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Children's Use of Inscriptions in Argumentation about Socioscientific Issues

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by

Sihan Xiao

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ABSTRACT OF THE DISSERTATION

Children's Use of Inscriptions in Argumentation about Socioscientific Issues

by

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Doctor of Philosophy in Education

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Professor William A. Sandoval, Chair

Engaging science in everyday life often means not advancing knowledge or making new claims, but evaluating given claims with available evidence. In everyday situations, evidence is usually presented in some type of inscription (e.g. tables, diagrams, and other images). This study explores elementary students' use of inscriptions as evidence in written arguments about socioscientific issues and how a school year of science instruction may play a role in that use.

Three science teachers and their 102 students in 5th and 6th grades at a progressive urban K-6 school participated in this study. I administered a written argument task at the beginning and the end of the 2013–2014 school year, in which students were asked to justify their personal decisions about either alternative energy use or genetically modified organisms. Throughout the year, I worked closely with the teachers to organize

classroom instruction towards promoting argumentation and coordination between claims and evidence, and videotaped their science lessons.

Content analysis on students' written arguments reveals that photos were cited the most in students' written arguments, while tables were cited the least. Students tended to merely point to an inscription without articulate its relation to a particular claim, or to assert that an inscription "shows" a claim without saying how. They were also likely to credit inscriptions that aligned with their own position rather than discount those that supported counterclaims. From pre to post, these patterns did not change significantly. Analysis on science instruction further shows that the contestability of the claims students encountered in the classroom was low, meaning that they were not framed in arguable ways. The resources available to students for resolving these claims were also limited. The classroom discourse was not open enough for productive argumentation. These patterns may potentially account for the lack of change in students' use of inscriptions in their written arguments.

This study extends previous research on what children think counts as evidence in arguing about everyday science. Findings suggest that while students learn to evaluate scientific explanations in school, they are put in a different position of having to justify their decisions when facing everyday science. School science should explicitly link the two tasks. Further, we need to frame the learning of science as stabilizing legitimately contestable claims, and provide relevant resources for students to argue with. Classroom discourse, lastly, should be open to argumentation and integrative with disciplinary and epistemic aspects of scientific practices.

The dissertation of Sihan Xiao is approved.

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CHAPTER 1

INTRODUCTION

Science has permeated our everyday life. On television we are told that hybrid cars save not just our money but also energy on this planet. From friends we may hear that carrots prevent cancer and zinc prevents flu. When making a phone call, we may recall a column article stating that using a wired headset protects us from radiation. When shopping for groceries, we may take a few minutes choosing between organic eggs and regular ones because of public debates about genetically modified organisms. To be able to make informed decisions about these issues has long been a key goal of science education all over the world (e.g., OECD, 2006; Ryder, 2001). The *Next Generation Science Standards* (NGSS), recently released and widely adopted in the United States, expects that students become “critical consumers of scientific information related to their everyday life” (NRC, 2011, p. 9). That is, students should be able to make informed judgments about science-related problems (i.e., socioscientific issues, SSI).

Science educators have long assumed that school science helps students come to such judgments outside of school, but we have little evidence this happens (Feinstein, 2011). In particular, we hope students use scientific knowledge in reasoning about SSI (e.g. Kolstø, 2001; Zeidler, Sadler, Simmons, & Howes, 2005), yet they often rely more on their personal experience, value judgments, and moral concerns (Grace & Ratcliffe, 2002; Jiménez-Aleixandre & Pereiro-Munoz, 2002; Yang, 2004). Why is that the case? Previous research has proposed several explanations. First, a lack of understanding of scientific concepts makes them unlikely to be used (e.g. Hogan, 2002; Sadler & Fowler, 2006). Alternatively, students may understand applicable science knowledge but not consider it relevant to the situation at hand (e.g. Feinstein, 2011; Nielsen, 2012c). More importantly, while school science teaches us "what is true," we have to decide "what to do" in everyday life (Nielsen, 2012a, 2012b). Engaging science in such situations often means not advancing knowledge but evaluating available evidence for given claims (Sandoval, Sodian, Koerber, & Wong, 2014). SSIs that we daily encounter involve, to complicate matters, scientific and non-scientific claims. What counts as evidence?

In everyday situations, evidence is usually presented in some type of inscription (e.g. tables, diagrams, and other images). When we face science in our daily life, we see inscriptions often simultaneously (e.g., in journalistic articles). In the classroom, as in the science laboratory, inscriptions mediate communications, foster evaluation of scientific knowledge, and support conceptual understanding (Cobb, 2002; Latour, 1990; Roth & McGinn, 1998). Yet little is known about how children use inscriptions to argue about science-related, daily-life issues and, more critically, how they perceive the role of different kinds of inscriptions as evidence in their arguments.

This dissertation explores elementary students' use of inscriptions in written arguments about SSI and how a school year of science instruction geared particularly towards coordination between claims and evidence and promoting argumentation may play a role in that use. I situate this study through a theoretical lens that sees argumentation as not only a cognitive process but a social endeavor of persuasion (Berland & Reiser, 2009; Kuhn, 2010). In this sense, using evidence to support arguments is to investigate not just "what is true," but also "who to trust" and "how to convince." It thus is, fundamentally, a conversation between arguers or, in a written case, between authors and the audience mediated by texts or other symbolic systems (Duschl, 2008). Accordingly, the deployment of inscriptions—a major mediator of science—in arguments is viewed in this study as a rhetorical act, by which an arguer weaves a variety of claims and evidence into a persuasive account to a particular audience (Sandoval & Millwood, 2005).

Research Questions

The aim of this dissertation is to investigate what inscriptions elementary students use as evidence in their written arguments in which they justify their decisions about a socioscientific issue, how they use inscriptions in their arguments, and how science instruction may play a role in that use. Two questions guide this study:

1) How do elementary students use inscriptions as evidence before and after a school year of science instruction?

2) How does this school year of science instruction geared towards coordination between claims and evidence play a role in students' use of inscriptions?

Overview of Chapters

This dissertation consists of 5 chapters. Chapter 2 provides a theoretical background that motivates me to explore children's use of inscriptions. Starting from a review of the notion of scientific literacy, I navigate through literature on argumentation, in SSI contexts in particular, and the role of inscriptions in science teaching and learning. Chapter 3 describes the methodology of this study. In particular, I delineate the study setting and participants and the context of science instruction. Then I detail the written argument tasks I administered. Finally, I describe the procedures of collecting the written arguments and classroom video data, and detail my approaches to analyzing these two sources of data. Chapter 4 reports the findings of this study in two parts. First, I report students' use of inscriptions in their written arguments, including what inscriptions they used and how they used them, and how such use differs from pre- to post-task. I then turn to the classroom instruction, delineating students' encounters with classroom tasks that required them to make or evaluate claims. Chapter 5 discusses implications of the findings in relation to how school science should prepare students to evaluate scientific information related to their everyday life when they leave schools.

CHAPTER 2

LITERATURE REVIEW

This dissertation draws upon four major strands of literature that underpin the significance for investigating the use of inscriptions in children's argumentation about SSI. This chapter explicates these strands: 1) science literacy and argumentation; 2) argumentation in SSI; 3) inscriptions in science; and 4) inscriptions in science education. I argue that while science literacy is widely considered as the ultimate goal of science education, empirical investigation into what science literacy looks like in everyday life is lacking. Also, while argumentation, especially in SSI, is important in science learning, most studies have not taken inscriptions, in spite of their pervasiveness in classroom and everyday settings, into theoretical consideration. Although inscriptions play a decisive role in the construction of scientific knowledge, as long investigated in sociology and anthropology of science, little is known about how inscriptions can support high-quality argumentation in educational settings. Furthermore, the use of inscriptions is particularly crucial in SSI argumentation because when we encounter science in our everyday life, we encounter inscriptions often simultaneously. In this sense, inscriptions can potentially play a significant role in the development of science literacy.

Science Literacy: Goal of Science Education

For over three decades at least, science literacy is central to science education research. This term may be retrospectively attributed to, most probably, Hurd's (1958) article, in which he pointed out the vast number of scientific illiterates as a challenge of American science education. Since the late 1980s, science literacy has become a key goal of science education nationwide (AAAS, 1989, 1993, 2001; NRC, 1996, 2011).

Although both policymakers and practitioners embrace the idea that we should teach for the development of science literacy, the picture of how it is conceptualized is much more blurry (DeBoer, 2000). In thirty years of research on science literacy, there are roughly eight theoretical approaches to conceptualizing science literacy: knowledge-acquisition, knowledge-about-science, practical, political, recognitional, fundamental, identity, and integrative.

1) The knowledge-acquisition approach views science literacy as acquisition and utilization of key concepts and knowledge of science (e.g. Hurd, 1998; Jenkins, 1992, 1999; Laugksch & Spargo, 1996; Miller, 1983, 1992, 2004; Mitman, Mergendoller, Marchman, & Packer, 1987; Shen, 1975). Typical is Miller's research, in which he defined science literacy as three-dimensional, including a vocabulary of the knowledge, an understanding of the process, and an awareness of the impact, of science (Miller, 1992). Similar is Hurd (1998), who argued that scientifically literate people will be able to produce and utilize scientific knowledge in human affairs. Though there is a spectrum about what kinds of knowledge should be targeted at, this approach sees knowledge, especially concepts and principles, as the core of science literacy.

2) The knowledge-about-science approach views science literacy as understanding of what counts as science and how it functions (e.g. Allchin, 2011; Kyle, 1995a, 1995b; Lee, 1997; Ryder, 2001). The Organisation for Economic Co-operation and Development [OECD] (2012), among others, differentiates knowledge about science from that of science; the latter includes the understanding of scientific inquiry as the central process of science and scientific explanations as its primary product. Ryder's (2001, p. 2) notion of functional scientific literacy explicitly entails not only conceptual

understanding of science but "more procedural understandings related to the collection and interpretation of scientific data" as well as "epistemic status, such as degree of certainty, both of the data and the theoretical frameworks being drawn upon." In a word, this approach claims that what is worthier of learning is the nature of science, rather than subject matter knowledge in scientific disciplines.

3) The practical approach views science literacy as participation in scientific practices and communities (e.g. Dillon, 2009; Hanrahan, 1999; O'Neill & Polman, 2004; Roth & Lee, 2002, 2004). Rather than focusing on knowledge, this approach is concerned more about how people act in social world. Roth and Lee (2002), in particular, argue that science literacy is socially distributed within a community of practice, and thus should be viewed as a property of collective praxis. That is, no single individuals can ever *own* science literacy; only when people participate in a meaningful activity collaboratively can they *share* and develop literacy.

4) The political approach views science literacy as capability of taking sociopolitical actions to reconstruct society (e.g. Dos Santos, 2009; Hodson, 1999, 2003). This approach takes a rather change-oriented standpoint, and claims that people with science literacy should be able to get involved and take actions in social reforms. Compared with the practical, the political approach is more directly targeted at legitimate social problems, such as environmental protection, empowerment of minorities, and democratization.

5) The recognitional approach views science literacy as appreciation or awareness of the importance of science (e.g. DeBoer, 2000; Eisenhart, Finkel, & Marion, 1996; Shamos, 1995). Unique about this approach is its broad, and somewhat loose,

viewpoint about what science education should pursue. For example, Eisenhart et al. (1996) critique the narrow, content-driven conception of literacy and propose a socially responsible use of science that entails understandings of influences, advantages, and limitations of science. Shamos (1995) states, more radically yet realistically, that it is not necessary to teach science content for all at the same level, not to mention the weak connection of what people learn as students and how they perceive science later on as adults. He thus argues that what science literacy should aim at is "to develop appreciation and awareness of the enterprise […] as a cultural imperative […] " and to "focus on technology as a practical imperative for the individual's personal health and safety […]" (p. 217).

6) The fundamental dimension argues for a return to the original sense of literacy; that is, reading and writing about science (e.g. Ash, 2004; Baram-Tsabari & Yarden, 2005; Hand et al., 2003; Howes, Lim, & Campos, 2009; Pearson, Moje, & Greenleaf, 2010; Webb, 2010). A relatively recent and increasingly influential voice, this approach brings literacy back to its fundamental sense—reading and writing. Often cited is Norris and Phillips' (2003) argument that science literacy should entail skills in interpreting scientific texts and talking about science. Also, scientifically literate people should be able to have and make sense of dialogue about science (Ash, 2004), engaging with the discourse of science (Krajcik & Sutherland, 2010), and so forth.

7) The identity dimension views the development of science literacy as construction of an academic, scientific identity (e.g. Brown, Reveles, & Kelly, 2005; Brown & Spang, 2008; Brown, 2006; Reveles & Brown, 2008; Reveles, Cordova, & Kelly, 2004). In this view, science literacy is seen as participation in discursive

interactions in which scientific knowledge is constructed and situated and as formation of "types of person" that is embedded in interactional exchanges. Reveles and Brown (2008), for instance, argue for looking separately into "scientific" and "literacy". Being *scientific* may be concerning the traditional process of learning scientific knowledge. Being *literate*, on the other hand, is to "appropriate the literate practices involved in doing science" (p. 1019). It is hence not only concerning reading and writing. Instead, at the core of being scientifically literate is an engagement with scientific context in in which children "change their ways of speaking, acting, and interacting with others in order to be accepted and to benefit from cultural membership" (p.1016).

8) Lastly, a small body of research takes an integrative approach, viewing science literacy as a combination of multiple perspectives (e.g. Choi, Lee, Shin, Kim, & Krajcik, 2011; Knain, 2006; Lawson, 2010; Wallace, 2004). This approach combines multiple viewpoints aforementioned and attempts to generate an integrative model of science literacy. For example, Choi et al. (2011) propose a science literacy model that involves content knowledge, habits of mind, character and values, science as human endeavor, and metacognition and self-direction. Identified from this model are knowledge-of-science approach, knowledge-about-science approach (e.g. understand science as constructed, tentative, testable, etc.), practical approach (e.g. learn to inquire and solve community problems), and recognitional approach (e.g. appreciate the importance of science in the 21st century).

These approaches portray a complex landscape about what science literacy should be. Yet ironically, most studies on science literacy seem not built upon what science literacy *is* in our daily lives. They simply take for granted that science *ought to be* useful, but fail to describe how people *actually* use science. Feinstein (2011) points out a lack of empirical work on whether science knowledge *can actually* help people “lead happier, more successful, or more politically savvy lives” (p. 169), and thus focuses on science literacy as "useful in daily life", framing the conception through two questions: "what does science literacy look like" and "what must people know or be able to do to be science literate" (p. 170). Feinstein proposes a “competent outsider” notion of science literacy, by which he argues that people interact with science in context-specific ways to solve everyday problems, and what they need is not to be a knowledgeable scientist, but to be capable of gaining access to specific scientific information, evaluating its credibility, and getting involved in science-related issues (Feinstein, Allen, & Jenkins, 2013).

