewable, locally produced, and carbon neutral. However, Jana struggled with what she saw as contradictory evidence of biomass' carbon neutrality. Frustrated by the lack of alternatives as indicated by the weak evidence in favor of solar or wind energy in her city, Jana argued for consideration of other technologies and for more research.

Jeremy and Jana are also consumers of dominant set frames. The two youth authored frames on the power plant in ways that positioned what they learned both *with* and *against* these dominant frames. We discussed earlier four frames that played powerful roles in their narratives: global warming, energy affordability, jobs and pollution. These were all at the forefront of Jana and Jeremy's minds as they evaluated the prospect of building a new power plant, but they played different roles depending upon how their own values- and beliefs-in-practice and understanding of the science fit those frames. Jeremy and Jana treated the link between job creation/saving money to environmental/personal health as important. However, how each youth made this link was related to the science they knew and their ability to leverage that knowledge to critically evaluate the frames and the assumptions that undergird them—scientific and otherwise.

While our study closely examines how two youth made decisions about a socioscientific issue, we believe our findings have implications for science teaching. Our study suggests that teachers need to help students learn to critically analyze how framing shapes public discourse on socioscientific issues as one way of delving into their complexity in ways that support meaningful learning in science. Frames make interpretive schema explicit so that they can be closely examined. By calling attention to frames, teachers can help make visible the interpretative schemas that students may use to understand an issue and how such schemas are tied to context. For example, teachers can pose question such as: Why does this issue matter? Who might be responsible for this issue or position? What should be done? (Nisbet & Mooney, 2007). When such questions are brought to the forefront of instructional practice, dialog can ensue about the different assumptions and meanings of words, catch phrases, metaphors, and images that are tied to different scientific ideas and value systems, such as the terms carbon neutral, green, or clean, as discussed earlier. These terms merge scientific ideas and value systems that, unless examined, can carry different meaning and purpose.

Additionally, as the field continues to struggle with meaningful engagement in science for *all* learners, teachers can also use frames as points of access to scientific ideas for their students. The frames themselves provide a context in which teachers can support talk about why an issue matters to students, and the implications this has for how students evaluate socioscientific issues. At the same time, frames make the science in socioscientific issues more visible, and open to examination from multiple perspectives. Teachers can help students analyze the frames they author or the set frames they appropriate as a means of better understanding how or why they might connect to an issue and ultimately to science.

As conceptual tools, frames also support teachers in making issues of power a part of the science curriculum when it comes to investigating socioscientific issues. Students may author frames to connect science to what matters to them. However, at the same time they may be complacent about the need to examine the assumptions and claims embedded in the frames they author. This is particularly problematic when the dominant frames to which youth (and teachers) are exposed are promoted and sponsored by powerful interests. Communication experts have become increasingly savvy about using opinion polls and market research to help politicians and other stakeholders successfully link dominant values and concerns to particular policy positions (Nisbet & Mooney, 2007). Some dominant set frames might point constituents in the direction of supporting policies that might be congruent with their interests, while others may be contrary to their interests. As we reflect on the role of science education in a globalized society, we believe that making visible and accessible for students how they are authors and consumers of frames provides the kinds of opportunities students need to be supported in being critical participants in the production of the common good with/in science, as argued for by Bencze and Carter (2011).

It could be argued that attention to frames and framing brings just one more thing into the science classroom at a time when teachers and students are inundated from all directions with various imperatives. We argue that without attention to frames and framing the primary goal of science education for a literate society could be lost. Framing offers a way to better connect science to these other things that shape decision making. How people come to see and understand specific claims embedded within frames (i.e., the future of clean coal) requires that people bring scientific ideas to bear to critique those frames. At the same time, how or why certain frames have resonance with a given person, in a given time and place, means knowing how those frames connect science with cultural practices and funds of knowledge in ways that are particularly meaningful to an individual or a community.

We have noted that recent attention has been paid to various pedagogical approaches that may be used in teaching about socioscientific issues. Tomas, Ritchie, and Tones' (2011) study revealed that incorporation of hybridized narrative writing on socioscientific problems increased student understandings of and attitudes towards such issues. Other approaches, such as reflective judgment on controversial issues, which integrate scientific understanding with criteria for evidence, alternative scenarios and moral consequences, shows promise in supporting students in developing more sophisticated epistemological stances towards socioscientific issues (Zeidler et al., 2009). Implicit in these approaches are opportunities for students to examine scientific knowledge and practice in light of their personal values, experiences and beliefs. We argue that framing, as a conceptual tool, can advance these and other approaches in how it calls attention to the ways in which people are always involved the processes of frame building (as authors) and appropriation (as critical consumers). If we can understand the role that authoring and consuming frames play as interpretive schema, as places of access and influence, and as integration of content with students' cultural lives, then we may better

be able to support students (and their teachers) in making *science matter* in debates about and decision making on socioscientific issues.