What, then, does science literacy means with regard to how an outsider gets access to, approach, and evaluate scientific information? From an empirical view, it is not difficult to find out a neglected focus of analysis within science literacy literature, that is, the use of inscriptions. Inscriptions, such as photos, diagrams, tables, maps, and drawings, penetrate fully into the world of science—not just in the laboratory, but also on newspapers, television, and the Internet, which are primary sources of scientific information for the public (McClune & Jarman, 2010; NRC, 2012). Making sense of inscriptions should thus be part of science literacy. Fundamental and practical approaches to science literacy partially support this view. By emphasizing the constitutive role of text in science, Norris and Phillips (2003, p. 228) involve “the panoply of literate objects including not only printed words, but also graphs, charts, tables, mathematical equations, diagrams, figures, maps, and so on.” These latter items are important because they enable and shape readers' reinterpretation of scientific texts (see the example they provide on p. 234). The practical stance on science literacy, on the other hand, argues that when a representation is made publicly visible, it is not owned by any individual anymore, and is no longer in anyone's control; rather, in dynamic interactions among members of different communities, "science literacy becomes a property of the situation" (Roth & Barton, 2004, p. 31).

Argumentation about SSI: Keys to Science Literacy

Let us look more closely into the science education tradition. Alongside and also within the vast body of relevant literature, there is another thread of research on argumentation in science education, which argues for the influences of practicing argumentation in the classroom on the development of science literacy (e.g. Jiménez-Aleixandre & Erduran, 2008; Millar & Osborne, 1998; Simon, Erduran, & Osborne, 2006).

This orientation could be seen as consonant with multiple approaches to science literacy, but most significantly, fundamental and practical approaches. This logic can be unfolded in two steps. First, since language is central to scientific practices, in order to be scientifically literate, people should learn to properly use the language of science (Ford, 2008; Lemke, 1990). As Osborne (2002, p. 214) put it explicitly, "knowing and understanding both some of the content and the appropriate use of language of science is an essential component on the path towards such scientific literacy." Second, argumentation is a central component of language practices in science, and thus an important vehicle for developing scientific discourse and participation. Jiménez-Aleixandre and Erduran (2008, p. 5) summarize five aspects of benefit for introducing argumentation in the classroom: 1) promoting cognitive and metacognitive processes, 2) developing communicative skills and critical thinking, 3) developing reading and writing skills in science, 4) understanding scientific culture and epistemologies, and 5) understanding rationality and developing rational reasoning. Thus, over more than two decades, researchers in science education have been exploring and documenting various ways of advancing argumentation in the classroom.

It turns out, on the one hand, that students often fail to construct well-structured arguments, usually vis-à-vis Toulmin's (1958) influential model (e.g. Jiménez-Aleixandre, Bugallo Rodríguez, & Duschl, 2000; Kelly, Druker, & Chen, 1998; Sadler & Fowler, 2006). On the other hand, it is possible that interventions enable development of argument skills and appropriation of argumentative discourse (e.g. Engle & Conant, 2002; Herrenkohl & Guerra, 1998; Ryu & Sandoval, 2012; Sandoval & Reiser, 2004). Cavagnetto (2010a) summarizes three approaches to promoting argumentation for science literacy. The first approach is to immerse students in scientific inquiry for learning to argue, the second is to teach explicitly the structure of argument, and the third is to introduce socioscientific issues (SSI) as a context of argumentation. While claiming that only the immersion approach touches on the epistemic nature of science, Cavagnetto states that SSI "provide[s] an authentic context for science instruction" (p. 351), which is consonant with the fundamental and practical approaches to science literacy.

Introducing SSI into the classroom has been considered as an approach to promoting science literacy as well (Driver, Newton, & Osborne, 2000; Kolstø, 2001; Zeidler et al., 2005). Take Sadler, Barab, and Scott's (2007) case to illustrate. They introduce a SSI scenario: a mayor of a large city wants to build a nuclear power plant to eliminate coal-burning pollution. However, it may also bring health risks to neighborhood residents, risks of accidents, as well as radioactive waste products. In this scenario, scientific knowledge of the energy cycle, nuclear power and air pollution are intertwined with social concerns of environmental protection, public health, as well as economics and citizenship. While the movement of STS, beginning from the 1970s, failed to integrate science education with broader picture of society (E. Pedretti & Hodson, 1995; Yager, 1996), SSI claims to emphasize people's everyday encounters.

Due to the lack of SSI-related activities in ordinary science classrooms, most existing studies conduct interventions to investigate how SSI plays a role in science teaching and learning. In general, there are two lines of research. The first line deals with how certain classroom activities, including argumentation (e.g. Albe, 2008; Dawson & Venville, 2010; Jiménez-Aleixandre & Pereiro-Munoz, 2002), decision-making (e.g. Grace, 2009; Papadouris & Constantinou, 2010; E. Pedretti, 1999), and other unspecified activities (e.g. Knippels, Severiens, & Klop, 2009; Y. Wu & Tsai, 2007; Yoon, 2008), shape students' performance. The second line explores a variety of factors that influence students' performance, including content knowledge (e.g. Castano, 2008; Lewis & Leach, 2006; Sadler & Fowler, 2006), personal epistemologies (e.g. Khishfe & Lederman, 2006; Sadler, Chambers, & Zeidler, 2004; Yang, 2005), and such personal dispositions as attitudes or moral sensitivity (e.g. Dawson & Soames, 2006; Fowler, Zeidler, & Sadler, 2009; Sadler & Donnelly, 2006; Tomas, Ritchie, & Tones, 2011).

A vast body of research focuses on argumentation as the primary activity regarding SSI-based learning. One common feature of students' arguments about SSI is that they do not commonly use relevant scientific knowledge, though they are able to evaluate the source of information from a general, non-scientific perspective (Levinson, 2004). Kolstø (2006) identified five types of arguments being used: 1) the relative risk argument that compares relative risks with other factors (e.g. cost); 2) the precautionary argument that weighs a precautionary principle (e.g. avoiding any risks) over other values; 3) the decision impossible argument that emphasizes the lack consensus within science community; 4) the small risk argument that sees small risks as of little importance; and 5) the pros and cons argument through which students consider pros and cons of a range of alternatives with regard to people's well-being. Albe (2008) also identifies key features of SSI-based argumentation as personal experience and social aspects of knowledge play a more important role than scientific and technical aspects of knowledge, and relationships and social roles assigned among students influence their collaborative argumentation. Studies also reveal that the interventions of introducing SSI into the classroom are related to the improvement of students' argumentation skills. In particular, explicitly teaching argumentation skills helps participants form more sophisticated arguments (Dawson & Venville, 2010; Zohar & Nemet, 2002; c.f. Evagorou & Osborne, 2013).

Nielsen (2012a, 2012b, 2012c) focuses on the pragmatic role of scientific knowledge in students' argumentation. Unlike studies that predetermine certain types of arguments as ideal, he does not prescribe any standards for students' interactions. Instead, he acknowledges the fact that scientific knowledge and value judgments are often intertwined in students' deliberation about SSI, and it is quite likely that they would confound the two. Using normative pragmatics analysis that treats the use of language as not just conveying information but also manifesting standpoint in a purposeful manner, Nielsen found that science was not only an element in the structure of students' arguments (i.e. as claim, warrant, backing, etc.). Science also serves not a role by which discussion could be grounded on factual content, but a co-optive role that framed the focus of argumentation or place value-laden challenges at the opponents.

A myth seems to be sustained in the research on SSI. Being put in an agenda of developing science literacy, which most claim to address, studies on SSI provide no more than a cloudy vision. A major reason is that many studies position students' performance in the context of SSI on a well-established, external rubric, or as compared with experts (e.g. scientists). Such positioning or scoring, however, does not start with an empirical description about what science literacy may look like in our everyday life, thus the evaluation of SSI-related behaviors, which is claimed to be centered on science literacy, remains in a rhetorical sense. These studies tried to link an internal objective of intervention (e.g. to improve argumentation skills) to an external goal of science education (i.e. to develop science literacy). Yet there exists a gap between the two, given the lack of evidence on how the "desired" performance *is* connected to science literacy. Moreover, if we take an empirical perspective, and look again into the body of research, it would not be a surprising fact that children do not use science much in their learning activities. Rather, from a practical and fundamental perspective of literacy, it is exactly what science literacy may look like in one's everyday encounters: being useful only when it can be related to personal experience and daily life.

Inscriptions: Making Science as Social Practice

To echo Feinstein's argument in terms of SSI-based learning, one might ask: What does arguing about SSI look like, if we see science as practice and science literacy as becoming a competent outsider? As I illustrate in the opening section, people argue about science *through* representations (e.g. Duschl, Schweingruber, & Shouse, 2007; Lehrer & Schauble, 2006). Material representations in scientific practices have been investigated in sociology and anthropology of science for over thirty years. Inscriptions, the terminology I will use in this study, originated in Latour and his colleagues' seminal work about construction of scientific knowledge, in which they use "inscription" to term the kinds of representations that are produced and mobilized in scientific practices. Specifically, Latour and Woolgar (1979) used this term to "summarize all traces, spots, points, histograms, recorded numbers, spectra, peaks, and so on" (p. 88). Latour (1990, pp. 44–47) described in detail the characteristics of inscriptions: 1) they can be moved; 2) they are immutable when moved; 3) they are made flat; 4) they can be rescaled; 5) they can be reproduced; 6) they can be recombined; 7) they can be superimposed; 8) they can be integrated into written texts; 9) they can be merged with geometry. All these features make inscriptions easy to manipulate and essential for scientific practices (see also Lynch, 1988).

These characteristics enable inscriptions to play a critical role in scientific argumentation, which is part of scientists' everyday practices. Latour and Woolgar (1979), for example, documented the ways in which artifacts produced in a laboratory, such as specimens of animal tissues, were inscribed on materials, converted into logs of numbers, and eventually became formal charts or tables in professional journals of science. In this way, the artifacts that are opened to debates gradually become published and public facts that are closed to debates. Latour (1987) further developed a method of investigating scientific knowledge: "Before attributing any special quality to the mind or to the method of people, let us examine first the many ways through which inscriptions are gathered, combined, tied together and sent back" (p. 258). By stating these, Latour argued that inscriptions be seen as a medium through which social actions (i.e. scientific practices) are arranged, transformed, and documented, and through which artifacts produced in one action become facts in a next (e.g. conducting an experiment, recording on a log, making a chart). Graphism, as Latour (1990) used to underline the dominance of graphic representations in scientific practices, distinguishes science from nonscience. Moreover, because of the compactness and cascade of information, inscriptions are routinely used in scientific argumentation and persuasion. That is, when a dissenter has doubt about, for instance, results of an experiment, what the experimenter will normally respond is to show him/her a chart or a table (i.e. an inscription) that demonstrate the results. Although the inscription itself may be self-contained and self-evident, it is an artifact rather than a plain truth. What is hidden behind the inscription may be a large number of specimens, a stack of experimental logs, a set of theoretical assumptions supported by references cited, and so forth; all the information is compacted, reproduced, rescaled, and superimposed into a final chart or table. As a consequence, it is difficult for the dissenter to challenge the credibility of that entire experiment (for a full discussion, see Latour, 1987). In a word, an inscription serves as an ultimate outfit of a whole "fabrication of facts" that closes up questions and debates. In fact, the more scientific (a.k.a. "harder") certain discipline is, the more inscriptions people within that field will routinely produce (Arsenault, Smith, & Beauchamp, 2006; Smith, Best, Stubbs, Johnston, & Archibald, 2000) ; the use of inscriptions makes the discipline scientific.

While sociologists focus on *inscriptions*, which play a role in scientists' everyday lives and knowledge production, anthropologists, particularly linguistic anthropologists, are interested in *people*, who use inscriptions in situ in real-time events of scientific practices. Inscriptions, among other artifacts, serve an important role in embodied interactions that shape people's perceptions, views, and actions. In a seminal article, Goodwin (1994) illustrated how professional workers interact with not only others but also the world in ways that shape their visions and perceptions. In particular, Goodwin described how, in professional activities, coding schemes, highlighting, and production of inscriptions can transform a mundane phenomenon into a perceptual field of certain profession, and how talk, gesture, and inscriptions can mutually elaborate on each other to form considerable power of persuasion (see also C. Goodwin, 2000; M. H. Goodwin, 2006; for in-depth discussions on the embodiment of material resources and interaction). Most importantly, the process of coding and highlighting on an inscription reorients audiences to what is supposed to be seen and put others into the background, thus has massive implications for persuasion. Streeck and Kallmeyer (2001) also reveal the hybridity of instrumental and symbolic functions of inscriptions and that inscriptions, when produced, serve as an interface through which talk and gesture can elaborate on each other.

Inscriptions in Education: Collaborative Learning

Due to its wide spread in other fields of social sciences, it is surprising, to some degree, that the notion of inscription has not so much been taken up by educational researchers. While Vygotsky's (1978) conception of mediating tool has gained wide reputation and applications, inscription draws much less attention, although these two notions share some theoretical features.

Roth and McGinn (1998) first propose a relatively comprehensive lens into inscriptions. Defining inscriptions as “graphical representations recorded in and available through some medium (e.g. paper, computer monitor)” (p. 35), they view inscriptions as not only objects *about* which classroom participants can talk, but more importantly, a mediating device *around* which pedagogical activities (e.g. reasoning, argumentation) can be organized and *through* which meanings can be socially constructed and negotiated. The latter point is crucial, as they put it, “any relationship between inscriptions […] holds because of agreed upon practices, not because of an a priori ontological identity between two inscriptions or an inscription and a natural phenomenon” (p. 42). Moreover, they argue for a shift from seeing the utilization of representations as cognitive enterprise to seeing it as a communal, situated, and social activity (see also C. Goodwin & Goodwin, 1996). In so doing, Roth and McGinn open up a new direction of research that is worth heading in. Most of the succeeding studies on inscriptions in educational settings deal with one of two questions. First, how do students perform with regard to learning through inscriptions? Second, how can we improve such kind of performance?

For the first question, the picture seems not promising. Bowen, Roth, and McGinn (1999) found that their college-level participants lack a competency to linguistically discern different terminologies, which results in conceptual ambiguities in group work. It is a challenge particularly for a learning environment that highlights the use of inscriptions given that the interpretation of inscriptions is intrinsically a social process of negotiation (C. Goodwin, 1994; Stevens & Hall, 1998). Similarly, Sandoval and Millwood (2005) reported that students do not commonly refer specifically to features of inscriptions related to a claim, and such interpretive reference to inscriptions, if taken place, is limited and vague. Other researchers explore the effects of inscriptions from a more individual perspective, and their studies provide another argument for the cloudy picture of using inscriptions. For instance, Schnotz and Bannert (2003), by conducting an experiment, reveal that inscriptions are not necessarily favorable with regard to learning; rather, since understanding texts and graphs is a goal-directed cognitive process, whether or not inscriptions are effective depends on whether they are appropriate to the present task. Similarly, Bowen and Roth (2002, p. 324) argue that students can only learn to use inscriptions by "engaging in activities during which inscriptions are something 'everybody uses' to convince others of the utility and accuracy of their arguments."

Another strand of research addresses the second question, hence concerns interventions that aim to facilitate productive use of inscriptions in classroom. The major finding in this strand is straightly that, the utilization of inscriptions fosters collaborative learning (e.g. Dillenbourg & Hong, 2008; Lehrer & Schauble, 2000, 2004, 2012; Schwarz, Schur, Pensso, & Tayer, 2011; Squire & Jan, 2007; van Amelsvoort, Andriessen, & Kanselaar, 2007). Enyedy's (2005) study, in particular, illustrates not only how children's individual inventions of inscriptions can be translated and integrated, via social interaction (e.g. negotiation, reinterpretation), into cultural conventions of classroom, but also how talk and gesture together support collective conceptual understanding and problem solving (see also Danish & Enyedy, 2007). These findings clearly echo the anthropological scholarship on inscriptions as aforementioned.

Five points need to be further elaborated on here. First, a few studies set SSI as the context of learning (e.g. Barab, Sadler, Heiselt, Hickey, & Zuiker, 2010; van

Amelsvoort et al., 2007). For instance, Barab, Sadler, Heiselt, Hickey, and Zuiker (2010) explore fourth-graders' learning in a virtual environment that addresses local issues of water quality. The environment is multi-user, narrative, and interactive, so that participants are able to gather information and reason about the issue in a collaborative way. The results show that participants are engaged in the activities and significantly gain both conceptual and ethical understanding of the given issue. Inscriptions play a role of supporting socioscientific inquiry in a well-designed narrative, as the authors find that "most involved and meaningful interactions occurred when students were required to interrogate the narrative and the relations of discovered inscriptions to the narrative" (p. 403). Second, argumentation has been seen as a critical part of learning in studies that highlight the use of inscriptions (e.g. Enyedy, 2003; Lund, Molinari, Séjourné, & Baker, 2007; Munneke, van Amelsvoort, & Andriessen, 2003; Nussbaum, Winsor, Aqui, & Poliquin, 2007; Squire & Jan, 2007). For example, Schwarz et al. (2011) provide eighth-graders with pictures of day/night cycle that represent different perspectives (e.g. egocentric, geocentric, universal), and guide them to argue about the topic in a computer program that documents and displays their argumentative moves. MANOVA test shows that participants significantly gain conceptual understanding on the day/night cycle; qualitative analyses further show that the use of inscriptions foster integration of different contexts and elaboration of scientific principles. Third, while other studies discuss how inscriptions mediate classroom activities, two studies explore other components in the activity system that mediate students' use of inscriptions. Specifically, Cobb (2002) discusses the socially constructed norms of reasoning with tools and inscriptions as mediating mathematical learning, and Radinsky (2008) found that emergent roles in collective activities serve as a site of learning that mediates students' reasoning and argumentation. The fourth remark is that, a majority of research in this strand is based upon the computer-supported learning environment and discusses how representations in multimedia, augmented reality, or virtual game settings, can shape the nature of children's learning (e.g. Enyedy, Danish, Delacruz, & Kumar, 2012; Johannesen, 2013; Mirza, Tartas, Perret-Clermont, & Pietro, 2007; Munneke et al., 2003; Schellens, Keer, Wever, & Valcke, 2007). In other words, few studies look into inscriptions in its traditional terms; that is, "paperwork" in a Latourian sense (Latour, 1990).

Finally, a small, mostly recent body of research integrates design and naturalistic approaches and documents how designed environment and teachers' scaffolding can contribute to children's appropriation of inscriptional practice. Unlike the cloudy picture aforementioned, this group of studies reveal that when supported by teachers, negotiations and re-interpretations in a well-designed context can become resources that enable productive use of inscriptions, development of competency, and positive outcomes of problem solving (e.g. Medina & Suthers, 2013; Moschkovich, 2008; H.-K. Wu & Krajcik, 2006a). Wu and Krajcik (2006b), moreover, propose four specific recommendations of how to design learning environment that supports inscriptional practice: 1) embedding the use of inscriptions in inquiry, 2) scaffolding inquiry process, 3) sequencing tasks, and 4) engaging students iteratively.

From the five points above, it is clear that SSI and argumentation have been brought separately to the fore in existing work. Yet those studies do not address SSI-related argumentation in particular, nor do they describe participants' use of inscriptions in depth. I argue that a closer look into students' use of inscriptions in their argumentation about SSI, and a process-based investigation of instruction vis-à-vis this use, provide a promising yet scarce direction worthy to be taken.

CHAPTER 3

METHODS

The aim of this study was to investigate elementary students' use of inscriptions as evidence in arguing about socioscientific issues, focusing on both the product (i.e., argument) and the process (i.e., argumentation) of arguing. In order to explore these aspects, I collected two sources of data: students' written arguments and videos of their classroom interactions. In accordance, two major methods, content analysis and interaction analysis, were used to capture the use of evidence as well as argumentation in general. In this chapter, I first provide an overview of the setting, participants, and the context of instruction, and then describe the materials and procedures of data collection. Finally, I describe the two methods I used to analyze the data.

Setting and Participants

This study took place in a K-6 laboratory school at a large public university in metropolitan Los Angeles during the 2013-2014 school year. This school serves an economically and ethnically diverse population: approximately 36% Caucasian, 20% Latino/a, 9% Asian, 7% African-American, and 28% Multi-ethnic. Progressive and reform-oriented, this school has a close partnership with the university and heavily focus on research that aims at innovation and diversity.

I recruited 102 students in the 5th- and 6th-grades in my study. The students' ethnicity largely mirrors the school demography: 29% Caucasian, 20% Latino/a, 11% Asian, 8% African-American, and 33% Multi-ethnic. The student age is 10.8 on average (10.3 for the 5th grade and 11.4 for the 6th grade).

Three science teachers also participated in this study. Ms. White and Mr. North taught the 5th grade, and Ms. Hill taught the 6th grade. These three teachers were in their second year of an ongoing program of professional development and research called the "work circle" (Shrader, Williams, Walker, & Gomez, 1999). The gist of this program was that university researchers and classroom teachers work closely on designing their lessons, sharing their observations, reflection, student work, and revising the design in an iterative manner. In 2013-2014, the aim of the work circle was to identify practices of coordinating claims and evidence across subjects (language arts, history, mathematics, science), and to develop instructional practices that improve such practices in the classroom.

The three teachers in my study, along with 3-4 teachers from other subjects and grade levels and 3-4 researchers (including myself), had a biweekly meeting throughout the school year. In this meeting, the teachers brought in student work and teaching artifacts that they found meaningful to share and talk about, and the participants had a discussion about each other's ideas, reflections, progressions, and plans for the upcoming instruction. Usually, each meeting had a focal subject for participants to focus on. Ms. White, Mr. Miller, and Ms. Hill represented the teachers of mathematics and science. Besides the work circle, the three of them worked very closely on lesson planning and enactment.

I took a role of participant observer during the school year in three ways. First, I participated in the work circle meetings and joined the discussion. Second, I was present, observed, and videotaped almost every science lesson in the three teachers' classrooms. Third, I had a great amount of informal communications with the three teachers before or after the lesson. Most of the communications were about the lesson plans, details of enactment, students' performance or behaviors, and so forth. So, to a large extent, I was a co-designer of the science lessons I observed, and I built a collaborative rapport with the three teachers that moved my data collection forward.

Context of Instruction

As a laboratory school that was committed to innovation, this school gave teachers considerable freedom to try out new materials and activities in their class. Due both to the implementation of NGSS and the work circle program, the three teachers in my study had a strong motivation to highlight the coordination between claims and evidence and promote argumentation in their lessons. Thus, we deliberately worked together on organizing the lessons towards that end. The overarching goal in the lessons, as shown below, was to promote argumentation with coordination between claims and evidence. Critical to promoting argumentation in schools is a development of epistemic culture that encourages and affords arguments (Ryu & Sandoval, 2012). Thus, I worked with the teachers throughout the school year to develop a culture in which consensus is the goal of collective discussion, and evidence should be used to support whatever claim one makes. In particular, the teachers elicited discussions concerning "how to know what we know," which is often termed as metadiscourse (e.g. Lemke, 1990; Sfard, 2008).

Ms. White and Mr. Miller taught two units of science during the school year in the 5th grade, one on astronomy and another on energy. Table 1 lays out the instructional topics and student activities in the morning group, which was essentially identical to those in the afternoon group. It is clear that the instruction was organized around a few key claims to be evaluated, or questions for which students made claims.

Table 1

Overview of science activities in the 5th-grade morning group classroom

Date	Topic	Student activity
	Astronomy	
11/04/13	Introduction to astronomy	Question collection
11/05/13		Video watching and discussion
11/06/13		Question organization
11/12/13	"Why is the Sun the brightest?"	Video watching and discussion
11/13/13	Claim evaluation: "The difference in the apparent brightness of the Sun compared to other stars is due to their relative distances from Earth."	Evidence collection
11/18/13		
11/19/13		Presentation of arguments
11/20/13	"Why are there shadows?"	Book reading and discussion
11/21/13		Student idea organization
12/02/13	Review of the solar system	Guided discussion
12/03/13	"What is the moon?"	Video watching and discussion
12/04/13	"Why are there phases of the moon?"	Model making
12/05/13		Model comparison
12/09/13	Review of the moon	Guided discussion
12/10/13		Model making
12/11/13	"How to evaluate our models?"	Discussion of the evaluative criteria
12/12/13		Model evaluation
	Energy	
12/16/13	Introduction to energy	Video watching and discussion
12/17/13	"How is the Sun's light energy used?"	Guided discussion
12/18/13	Review of student ideas	Guided discussion
01/06/14	Focal argument: "Plants get the materials they need for growth chiefly from air and water."	Evidence collection
01/07/14		Evidence collection
01/08/14		Evidence collection
01/13/14	"What is a food chain and where to find it?"	Guided discussion
01/15/14	Focal argument: "Which book is better about the food chain?"	Guided discussion

01/21/14	"What is a food chain and where to find it?"	Model making
01/23/14		Model presentation
01/24/14		Model presentation

Ms. Hill also taught two units of science in the 6th grade. The first unit was about the Earth—earthquake and volcano in particular. Table 2 lists the instructional topics and student activities in the morning group of 6th-grade classroom, which, again, were nearly identical to those in the afternoon group.

Table 2

Overview of science activities in the 6th-grade morning group classroom

Date	Topic	Student activity
	Earth	
10/28/13	Introduction to the new unit; Establishment of Professional Partnership Norms	Guided discussion
10/29/13	Review Professional Partnership Norms and start individual projects	Guided discussion and group work
11/05/13		Group work
11/07/13	Discussion on rubrics for evaluating presentations	Guided discussion
11/08/13	Group work on project	Group work
11/12/13	Discussion on a new rubric for evaluating presentations	Guide discussion and group work
11/13/13		Group work
11/15/13		Group work
11/18/13		Group work
11/19/13		Group work
11/20/13		Group work
11/21/13		Group work
11/22/13		Group work
11/25/13	Presentation of "mutual teaching"	Group presentation and discussion
11/26/13		Group presentation and discussion
	Astronomy	
03/03/14	Introduction to astronomy	Question collection
03/07/14		Question organization
03/10/14		Question organization
03/11/14		Question organization

03/14/14		Review question posters
03/17/14	Preparation for individual project	Guided discussion
03/18/14	Discussion on measurement	Guided discussion
04/01/14	Discussion on evaluating claims	Guided discussion
04/03/14		Guided discussion
04/07/14		Guided discussion
04/08/14		Guided discussion
04/10/14		Guided discussion
04/11/14		Guided discussion
04/15/14	Individual work on project	Individual work
04/21/14		Individual work
04/23/14		Individual work
04/24/14		Individual work
04/28/14	Discussion on "how hot is the Sun" and "why is the Sun so hot"	Guided discussion
04/29/14		Guided discussion
05/09/14	Individual work on project	Individual work

As shown in Table 2, the 6th-grade instruction was organized around two major projects, one in each unit. The project in the Earth unit was a group one in which students were asked to gather and organize relevant information to mutually "teach" each other about volcanoes or earthquakes. The project in the Astronomy unit was an individual one in which students were asked to ask a research question of their own and make a poster to investigate it. In both projects, Ms. Hill constantly emphasized the importance of using evidence to support claims and supervised students' work to make sure they coordinated between the two.

It is notable that there was a difference of instructions between the 5th and the 6th grade. That is, in the 6th grade, argumentation rarely took place in the making of science projects. Instead, Ms. Hill and I designed a set of discussions that particularly aimed to deepen students' understanding of making claims, using evidence, advancing argumentation, and so forth. In the Earth unit, such discussions took place mostly on 11/07/13 and 11/12/13. In the Astronomy unit, they took place from 03/18/14 to

04/11/14. These discussions offered an opportunity for 6th-grade students to explicitly deliberate and talk about how they know what they know.

Materials

I used a paper-and-pencil written argument task to measure students' use of inscriptions in arguing about socioscientific issues (see Appendix A and B). Adapted from previous studies on written arguments, this task included three parts. The first part was a written scenario that involves a dilemma to be solved. I used two scenarios in this study. The energy task presented a scenario I adapted from Sadler and colleagues (2007), which posed that residents of a fictional city were asked to decide whether or not to replace a coal-burning power plant with a nuclear power plant. The GMO task presented a scenario that introduced some information I adapted from relevant news articles about the possible benefits and risks of genetically modified organisms (GMOs). Importantly, I involved two opposite dimensions of information in each scenario (e.g., the pros and cons of GMOs) to make it an unsolved problem. I slightly revised the text of these two scenarios in consultation with the three participating teachers to ensure comprehensibility for this particular group of students.