Conclusion

This study suggests the need to think critically about the role framing plays in how youth negotiate and learn about and from socioscientific issues. Frames play an important role in connecting what youth care about and believe to particular policy issues as Jana and Jeremy's stories reveal. In some instances, students may bring these connections with them into the classroom, providing them the motivation to learn more about a topic. In other instances, teachers may (either explicitly or unknowingly) draw upon popular set frames as a means of engaging youth in controversial science-related issues.

Teachers need tools by which to identify the frames their students author with and against the narratives of their lives, and to help students do so as well. We believe our findings support the use of frames as conceptual tools by illustrating how youth author frames and critically consume set frames: (i) in making visible the interpretive schema that people use to understand an issue-in-context, and how those interpretive scheme are informed by their cultural lives and how they are positioned by the dominant narratives to which they are exposed, and (ii) in illustrating the powerful importance of opening up the different assumptions and meanings (scientific and otherwise) of terms, catch phrases and metaphors that dominate public discourse on socioscientific issues. Because our study involves youth from nondominant backgrounds—youth whose families struggle to pay their electricity bills, youth who have seen the impact first hand of the lack of opportunities for work—then having a way to clearly make sense of how these experiences shape when, how or why they might leverage their scientific understandings to make good and justifiable socioscientific decisions is especially important. This last point sheds light on how using social practice theory to make sense of how youth author frames advances the literature on framing to attend to issues of power and positionality.

However, for frames as conceptual tools to carry pedagogical or analytical meaning, both teachers and students need experience in navigating, analyzing, and identifying the interests behind the various frames to which they are exposed and the claims embedded in them. This means becoming critical consumers of the messages by learning to ask questions about the power and politics behind particular messages. Who is funding a particular frame? What is their interest in doing so? What evidence is there that links the value or concern to the policy? What kinds of claims are embedded in particular frames and what evidence supports those claims? Students need to be taught to identify how those frames impact their own views and meanings and the socio-political context that gave rise to them.

Students will need a range of scientific and other tools and skills to meaningfully navigate the multiple and sometimes conflicting frames to which they might be exposed. In some instances, science will play a central role in helping youth critique the claims embedded in particular messages. For example, Jana's understanding of the distinction between particulate pollution and carbon dioxide emissions and the implications of each led her to question what the Electric Company meant when they referred to the new plant as being "cleaner." Other claims cannot be critiqued using science alone. For example, the economic frame that cast the new hybrid power plant in terms of lower "costs" narrowly defines the "costs" in terms of price paid by customers. Understanding the difference between internal and external costs, economic concepts, would allow students to ask questions about the range of costs considered in the analysis and to consider the "costs" on society that have been excluded from the analysis. Some of those costs, in turn, involve understanding the science behind the

environmental impact of pollution on public health or carbon dioxide emissions on the environment, for example.

There is a growing consensus that simply learning enough science to decipher public debates on socioscientific will not make citizens better equipped to handle the complex and ill-structured problems these controversial issues present (Nisbet & Scheufele, 2009; Sadler & Zeidler, 2009). This study highlights the interaction and complex interplay between authoring and set frames. The new *Frameworks* in science education remind us of how much science and technology are integral dimensions of everyday life (NRC, 2012). As they state, “America’s children face a complex world in which participation in the spheres of life—personal, social, civic and political—require deeper knowledge of science” (p. 278). Based on this view of the role of science in everyday problems and policies, the range of knowledge and experiences youth bring with them are powerful and legitimate resources for making sense of socioscientific issues. This study points to understanding frames and framing as an integral part of instruction and as a starting point for critically examining the cacophony of voices presented in the public domain.

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Notes

¹As part of the biomass investigation, GC youth sent surveys to eight local experts (e.g., engineers, environmental advocates, and farm industry representatives) asking them for their views on the use biomass for electricity production. Survey results indicated that experts were split: four supported biomass for electricity production and the other four said that “it depends.” All respondents indicated that biomass was an important renewable energy source, and that it released CO₂ when burned. However, five respondents indicated that it was carbon neutral while three indicated it was not due to the broader infrastructure needed to cultivate and deliver the biomass.

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