The second part of the task was a question I posed. For the energy task, it was "if you live in this city, which type of power plant would you vote for;" for the GMO task, it was "would you buy GMO foods on a regular basis." Students were asked to write down an argument of why a certain decision was made. In the prompt, I explicitly stated that like many real-life situations, there is no single right or wrong answer, and I framed the questions so that it elicited a personal decision, instead of some remote, policy-making, consideration.

Another request I put in the prompt was that students should use the inscriptions (which we referred to as "images" in the survey) I provided as many as they think would help them make the best case possible for their arguments. Thus, the third part of the task was eight colored inscriptions I found in science news articles (mostly from the *New York Times*) that were related to the scenarios. Each task provided 8 inscriptions: 2 tables, 2 diagrams, 2 photos, and 2 drawings, along with their original caption adapted from the source article to help students understand the information they convey. These inscriptions were numbered, and when students used them to support some ideas, they cited the number in their arguments.

Considerations about the tests should be made clear. First, I categorized inscriptions into tables, diagrams, photos, and drawings out of other types of representations, because these four are the most common. Diagrams refer to geometric, schematic representations of information. Tables refer to the arrangement of information, mostly numbers, in rows and columns. Photos specifically mean real-life pictures taken by camera, while drawings refer to imaginary pictures made with painting instruments. Second, I chose 2 inscriptions for each type, 8 in total, because it is an amount that is feasible to handle yet maintains enough variation. Third, I put with each inscription a caption, which, excerpted from the original news article that comes along with that very inscription, would help children comprehend the information conveyed in the inscription. More importantly, the captions served as a resource that structures and facilitates children's interpretation of the inscriptions, and open up opportunity for children to rethink and argue about what is in the inscriptions (Bernard, 1990; Roth, 2010; Slough, McTigue, Kim, & Jennings, 2010). Fourth, children participating in this study had not learned the scientific knowledge about any of the scenarios yet, so that their prior knowledge had minimum, if any, impact on how they reason about the issues. Fifth, all the three questions posed at the end of each scenario are concerning personal decision making because it represented how people commonly encounter and use science in everyday life.

Procedures of Data Collection

I administered the pre-task early in the school year (mid-October 2013) and the post-task near the end of the school year (late May 2014). Presentation of tasks was counter-balanced: participants were randomly divided into two groups in each grade, with half of them completing the energy task as the pre-task and the GMO task as the post-task, and the other half completing the tasks in the opposite order. This counter-balancing mitigated potential effects from task ordering or difficulty.

I gave oral instruction to participants prior to each task. They were then asked to read the single-paragraph scenario and make a personal decision (either “if you lived in this city, which power plant would you vote for” or “would you buy GMO foods on a regular basis”), write down their decision and explanation, and use inscriptions provided as many as necessary to support their decisions. No discussions were permitted during the task, but they were allowed to ask the classroom teacher or me any questions regarding task comprehension.

Another source of data is the science instruction throughout the 2013-2014 school year. I videotaped the science lessons via a digital camcorder. There were 53 lessons in the 5th grade and 68 lessons in the 6th grade videotaped for this study (see Table 1 and Table 2 for topics of these lessons). While videotaping the lessons, I observed the situation and took field notes in order to document the contextual information that could not be recorded through the camera (e.g., the distal causal links of events, my own emotions, occurrences that took place outside the camera's range). Usually, a clip-on microphone was provided for the teachers to ensure the clear recording of their voice. For small group discussions, I used a group sampling method; that is, I videotaped Group 1 on Monday, Group 2 on Tuesday, Group 3 on Wednesday, Group 1 again on Thursday, and so forth, suppose there were 3 groups in total. In doing so, I was able to collect discussions in each group with clear soundtrack recording in a systematic way.

Analytic Approaches

This study uses two approaches, content analysis and interaction analysis, to analyze the written argument data and video data of classroom instruction respectively.

Qualitative content analysis was used to explore how students used inscriptions in the pre- and post- written tasks. Three aspects of the use of inscriptions were analyzed. The first aspect concerns what inscriptions were used in the written arguments. I counted the frequencies of students' citing each inscription.

The second aspect concerns how students used inscriptions in rhetorical ways to support their claims. I adapted a coding scheme developed to categorize levels of "rhetorical reference" to inscriptions of data (Sandoval & Millwood, 2005). There are five levels of rhetorical reference (examples verbatim from students' responses): 1) *pointing*, referring to some inscription as relevant without saying why (e.g. "I would vote for nuclear plant energy because of image 5."); 2) *description*, describing the content of an inscription without linking it to a claim (e.g. "No [GMOs] because in pic 8, a food turned into a crazy animal. This animal can kill the humans and multiply."); 3) *echoed* *assertion*, using words directly from an inscription to assert that an inscription "shows" or "support" a claim without explaining how (e.g. "Also, on picture #1, the only reason that they say coal is better is that it is cheaper than nuclear."); 4) assertion, using one's own words to assert that an inscription "shows" or "support" a claim without explaining how (e.g. "Coal can be worse as picture number 5 and 7 shows."); and 5) *highlighting*, draw readers' attention to a particular part (or a lack of certain part) of an inscription in relation to a claim (e.g. "I think we should not buy GMO foods because it sounds very unhealthy and not only did it cause Inflammatory Bowel disease to go up by 24% in number 2, just imagine what the culinary world would be like with so many GMOs and "super foods."). For each inscription, I identified and coded its rhetorical reference.

The third aspect focuses on the rhetorical actions a student takes upon an inscription. One action is *crediting*; that is, a student may credit the trustworthiness or relevance of an inscription in relation to a claim. Alternatively, he or she may *discount* those of an inscription, using it to argue against the claim to which it points. Again, I coded the rhetorical action for each inscription throughout the two tasks.

On the other hand, my approach to understanding the influence of instruction on students' written performance was guided by principles of interaction analysis (Jordan & Henderson, 1995). First, I reviewed the science lessons entirely for several times to get a general sense of the classroom ecologies. Major shifts of instructional topics and participant structures in each lesson were indexed. I then identified all the major claims students encountered or questions for which they were asked to make claims. I marked and looked into episodes around these claims that involved argumentation or conversations that focused on the use of evidence. Potential accounts for explicating students' performance in the written arguments were emerged through the closer read. Key segments of episodes were then transcribed, allowing me to notice interactional nuances. Finally, I brought these themes and instances back to the whole set of videos, reviewing the entire dataset again to confirm the typicality or atypicality of the instances (Erickson, 1992, 2006).

CHAPTER 4

FINDINGS

I present the findings in two sections. I first describe students' written arguments in the written argument tasks in terms of what inscriptions they cited, how they cited them, and so forth. For each aspect, I also compare students' performance from pre to post. In this section, I provide a range of examples verbatim from students' responses (in italics) to illustrate the ways in which they used inscriptions in arguing about the given SSI.

In the second section, I delineate instructional practices and interactions in the classroom, focusing on features of the claims that students encountered and classroom discourse organized around these claims. As aforementioned, the coordination between claims and evidence was a central theme in the work circle program, and I worked closely with the teachers to organize instructional units and classroom activities around the goal of highlighting such coordination and, accordingly, encouraging argumentation in the classroom. Again, I provide examples of classroom interaction to illustrate the features of instruction I identify in the analysis.

Students' Use of Inscriptions in Written Arguments

In this section, I present the findings from three aspects of students' written arguments with regard to three sub-questions in the first research question. First, what inscriptions did students use? Second, how did they refer to these inscriptions? Third, what rhetorical actions did their use of inscriptions take?

Citations of Different Types of Inscriptions

Altogether, the 102 students who participated in this study made 210 citations of inscriptions in the pre-task (121 for the energy task and 89 for the GMO task). In the post-task, they made 241 citations (125 for the energy task and 116 for the GMO task). Table 3 shows descriptive statistics of these citations. On average, students cited about 2 inscriptions in their arguments. They made slightly more citations in the post-task than in the pre-task due to more citations in the GMO task. With a relatively large standard deviation, the distribution is asymmetrical with a long tail to the right, suggesting that there were more students citing less than 2 inscriptions, while a few cited far more than 2.

Table 3

Descriptive statistics of citations of inscriptions (N = 102)

	Pre-task	Post-task
Mean	2.059	2.363
Median	2.000	2.000
Std. Deviation	1.225	1.406
Minimum	0.000	0.000
Maximum	8.000	8.000

Figure 1 and Figure 2 show the frequencies of citations on each type of inscriptions in the energy tasks. Across pre- and post-tasks, students preferred photos to other types of inscriptions in their arguments. Drawings were used relatively more frequently than diagrams and tables.

More specifically, in the energy task, students frequently cited: 1) the drawing that portrays nuclear reactors as green leaves with the embedded title "Nuclear Energy Clean Air" (inscription #4, 21 times in the pre-task and 13 times in the post-task); 2) the photo that shows working coal-burning power plants in Ukraine (inscription #5, 17 times in the pre-task and 32 times in the post-task); and 3) a photo of nuclear reactor explosions in the 2011 earthquake in Japan (inscription #8, 27 times in the pre-task and 26 times in the post-task).

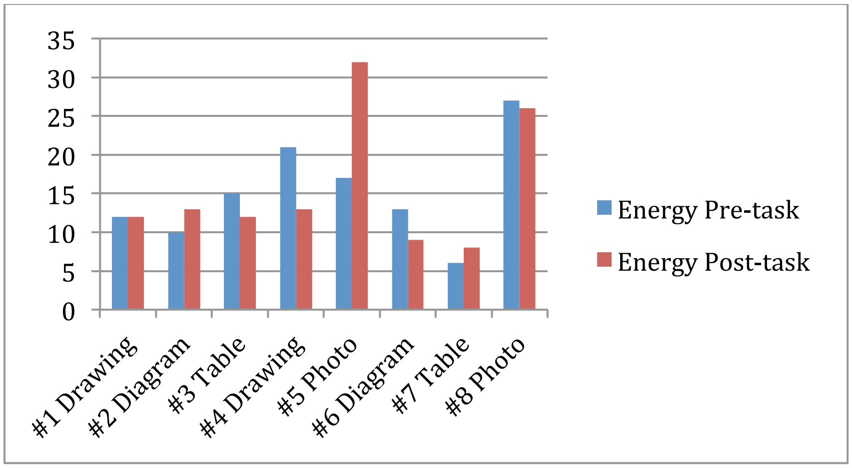


Figure 1. Frequency of inscriptions cited in the energy task

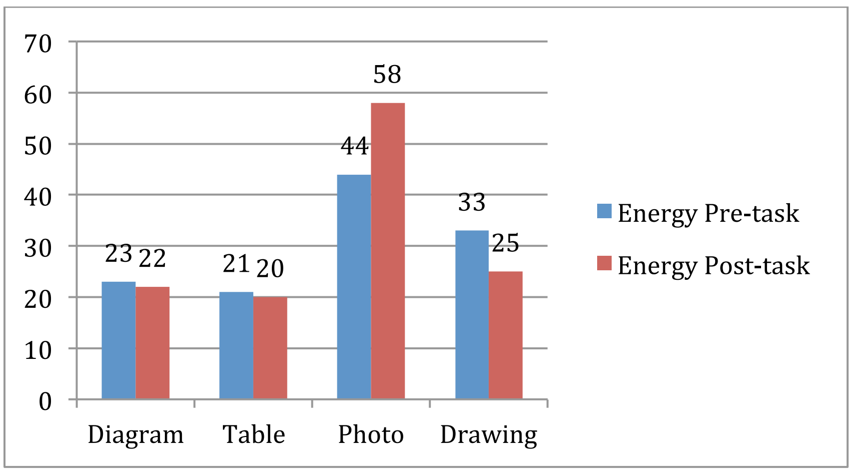


Figure 2. Frequency of types of inscriptions cited in the energy task

Figure 3 and Figure 4 show the frequencies of citations on each type of inscriptions in the GMO tasks. In comparison with results in the energy task, there are two patterns here. First, students cited photos and diagrams almost equally frequently. The citations of diagrams, however, were not equally distributed in the two diagrams, as can be seen in Figure 3. Students relied mostly on the #2 diagram, a line chart that showed changing rates of inflammatory bowel disease before and after GMO foods were introduced to a certain population, rather than the #3 diagram that depicted a procedural model of edible vaccination. Second, tables, as a type of inscriptions, were used the least in both the energy and the GMO tasks, as shown in both Figure 3 and Figure 4.

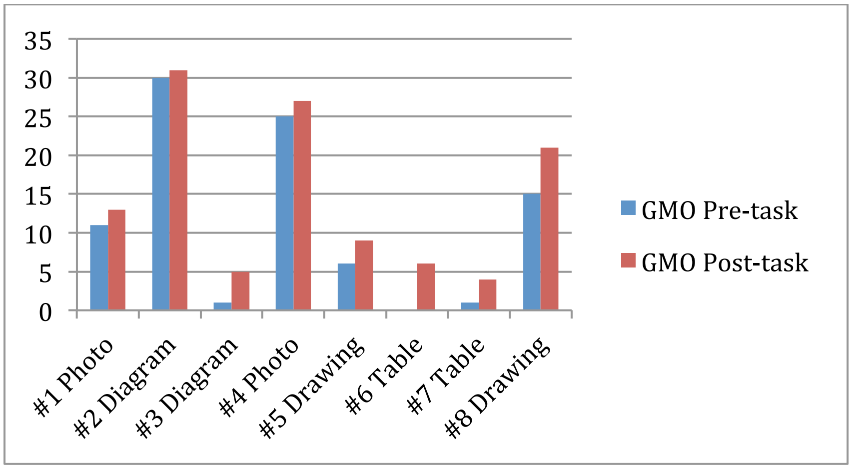


Figure 3. Frequency of inscriptions cited in the GMO task

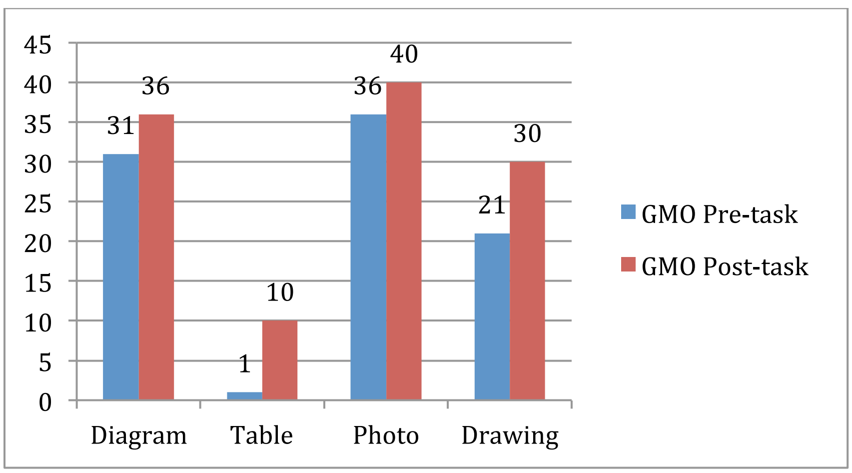


Figure 4. Frequency of types of inscriptions cited in the GMO task

More specifically, students frequently cited: 1) the diagram of changing rates of a disease (inscription #2, 30 times in the pre-task and 31 times in the post-task); 2) the photo in which a little girl was holding up a sign during a street protest against GMO (inscription #4, 25 times in the pre-task and 27 times in the post-task); and 3) the drawing that pictures a fictional creature and goes with a caption, "GMO's threats to biodiversity" (inscription #8, 15 times in the pre-task and 21 times in the post-task).

Altogether, photos were cited the most frequently in students' written arguments. It indicates that in general, students considered photos as evidence the most relevant to their claims and justifications about a SSI-related decision. Tables, on the other hand, were used the least frequently across all tasks.

Pre-/Post-task Comparison. In general, the broad patterns described above did not change from pre to post. Chi-square tests on citations of each type of inscriptions did not yield any significant differences from pre to post. At an individual student level, paired samples *t*-tests on both total number of citations and the numbers of citations of each type did not yield any significant differences from pre to post. These results suggest that students' use of these inscriptions was consistent between pre- and post-tasks.

Rhetorical Reference to Inscriptions

Table 4 shows the code frequencies of the five ways of rhetorical reference to an inscription. Three patterns could be identified.

Table 4

Rhetorical References to Inscriptions

	Pointing	Description	Echoed Assertion	Assertion	Highlighting
Energy–Pre	59	9	15	26	12
Energy–Post	78	10	5	17	15
GMO–Pre	41	15	4	21	8
GMO–Post	48	9	10	36	13
Total–Pre	100	24	19	47	20
Total–Post	126	19	15	53	28

First, students tended to only point to an inscription without explicitly linking it to a particular claim. The following examples show the rhetorical reference of pointing. The italicized text is verbatim from students' responses, while the text in brackets is identifier of the data source the example comes from.

> *Even though it produces air pollution, Nuclear power plants have hazardous waste and the radiation is dangerous (image 3)*. [5th grade – Energy pre-task]
>
> *GMO causes plants to have unexpected reactions because GMO is filled with viruses and Deseases. It is extremly dangerous for kids and adults, that is why people and protesting. 5 and 4*. [6th grade – GMO post-task]

In these two examples, the students did not attempt to describe the content of the inscriptions they were citing. Nor did they link these inscriptions to the claims they were making (i.e. a descriptive claim about the danger of nuclear power plants in the first example, and a causal claim about GMO causing diseases in the second example). As a result, one who solely read these two arguments would not understand what evidence they referred to or the relationship between such evidence and the claims they stated.

This result is consistent with Sandoval & Millwood's (2005) study, which claimed that students might see data as self-evident, with no need for further interpretation. Take the energy argument above for example. The #3 inscription the student cited is a table that lists health consequences (diseases, disorders, etc.) of the Chernobyl nuclear accident in the first 15 years, including various types of cancers, environmental stress disorder, and so forth. The table also shows numerical data about morbidity and mortality of these consequences. It is possible that this student considered information provided in this table as self-evident enough for the claim that nuclear power plants are dangerous, without stating, for example, that cancers do harm to our health or that stress disorder is normally undesirable for people.

The second pattern is that in some cases, students asserted that an inscription "showed" or "said" a claim by quoting the exact words in the inscription. This way of reference was coded as echoed assertion, as shown in the following examples.

> *I chose picture #8 because it even says that the GMOs threats biodiversity.* [5th grade – GMO pre-task]
>
> *On #8 pg. 5 it shows an image about GMO's threats to biodiversity & how GMO is not healthy*. [5th grade – GMO post-task]
>
> *I agree with the girl because in image #8 it says GMOs threats to biodiversity*. [6th grade – GMO post-task]

These three examples all involve a citation of the #8 drawing. Clearly here, the students used the caption from the drawing, "GMO's threats to biodiversity," directly in their arguments. Interestingly, there is another phrase within the drawing, "It's perfectly natural," which serves as an irony against GMOs. Yet none of the students in this study quoted this phrase. The students recruited the caption of this inscription directly in their arguments without further articulating what it meant in relation to a particular claim. This rhetorical reference of echoed assertions was also found in the energy task, as shown in the following examples that echoed the statement in the #1 drawing that coal power is "cheaper" than nuclear power.

> *1: It shows that it is cheaper*. [5th grade – Energy pre-task]
>
> *On picture #1, it says it's cheaper*. [6th grade – Energy pre-task]

I would vote for a coal burning power plant, because first of all, as it says in pic. 1, coal is much cheaper than nuclear power plants, which would make it less of an issue with money. [6th grade – Energy post-task]

The third pattern with regard to rhetorical references is students' frequency use of assertions. In total, assertions (non-echoed) are the second most frequently used reference in the written arguments (see Table 4). The following example illustrates how students assert that an inscription "*shows*" a claim without explicating how.

Picture 3 shows that the nuclear power plant is unhealthy for humans and the accidents that could happen. I think that coal burning is at least more healthier than nuclear power plant. [5th grade – Energy pre-task]

In this example, the student cited "picture 3" (i.e. the #3 table of health consequences in Chernobyl nuclear accident) as evidence to support a fairly broad, descriptive claim that "nuclear power plant is unhealthy for humans and the accidents that could happen." However, this student did not describe what "picture 3" is, nor did he or she explicate why this picture was supportive. Rather, he or she simply asserted that an inscription showed that a claim was valid.

In another example below, the student argued that image 8 (i.e. the #8 drawing of a fictional animal) showed a causal claim that "GMOs can affect animals." Yet likewise, necessary information about the image per se and, more importantly, reasons regarding how this image could support a causal claim, were missing from the argument.

Also image 8 it shows that GMOs can affect animals and turn them into a non-existent creature. [6th grade – GMO post-task]

Highlighting, on the other hand, was used less often. Similar to "interpretation" in Sandoval and Millwood's (2005) coding scheme, highlighting entails that the arguer selectively pointing out some specific part(s) of an inscription to explicate its relation to a particular claim. Below is an example of highlighting.

> *Another reason I chose coal power was that according to picture 6 nuclear electricity is the most expensive, and in america many people don't have enough money to pay for nuclear electricity, so many americans must use coal power to save up for important neccesities*. [5th grade – Energy pre-task]

In this example, the student first cited picture 6, a diagram depicting costs of different sources of energy, to support his or her decision of choosing coal power. By saying that "nuclear electricity is the most expensive," this student drew readers' attention to a specific part of the #6 diagram, that is, the cost of nuclear electricity in comparison to that of other sources of energy. Nonetheless, if the argument stopped here, it would still be a description—describing the content of an inscription without further stating its relation to a claim. But the student went further and provided a linking statement from that evidence to the decision. That is, he or she stated that in this country people had to save money up for important necessities other than energy, and that is why "more expensive" is not desirable. By doing so, this student explicated why cost was key to deciding on the source of energy, and made clear not only what evidence there was in picture 6, but also why that piece of evidence was important for a particular claim. What follows is another example in the GMO task.

In picture 7 you see the U.S. and many other countries are making a lot of money off of GMO foods so that means there are many people who trust GMO foods. [5th grade – GMO post-task]

In this example, the #7 table that shows GM crop farms' income benefits and average yield increase across countries during 1996–2008 was used to form an argument that people actually trusted GMO foods. Instead of merely pointing to it (e.g., "see picture 7") or asserting that it shows the claim (e.g., "Picture 7 shows that people trust GMO foods"), this student not only summarized the content of the table but, by pointing to the U.S. in the table and using the qualifier "many," he or she also highlighted the prevalent acceptance of GMO foods in many countries, including the U.S. Such rhetoric makes this argument more cohesive.

Pre-/Post-task Comparison. To compare students' performance in terms of rhetorical reference to inscriptions, I computed the percentage of each category of reference within an individual student. I then conducted a set of nonparametric sign tests on the categories of reference. Results showed no significant differences between pre-task and post-task in any categories. It suggests that students' rhetorical references to inscriptions were consistent during the study.

Rhetorical Actions upon Inscriptions

Finally, I explored the rhetorical actions students took upon the inscriptions they cited in written arguments. Table 5 shows the code frequencies with regard to this analysis.

Table 5

Rhetorical Actions upon Inscriptions

	Crediting	Discounting

Energy–Pre	101	20
Energy–Post	114	11
GMO–Pre	87	2
GMO–Post	111	5
Total–Pre	188	22
Total–Post	225	16

Clearly, students preferred crediting to discounting across all the tasks. It means that they tended to cite and credit evidence that aligned with their own stance, rather than cite and discount evidence that supported alternative perspectives or counterarguments. This finding is resonant with previous research on students' evaluation of information, which revealed the relative rareness of students' discounting evidence (e.g. Kuhn, Iordanou, Pease, & Wirkala, 2008; Newman & Ruble, 1992). The following examples illustrate how students in this study credited inscriptions they cited for supporting a claim.

> *On picture A5 it shows how much the coal power plant pollutes*. [5th grade – Energy pre-task]
>
> *Second of all, these genetically modified seeds have been giving certain people organ failure, cancer, and other diseases, and are certainly unhealthy for humans. See image 4*. [6th grade – GMO pre-task]
>
> *If you look at picture #5, you can see what coal power plants do to the environment*. [6th grade – Energy post-task]
>
> *Image 4 shows a little girl going against GMO, because the GMO foods might not exactly be good for you*. [5th grade – GMO post-task]

What is common in these examples is that students took whatever in the inscriptions they cited as true, valid, or warranted, and used them directly to make their claim. Compare them with the following examples.

> *I vote for Nuclear because image #1 talks about coal but it only says that its cheaper than nuclear and it dosent say anything about pollution*. [5th grade – Energy pre-task]

Image #1 is an ad (i.e. drawing) that states coal is cheaper than nuclear. The student in the example, however, supported nuclear power source. He or she used this drawing for an opposite stance by discounting the comprehensiveness of information presented therein.

> *Also nuclear power plants can be dangerous like number 8 and 3 shows, but those things don't happen very often*. [5th grade – Energy pre-task]

In this example, the student chose nuclear power plants. He or she, however, used two inscriptions, #8 photo about nuclear reactor explosions in Japan and #3 table about health consequences in Chernobyl nuclear accident, evidence for the danger of nuclear power. To argue against these, this student discounted the opportunity of nuclear accidents reflected in these two inscriptions, arguing that they were actually quite rare.

> *Though in picture 2 you see the rate for inflammatory bowel disease has gone up since the release of GMO, but with science today in ten years maybe scientist will have lowered that risk or removed it all together, so I would eat GMO foods*. [6th grade – GMO post-task]

In the example above, this student cited the #2 diagram about increasing rates of inflammatory bowel disease and admitted that it might be caused by GMO foods.

However, he or she then discounted the validity of information from today's perspective by pointing out that science was advancing rapidly and the data presented in the diagram might be out of date.

Pre-/Post-task Comparison. Similar to analysis of rhetorical reference, I also computed the percentages on the two categories of rhetorical actions within each individual student. A nonparametric sign test was conducted to compare the pre- and post-task results, which yielded no significance on any categories. Thus, there is no significant difference between students' performance regarding rhetorical actions upon inscriptions from pre-task to the post-task.

Summary

Using content analysis, I revealed patterns on what inscriptions students used and how they used them. First, photos were cited the most in students' written arguments, while tables were cited the least. Second, students tended to merely point to an inscription without articulate its relation to a particular claim, or to assert that an inscription "shows" a claim without saying how. Third, students were most likely to credit inscriptions that aligned with their own position rather than discount those that supported counterclaims. From pre to post, these patterns did not change significantly. Why was there little change, after a school year of science instruction geared particularly towards argumentation and coordination between claims and evidence, in students' use of inscriptions? The next section addresses this question.

Classroom Instruction

In this section, I delineate classroom instruction in the 5th and 6th grades in order to explore potential accounts for students' written argument performance from pre to post.

In particular, I focus on two types of practice that the three teachers asked students to carry out as targeted in the work circle program: 1) evaluating a given claim; and 2) proposing and then evaluating a claim for a given question. Following Manz's (2014) framework, I specifically looked into the processes in which a claim, either given by the teacher or proposed by students, was problematized (framed by the teacher as something to be resolved) and stabilized (contested by students).

There were two types of claims evaluated or proposed in the classroom. One is the disciplinary claim that is concerned with domain knowledge (e.g., about energy conservation, ecosystem, the Sun). The second type is the epistemic claim, that is, regarding knowledge per se (e.g., about how we know what we know, what source of knowledge is reliable). Table 6 shows all the claims or questions requiring claims that students encountered throughout the school year.

Table 6

Claims and questions requiring claims in the science instruction

	5th Grade	6th Grade
Disciplinary	1. The difference in the apparent brightness of the Sun compared to other stars is due to their relative distances from Earth. 2. What causes dawn and dusk? 3. What causes the phases of the Moon? 4. Plants get the materials they need for growth chiefly from air and water.	1. How hot is the Sun? 2. Why is the Sun so hot?
Epistemic	1. Which book is better about the food chain? 2. What do we need to do if we don't all have the same information?	1. How to evaluate each other's presentations about earthquake or volcano? 2. How to prove that a claim is accurate?

This section is organized in the following parts. First, I provide an overview of lessons in the two grades in which the claims or questions in Table 6 were embedded. Then, I argue that there were three aspects of instruction that may account for students' performance in the pre- and post-task of written arguments: 1) the claims students encountered were not contestable; 2) the resources available for students to stabilize these claims were limited; and 3) the discourse through which students talked about how to evaluate claims and what counts as reliable evidence (i.e., epistemic discourse) was closed. For each aspect, I differentiate between disciplinary and epistemic claims, and provide one example for each type of claims from either 5th or 6th grade to illustrate and evidence my points.

I used the transcription convention developed largely by Gail Jefferson for transcribing the classroom talk (Sacks, Schegloff, & Jefferson, 1974), shown in Table 7.

Table 7

Transcription convention used in this study

Symbol	Function
	Speaker (at the left side of the line)
W / M / H	W/M/H represent Ms. White, Mr. Miller, and Ms. Hill, respectively.
SS	SS represents students' choral response.
S_n	S_n represents an individual student's response; n represents his/her order of speaking in the particular conversation.
	Utterance
,	A comma indicates a continuative intonation.
.	A period indicates a terminative intonation.
?	A question mark indicates a rising intonation.
[	Left-side brackets indicate where overlapping utterances begin
-	A dash indicates a cut-off sound.
=	Equal signs indicate a latching sound that follows a preceding one without any perceptible break.
:::	Colons indicate a prolonged sound, proportional to the number of colons
__	Underlining indicates stressed sound

BUT	Upper case indicates stressed sound that is louder that underlined one
(0.6) / (.)	Numbers in parentheses indicate intervals without speech in seconds; a dot in parentheses indicates a brief interval of less than 0.2 second.
( )	Words in single parentheses are transcriber's best guess of what is being said that is difficult to recognize.
(( ))	Text in double parentheses provides observational information (e.g., bodily movements) or transcriber's comments.

Overview of Lessons

There were two units of science taught in the 5th grade, astronomy and energy. The astronomy unit was from late October 2013 to mid-December 2013, and the energy unit was from mid-December 2013 to late January 2014. Two units were taught in the 6th grade: earth science and astronomy. The earth unit was from the end of October 2013 to the end of November 2013. The astronomy unit was from the end of February 2014 to mid-May. The general processes of instruction are described below.

5th-Grade Astronomy. Students in the 5th grade finished a unit on the biosphere at the end of October, and had an astronomy-focused field trip. In early November, Ms. White and Mr. Miller asked students to list questions they generated from the field trip. Then, students were asked to categorize and organize these questions on a poster. After watching some introductory videos about the stars and the Sun, the teachers presented to students a claim, "The difference in the apparent brightness of the Sun compared to other stars is due to their relative distances from Earth." The teachers then asked students to collect evidence to prove or disprove this claim. They spent two lessons on this task, and had one lesson of whole-class presentation to report their findings. Ms. White and Mr. Miller then introduced the concepts of shadows and twilight. They asked students to explore the question of "what causes the shadows" and write their ideas down on sticky notes. Students were then asked to make models of the sunset and sunrise or the phases of the Moon (in 2-D or 3-D). They spent 4 lessons on this project. In between, Mr. Miller led a discussion (approx. 1 lesson) about what criteria they should use to evaluate the model. In the next lesson, students evaluated their own models, and finally presented them to the whole class.

5th-grade Energy. In mid-December, Ms. White and Mr. Miller introduced the basic concept of energy. They discussed how the Sun's light energy is used on Earth. After the winter break, Ms. White and Mr. Miller presented a claim, "Plants get the materials they need for growth chiefly from air and water," to the students, and asked them to collect evidence to argue for or against this claim. They spent three lessons on this task, and did a gallery walk to share their findings at the end. Then, Ms. White and Mr. Miller introduced the ideas of food chain and food web. In mid-January, they did an argument task about "which book is better" with regard to two books about food chains and webs they used in the unit. Students were then asked to make a model to represent a certain type of food web/ecosystem. They worked on this project in small groups, and presented their models to the whole class eventually. The entire science instruction of the 2013–2014 academic year ended on January 24, 2014.

6th-grade Earth. At the end of October, Ms. Hill told Room 5 that they were going to start a new project about earthquake and volcano. At the beginning of the project, Ms. Hill led students to discuss and establish a classroom norm that they called "professional partnership norm." They then did a set of whole-class discussions to collect and organize students' own ideas and questions. Then, students started to work on the project in small groups. In general, they used computers to find information on the Internet and to make keynote slides. This group activity lasted for approximately two weeks (10 lessons). At the end of November, students spent 2 lessons to do “mutual teaching” in which one group “taught” another group about their findings and vice versa.

6th-grade Astronomy. Students in the 6th grade had an astronomy-focused field trip at the end of February. At the beginning of March, Ms. Hill told students that they were going to learn about astronomy. First, Ms. Hill asked students to list questions they generated from the field trip. They categorized and organized their questions on the poster for 3 lessons. On mid-March, then, they reviewed and discussed each other’s posters. Starting from March 17, Ms. Hill led students to discuss about claims and evidence. She told students that they were going to conduct an individual project in astronomy, but in order to do it well, they should better understand what claims and evidence mean. So they spent about two weeks (7 lessons) talking about what a claim was, and how to know whether a claim was accurate or inaccurate. On mid-April, students started to work on the individual project. Ms. Hill asked them to choose a topic that they really cared about, and to pose and answer research questions. The key, Ms. Hill emphasized, was to generate a claim (or a set of claims), which should then be supported by evidence. The product of this individual project should be a poster of arguments, which they would present to the whole school community in late May.

Notably, near the end of the unit, Ms. Hill and I designed an activity that was aimed at enhancing students’ understanding of what descriptive claims and explanatory claims mean and how to coordinate between particular types of claims and evidence. We picked “how hot is the Sun” as the descriptive claim and “why is the Sun so hot” as the explanatory claim, and facilitated two separate discussions for two halves of 6th-grade students in which we talked about how to find evidence for these claims and what the answer might be. We spent 2 lessons on these two discussions.

Low Contestability of Claims

Disciplinary claims. An example of low contestability of disciplinary claims is the claim about the brightness of the Sun in the 5th grade. On November 13, Ms. White presented a claim to students: "The difference in the apparent brightness of the Sun compared to other stars is due to their relative distances from Earth." She asked students to explicate what this claim was actually saying. Having gathered a few initial ideas, Ms. White (W) said to the whole class:

((11/13/13 Morning Group))

W: Nice, so you guys have read it, and interpreted that and understand what it's asking for, right? But what we're gonna ask you to do is, not to say yep, or no, I agree, but it is to say, yes I agree, or hmm, I disagree, but you have to show us evidence. What is the scientific evidence for them, okay? It can't just be an opinion without any evidence for it. What do I mean by you have to provide some evidence for what you think? What do you think? What do I mean by that? ((W names a student.))

S_1: Em, (0.6) it means (.) like you can't say like, oh, the star looks brighter than this star because it can fly. ((Many students laugh.)) You have to provide some actual evidence?

W: ACTUAL [evidence.

S_1: [Yeah. Em, and you can't just say oh this star is bigger than this star you have to- you have to prove it.

W: Could you say this star is bigger because it looks bigger?

S_1: No.

((Many students laugh.))

W: That's not enough, right?

Ms. White then went on to talk about what specifically students needed to accomplish in this evidence-seeking task.

((11/13/13 Morning Group))

W: So look at this. You're going to work with a partner, with your desk partner, and you're gonna find your evidence. See what I say source right here? Source number 1? That's where you're gonna write down a website you're looking at. Where the information is coming from. Okay? And then you're gonna write down the evidence that supports what we're saying here ((pointing to the claim)). Okay? Not just one source of evidence but, another source of evidence that will support the same claim. (2.0) And, at the back, there is a third source you need to find, supporting evidence. Okay? Now look at here. When we ask you, write an argument that JUSTIFIES. What does that word mean? An argument that justifies your current claim. What is your current claim.

Without further eliciting students' ideas about these questions, Ms. White asked them to group in pairs with one laptop computer per pair to find and discuss sources of evidence and finish the task. This activity lasted for 30 minutes. During the group discussion, Ms. White walked around the classroom and discussed issues with each pair.

This claim poses a causal link between the brightness of the Sun and its distance from Earth (and implicitly, from other planets). The disciplinary knowledge upon which it touched was well established in the domain of astronomy. Students' job, therefore, was to seek the exact same proposition as the given claim, or that contradicted this claim so as to discount it and warrant an alternative claim. For example, a counterclaim might be that "The difference in the apparent brightness of the Sun compared to other stars is due to their different sizes." Students did not, however, raise such counterclaims in the whole-class discussion, as they had "resolved" the claim in their groups. Thus, the claim per se was not legitimately contestable for any argumentation.

Epistemic Claims. An example of low contestability of epistemic claims is the claim 6th-grade students encountered during the earth unit. Right after students started to work on their group project about knowledge presentations, Ms. Hill and I decided that there should be standards about what counts as a good presentation. We thus created an initial worksheet of criteria, and on November 7, Ms. Hill guided students to talk about and revise the criteria as a whole class. They looked at a sheet of criteria together through the overhead projector, and talked about what the criteria mean and what they should do. The following episode shows what this discussion looked like at the beginning.

((11/07/13 6th Morning Group))

H: So we're gonna go through this and talk about the project. I wanna make sure that everyone is clear about what we're doing, and how we're going to be evaluating (0.6) em (0.4) looking at (0.6) evaluating this. (2.0) So (0.6) em (0.6) okay, so we talked earlier about that fifteen slides and (0.8) as I said, you can go up to twenty slides. That would be the *maximum. (2.0) We talked about the background enhancing the graphs and the texts. How many- how many backgrounds should you actually use? ((M names a student.))*

S_1: One.

(1.0)

H: Really (0.4) that's- good point (0.4) why (0.4) why would you use one background for your [entire

S_1: [Coz if you use multiple you're gonna be wasting A (.) color and then if you're fortunate enough you're gonna go print it and it looks horrible.

H: Well you're not gonna be printing it off anyway [so

S_1: [Yeah.

M: So (0.4) your second idea is what.

(0.8)

S_1: I don't know.

H: You just said [it. You sai-]

S_1: [OH. E:h things look horrible?

H: Okay so it's gonna look a lot better if you do one- one background for. Yeah? ((M points to another student.))

S_2: And also if you XXX background color and that affect with the text then no one could read.

H: Right, so it's gonna look better people would be able to read it better and understand it. Yes? ((M points to another student.))

S_3: An' also be better be one background (0.6) then you don't have to keep switching color (.) to be with one color and one background (0.6) so it won't be confusing=

H: =Exactly. So all of those ideas are correct.

In this segment of conversation, Ms. Hill did not frame the discussion as having a problem students needed to solve and reach consensus for (i.e. how many background students should use in their slides). Instead, the aim of this discussion was to make sense of an existing point, that is, one background would be good. Ms. Hill thus asked the three students to justify a single decision, rather than eliciting different opinions and promoting argumentation.

Remarkably, they talked about using pictures in the presentation, as shown in the following episode.

((11/07/13 6th Morning Group))

H: The next one, re:::ad the next one, Tilly.

S_1: (4.0) We gotta use one picture on each slide to support the comment=

H: =the con<u>tent</u>. Okay so why would you wanna have a picture on every slide.

((More than half of the students raise their hands.))

H: A lot of people have ideas about this, let's start with you P, and then Lilia.

S_2: Well, like you can show the reader this is how it looks like and.

(1.0)

H: What do you mean show the reader?

S_2: Like- I mean like show the reader (1.0) let's say you have a map of- that you can show the area.

H: Okay, so you're showing as well as- as (0.6) having, what else. ((M points to another student.))

S_3: Em, you can also (0.6) em have a picture on a slide to em (0.4) kinda like (0.8) sum up what you're talking about and (0.4) make it more clear you're talking about in the presentation=

H: Okay so clarity and summin- sum- summing 'formation or something, what else.

S_4: ((Inaudible response))

H: Yeah, so it creates a lot more interests doesn't it? If you just have words on the slide (1.6) you're right it's not gonna b::e (0.6) it won't be boring if we have a picture with it. ((M points to another student.))

S_5: It will also be better so that they can understand what we're going to say. If just words they're not gonna (.) be able to visualize what you're actually trying to say=

H: Okay.

In this episode, four students (S_2 to S_5) provided ideas about why using pictures in their presentation slides was necessary. There were three views: showing the points the presenter makes (S_2), summarizing information (S_3), increasing interests (S_4), increasing clarity and understandability (S_3 and S_5). However, they did not further discuss why pictures could serve these purposes, for example, why pictures could present information more clearly than texts. And again, as they were listing non-conflicting ideas, there was no argument about what functions pictures should have in this particular discussion.

Overall, the purpose of this whole-class discussion on November 7 was to make sense of a given set of criteria, instead of co-establish criteria in a generic way. Ms. Hill did not elicit students' own ideas or encourage them to come up with their own criteria. Yet the epistemic claims they faced (e.g., having one picture on every slide is better for a presentation) were not legitimately contestable. Consequently, Ms. Hill and students did not have arguments about how to evaluate students' presentations in this discussion.

Limited Resources for Stabilizing Claims

Disciplinary Claims. An example of limited resources for stabilizing disciplinary claims is the claim 5th-grade students encountered about what causes dawn and dusk. On November 20, Ms. White and Mr. Miller told students, in their respective class, that they were going to learn a new topic. They picked a picture book about twilight beforehand. The teacher read it aloud slowly to the whole class. Between pages, the teacher stopped to let students think about what the book was saying. After reading, the teacher asked students to recall what dawn and dusk were according to what they just read. Then, the teacher posed a question to students as shown in the following episode.

((11/20/13 Morning Group))

W: So I'm gonna ask you now, to write something down. I'm gonna give you a green post-it. ((W gets up and gets a large post-it from a desk.)) And on this green post-it, you're gonna break down your answer to this question. ((W hangs the post-it on the whiteboard.)) Who'd like to read that. ((W names a student.))

S_1: Eh, what causes dawn and dusk to occur everyday.

W: Okay. We don't wanna know what is dawn. Because we talked about it. We don't wanna know what is dusk. Because we talked about it. But we want to talk about what causes dawn and dusk to occur everyday. ((Several students raises hands.)) We're not gonna listen to the audience right now. I'm gonna give you the post-it and you're going to write it down. When you go back to your seats to write this down, you're gonna keep this to yourself. That's why I want you to write it here. ((W touches the post-it in her hand.)) There won't be any side conversation, you're doing it independently. Okay, write it down, and you give it to me.

As shown above, this was an individual task. Students went back to their seats after this whole-class interaction, and worked on this task for approximately 10 minutes.

Unlike the aforementioned task of evaluating a claim about the brightness of the Sun, students here did not face a given claim in the first place. Instead, they were asked to propose a claim by themselves. Also, they were not allowed to use laptops, as in the previous task, so they did not have access to online information. This still was, however, an evaluative activity in that students have read the book about twilight together, and there was information relevant to the cause of dawn and dusk, so their task could be translated into an evaluative one, that is, whether they should trust what the book said about dawn and dusk.

Therefore, the major epistemic resource on which students relied when tackling this task was the book about twilight they just read. Students were aware of this resource at the onset of the task, which was reflected in a discussion right before students went back to their seats.

((11/20/13 Morning Group))

((A male student raises his hand.))

W: Yes.

S_1: Em, I don't really understand how that book is about science.

W: You don't understand how the book is about science?

SS: Yeah…

W: Who does understand why the book is about science? ((W picks up the book again and shows the preface page to the whole class.))

((About 5 students raises their hands. Some murmur. W waits for about 10 seconds.))

W: Who does. I see a lot of hands up, how is this about science? ((W names a student.))

S_2: Eh, it's because, eh, it's because, em, well it doesn't really sound very sciency=

W: =Uh-huh. ((W nods.))

S_2: It's more poetic=

W: =Yes. ((Some students laugh.))

S_2: But-em, but, but it's like tiny grain of size in it about, about how the Earth is spinning.

W: It's not about scientific=

S_2: =twilight. The twilight.

W: It's talking about <u>*twilight*</u>*.*

S_2: So that's what it is about.

W: It makes you think about twilight. ((W gazes at the student who posed this question.)) Dawn and dusk.

S_2: Wait, so because the Earth is spinning=

W: =Shhhh. ((W raises the post-it in her hand.)) You have this to write down your information, right?

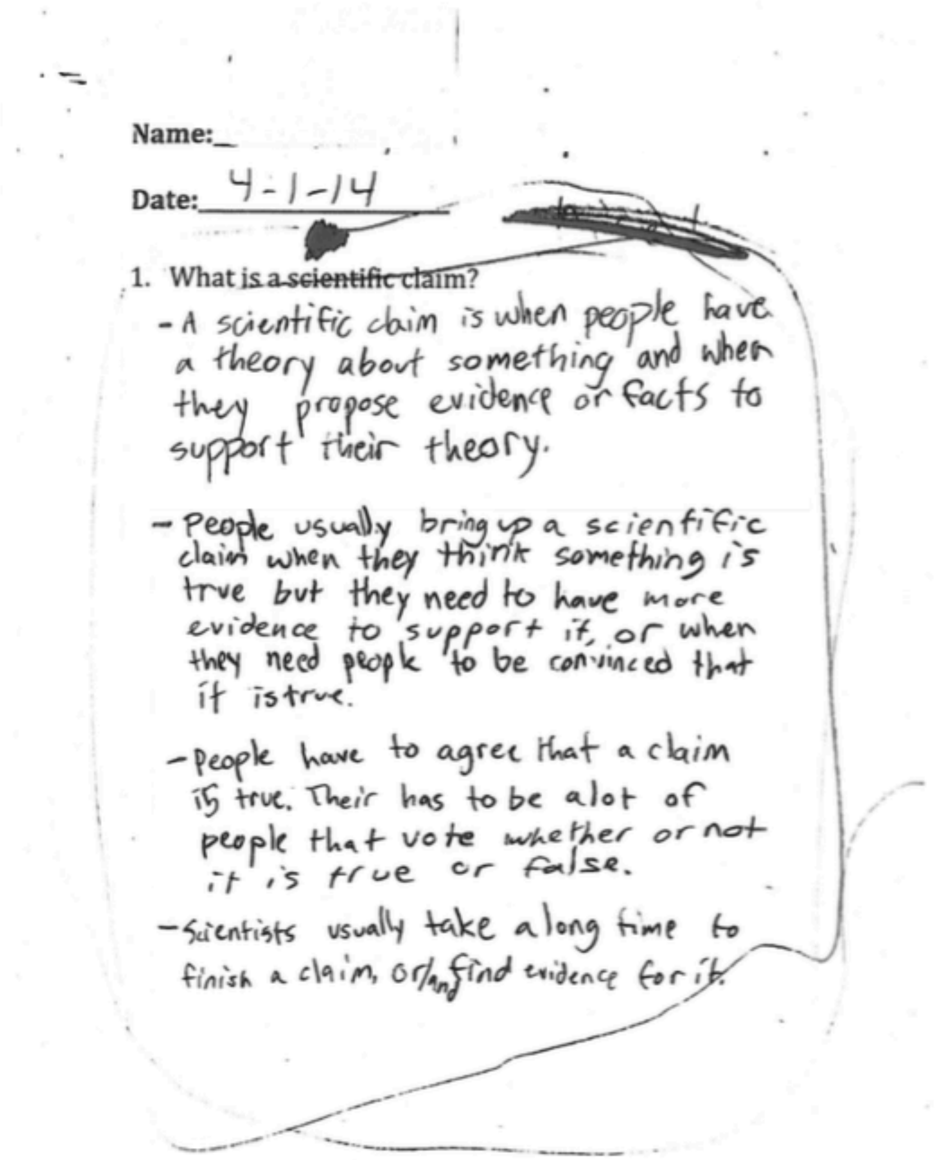
As shown in this transcript, a student was confused about why the book Ms. White just read to the whole class was about science. Indeed, it was a picture book organized around a poem about twilight. As S_2, another student, pointed out, this book was "more poetic." Ms. White aligned with him. S_2 continued to comment that there was a "tiny grain of size in it" about science, that is, "how the Earth is spinning." Ms. White confirmed that again. Eventually Ms. White concluded that this book made people "think about twilight" and, further, "dawn and dusk." It suggests that the teacher and students agreed upon the idea that this book was a potential resource for finding out information about the task they were going to carry on. Yet, this book was perceived as the only resource students could resort to when dealing with this task. Consequently, all of them came up with the claim that it was the Earth's revolving that caused dawn and dusk. Little argumentation, therefore, took place in the discussion.

Epistemic Claims. An example of limited resources for resolving epistemic claims is the claim 6th-grade students encountered about how to evaluate a claim. As shown in Table 2, after the introduction to astronomy in which students posed and organized their own questions, Ms. Hill told them that they were going to work individually on a project of poster presentation, and they should first have some basic understandings about what a good claim is. Mr. Hill thus posed an overarching question: "How to prove that a claim is accurate?" They worked collectively on this question for six days. The following episode shows how Ms. Hill framed the overarching question on April 1, the first day of their discussion.

> *((04/01/14 6th Afternoon Group))*
>
> *H: So, okay (1.0) today we're going to- I want you to (0.6) help me with something. The idea here is that I need to get some ideas from <u>you</u> (0.8) and you know often we do research here to look at what kids think (0.6) and so this is about what you think about something. (1.0) And the question is going to be- (2.0) could you sit here please? (1.0) The question is going to be what is a scientific claim. Now, I don't wanna hav- put your hand down (1.0) I don't wanna have a discussion here at the rug what I want you to do is you're gonna think about that question. (0.6) What is a scientific claim. (2.0) So what does it mean to you. And you're going to- you have to use complete sentences you can jot down your ideas (.) use bullet points but you're going to work alone. (0.8) I want <u>your</u> information, not your partner's. I want you to write down the things you think are important.*
>
> *((Several lines on classroom management omitted.))*
>
> *H: So you're gonna go work independently for a period of time. Then I'm gonna ask you (.) I'm gonna put you into groups (0.4) of three. You're gonna share with each other (0.6) and then we're gonna come <u>back</u> to the*

rug and you're gonna sit in your group on the rug (.) We're gonna go around and I wanna hear what different ideas you come up with (2.0) So, when we share ideas, it's gonna be really important that you're listening carefully (1.0) we're not gonna be judging people's ideas (1.0) we're just gonna be hearing their ideas (1.0) I'm gonna be jotting them down (.) and you're gonna be writing them somewhere as well. But- (.) what I want is that I want a- a discussion <u>not</u> the kind of discussion we talked about whether this is a good idea or not a good idea (.) this is a viable idea or whatever. It's about just sharing <u>all</u> the ideas we have (0.6) now if you hear somebody give your idea, do <u>not</u> bring that idea up (1.0) we're gonna try to write them down (.) they have to be different ideas (0.8) does that make sense.

In this episode, Ms. Hill framed the task as an individual work that did not involve any discussions with other peers. She also gave students a plan of what they were going to do for the next few days. Following this discussion, Ms. Hill asked students to write their ideas down on a worksheet, and collected them back at the end of the lesson. An example of student work on this worksheet is shown in Figure 5. On this worksheet, this student freely expressed his/her ideas about what a scientific claim is and how to decide whether a claim is scientific (e.g. "need to have more evidence to support it," "people have to agree").


Name:_

Date: 4-1-14

1. What is a scientific claim?

- A scientific claim is when people have a theory about something and when they propose evidence or facts to support their theory.
- People usually bring up a scientific claim when they think something is true but they need to have more evidence to support it, or when they need people to be convinced that it is true.
- People have to agree that a claim is true. Their has to be alot of people that vote whether or not it is true or false.
- Scientists usually take a long time to finish a claim, or/and find evidence for it.

Figure 5. Student work of the worksheet on “what is a scientific claim”

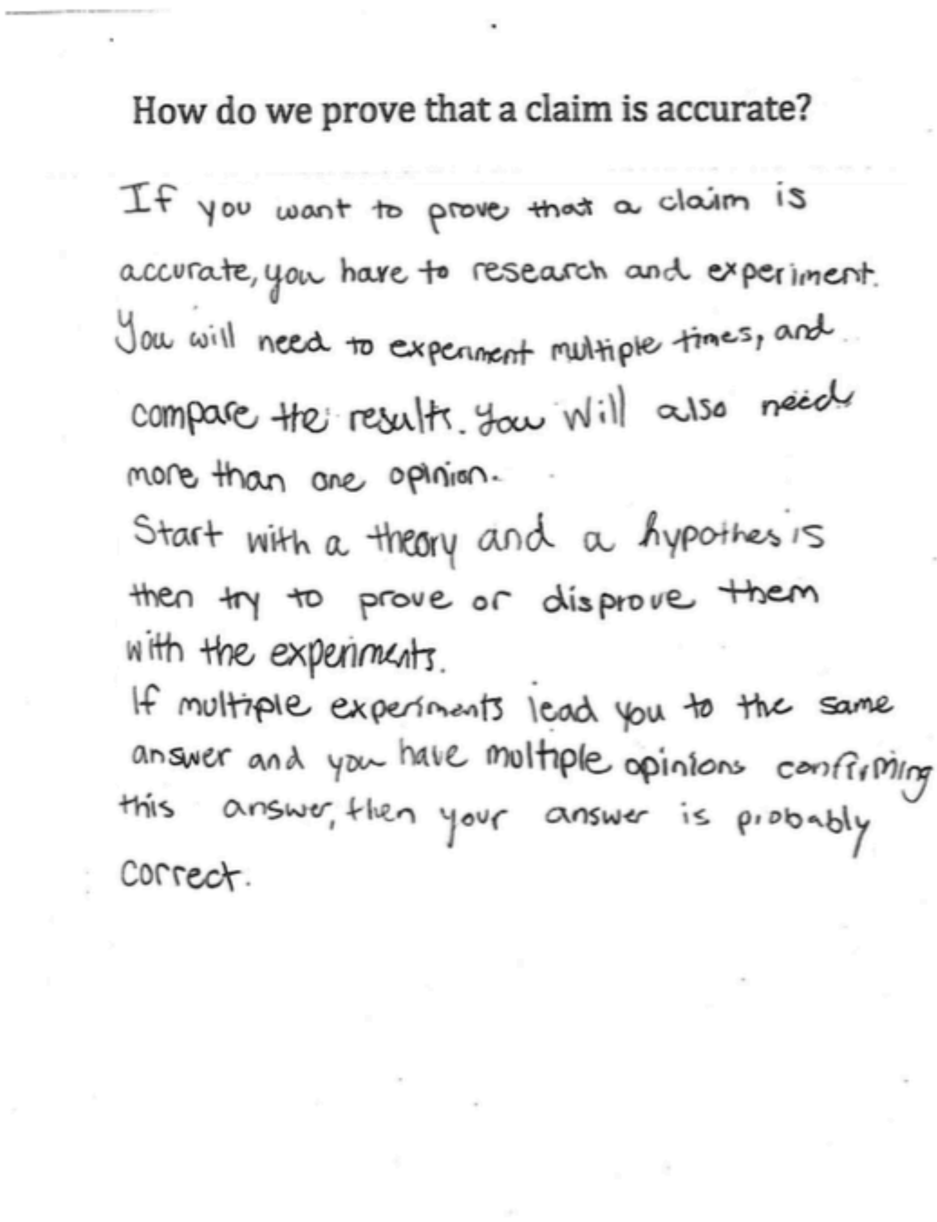
On November 3, Ms. Hill handed the worksheets back to students, and they had a discussion. The following episode shows how Ms. Hill started this discussion.

((04/01/14 6th Afternoon Group))

H: What I wanna do today is this (5.0) we’re actually going to look at (0.6) the definition of a claim. And my goal (2.0) today is to have you look *at what you wrote down. You're gonna take- take a moment to look at what you said and what the actual definition of a claim is. Now, what I want you to do on your paper is to circle parts that- that are part of a claim that I'm telling you. Now, I also put here a definition for a hypothesis, and a theory. So you had an idea of what that- what those words mean. Now I know you have an idea coz you're very smart people, and Sihan and I are very impressed with what you came up with the other day. So you're doing a great job.*

Then, Ms. Hill led a whole-class discussion in which students and the teacher went through the ideas they came up with the other day and talked about what a scientific claim, a hypothesis, and a theory meant. A great number of students' talk occurred in this discussion, as students provided their own ideas about those concepts. However, most of their talk was oriented to Ms. Hill, and there was little student-to-student conversation.

On April 7, Ms. Hill asked students to take back their own worksheet about what a scientific claim is and to think of how to prove a claim is accurate. Students were asked to write down their ideas. An example of student work is shown in Figure 6. This work is more specific than that in Figure 5 in the sense that the student here had more concrete ideas about how to decide whether a claim is accurate (e.g., "you have to research and experiment," "to experiment multiple times, and compare the results"). Note that students were not asked to back up these opinions with any sources of evidence.

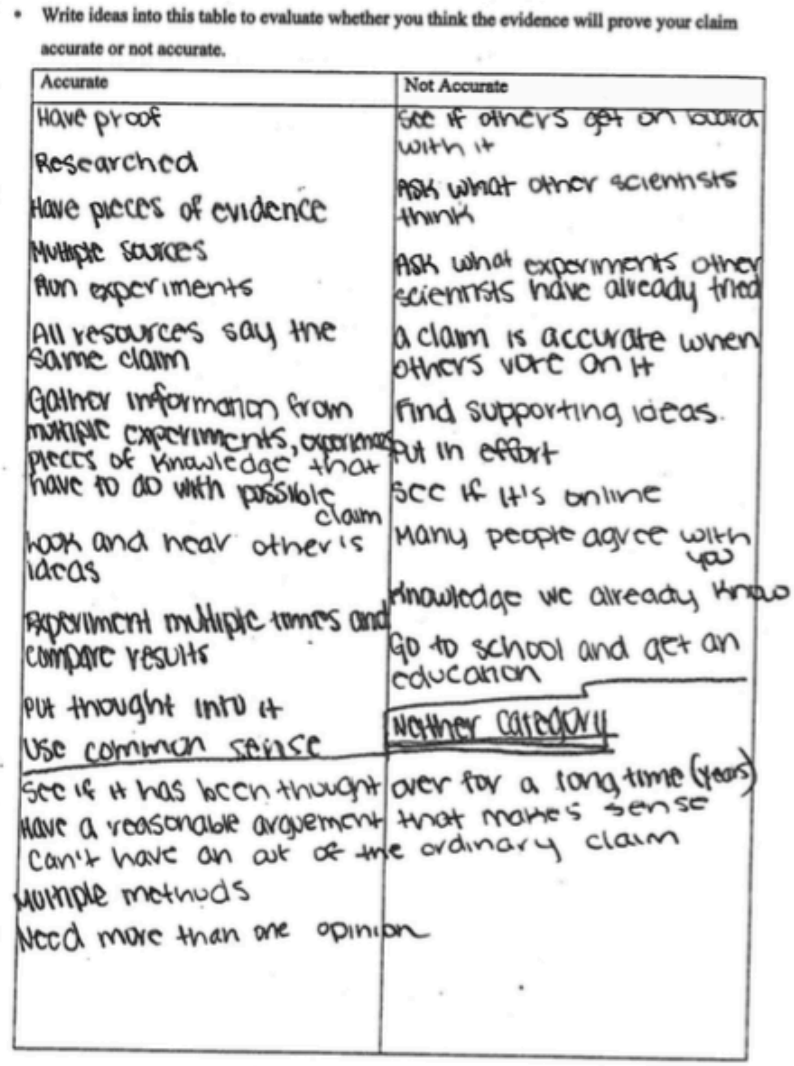


How do we prove that a claim is accurate?

If you want to prove that a claim is accurate, you have to research and experiment. You will need to experiment multiple times, and compare the results. You will also need more than one opinion.
Start with a theory and a hypothesis then try to prove or disprove them with the experiments.
If multiple experiments lead you to the same answer and you have multiple opinions confirming this answer, then your answer is probably correct.

Figure 6. Student work of the worksheet on how to prove a claim is accurate

Then, Ms. Hill asked students to strip off their ideas and sort them out in terms of degree of importance. Ms. Hill handed out another worksheet in which students were asked to list out their ideas of what could prove a claim is accurate and what could not. Figure 7 shows an example of student work on this worksheet.



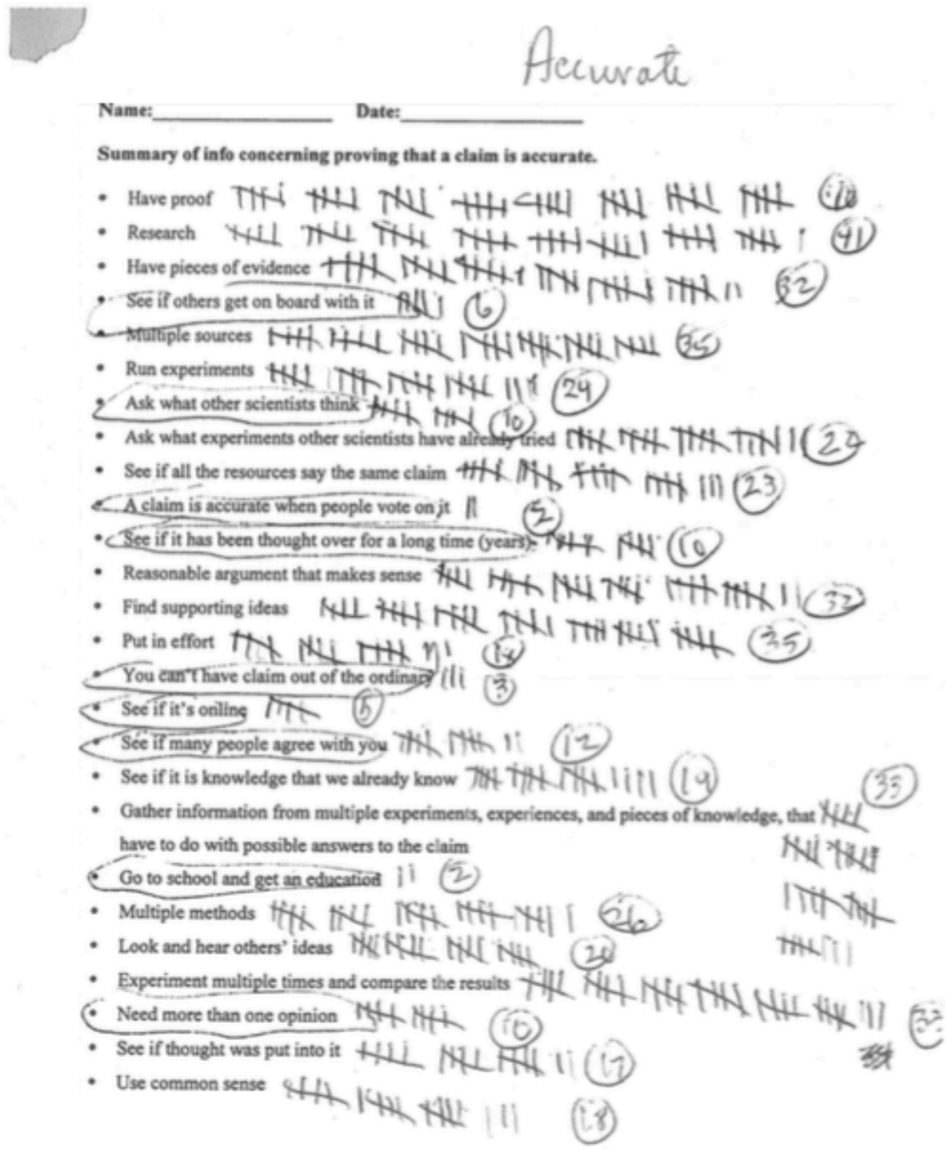
- **Write ideas into this table to evaluate whether you think the evidence will prove your claim accurate or not accurate.**

Accurate	Not Accurate
Have proof	See if others get on board with it
Researched	Ask what other scientists think
Have pieces of evidence	Ask what experiments other scientists have already tried
Multiple sources	A claim is accurate when others vote on it
Run experiments	Find supporting ideas.
All resources say the same claim	Put in effort
Gather information from multiple experiments, experiences, pieces of knowledge that have to do with possible claim	See if it's online
Look and hear other's ideas	Many people agree with you
Experiment multiple times and compare results	Knowledge we already know
Put thought into it	Go to school and get an education
Use common sense	Neither category

See if it has been thought over for a long time (years)
Have a reasonable arguement that makes sense
Can't have an out of the ordinary claim
Multiple methods
Need more than one opinion

Figure 7. Student work of the worksheet on accurate vs. not-accurate

At the end of the lesson, Ms. Hill collected those worksheets back, and worked with me to identify all the ordered criteria students came up with. We sorted out all of students' criteria again. Figure 8 shows our working table of frequency counts.



Accurate

Name:________________ Date:________________

Summary of info concerning proving that a claim is accurate.

- Have proof
- Research
- Have pieces of evidence
- See if others get on board with it
- Multiple sources
- Run experiments
- Ask what other scientists think
- Ask what experiments other scientists have already tried
- See if all the resources say the same claim
- A claim is accurate when people vote on it
- See if it has been thought over for a long time (years)
- Reasonable argument that makes sense
- Find supporting ideas
- Put in effort
- You can't have claim out of the ordinary
- See if it's online
- See if many people agree with you
- See if it is knowledge that we already know
- Gather information from multiple experiments, experiences, and pieces of knowledge, that have to do with possible answers to the claim
- Go to school and get an education
- Multiple methods
- Look and hear others' ideas
- Experiment multiple times and compare the results
- Need more than one opinion
- See if thought was put into it
- Use common sense

Figure 8. Working table of frequency counts that Ms. Hill and I generated

On April 8, Ms. Hill launched a discussion mediated by the list of ordered criteria we sorted out. The students talked about these ideas of how to prove a claim is accurate with regard to whether one particular criterion should stay in the "accurate" column or should be moved to the "inaccurate" column. The whole class continued this discussion till April 10, by which they had finalized a list of criteria on how to prove a claim is accurate, as shown in Figure 9.

- Room 5 Name__________________ Date:__________________
- Write ideas into this table to evaluate whether you think the evidence will prove your claim accurate or not accurate.

Help Prove(Accurate)	Not Help Prove (Not Accurate)h
• Research -Gather information from multiple methods and sources - experiments, experiences, and pieces of knowledge that have to do with possible answers to the claim • Have Proof /Evidence • Find supporting ideas • Experiment multiple times and compare the results • Reasonable argument that makes sense • See if most resources prove the same claim • Ask what experiments other scientists have already tried • Look and hear others' ideas • See if it is knowledge that we already know	• See if others get on board with it • Ask what other scientists think • A claim is accurate when people vote on it • See if it has been thought over for a long time (years) • You can't have claim out of the ordinary • See if it's online • See if many people agree with you • Go to school and get an education • Need more than one opinion • Put in effort • Use common sense • See if thought was put into it

Figure 9. Finalized list of how to prove a claim is accurate

Throughout a week of discussion on this problem, there were few epistemic resources the students could resort to. As illustrated in the procedure, although students moved from one worksheet to another, no new sources of information were added to their work. Most often, students relied on their prior knowledge about science and personal experience about what scientists do when thinking of this problem. For prior knowledge, they often used “I think” or “I feel” to assert a claim about what science or research is, as illustrated in the following example in which a student tried to move “using multiple methods” to not-accurate column because she asserted that it was the same as “gather information from multiple sources.”

((04/07/14 6th Morning Group))

S_1: Em, yeah, I think multiple methods (.) I agree with Lilly that it should move (.) like, gather information from multiple sources.

For personal experience, students often referred to someone they knew or something they’ve witnessed as evidence in making a claim, as shown in the following example in which a student was talking about how her father conducted research in order to assert that “doing experiments for multiple times and compare the results” is not a necessary way of proving a claim is accurate.

((04/07/14 6th Morning Group))

S_1: Well my dad is a political scientist.

H: Right. So when he does research, can you talk about what- (0.4) does he look at experiences.

S_1: Well, sort of.

H: Does he look at experiment thing. I mean, so, see if you can help us with that.

S_1: Eh, yeah, I guess he does. But the thing is, I feel like that <u>is</u> all part of research because, eh, he studies Russia, so he looks at like experiences

that were happened in Russia that (0.4) formed the nation. He looks at experiments happened in Russia and, wait-

H: So, so in fact, she's saying that her father actually works at experiences in Russia.

The student in this episode used her personal experience of observing how her father worked as a political scientist. The only epistemic resource she used was her own personal observations. It was thus not likely that other students were able to argue with her about how a political scientist worked. No one argued with her about how a political scientist could be generalized to scientists in other disciplines either due to a lack of epistemic resources at the same personal level. There was hence no argumentation among students about her assertion.

Closed Discourse for Contesting Claims

Disciplinary Claims. An example of closed discourse for contesting disciplinary claims is the claim, "why is the Sun so hot," that 6th-grade students encountered when Ms. Hill and I tried to explicitly teach students how to coordinate between claims and evidence in the astronomy unit. As aforementioned, Ms. Hill and I designed two questions that represented two types of claims: descriptive claims generated from "how hot is the Sun," and explanatory claims from "why is the Sun so hot." On April 29, Ms. Hill and I split the classroom into two groups. In one group, I guided a half of students to discuss "how hot is the Sun," while in the other group, Ms. Hill guided another half of students to discuss "why is the Sun so hot." The following episode shows how she framed the discussion.

((04/29/14 6th Afternoon Group))

H: Okay (.) so what we're gonna do is I want you to take notes on your sheet (0.6) you need to take notes from this on your sheet. So under evidence it says evidence (.) why is the Sun so hot (0.6) go to that spot that's where we're gonna write this down. Tim, give us one piece of evidence.

S_1: Well (.) [what I get is

H: [No I don't wan- no I want one piece that you understood (2.0) you're not giving that whole paragraph (2.0) one piece of it (.) why is the Sun so hot.

S_1: [Okay] the Sun is hot because of the nuclear radiation.

((H writes S1's response down on a poster attached to the whiteboard.))

S_2: So nuclear radiation because-

H: Ah you know (.) this is only gonna work if you just listen when people share their ideas because (1.0) e::h. ((H continues to write on the poster.))

It is clear from this excerpt that Ms. Hill framed the discussion as a sharing idea activity, in which the students gave their ideas about why the Sun is so hot without confronting each other's different information. Accordingly, students started to provide their own ideas with little argumentation among them. Ms. Hill collected and jotted their ideas down on the poster. Twenty minutes later, there were a handful of ideas on the poster, and Ms. Hill asked students to come up with a claim in their small groups. Then they came back to a whole-class discussion in which each group proposed their claim and Ms. Hill wrote them down on the whiteboard next to the poster. The following episode shows how Ms. Hill organized the discussion.

((04/29/14 6th Afternoon Group))

((A group just gave their claim; Ms. Hill wrote it down on the whiteboard.))

H: Eh (.) so (.) the Sun's heat is caused by nuclear fusion. What else (0.6) what else.

((A student points to the claim on the whiteboard and tends to say something.))

H: Wait- don't say anymore I want other people to- (.) what else, is caused by nuclear fusion what else. ((H points to another student.))

S_1*: Ah (1.6) like (.) the gravity pulls everything together, but- but- [but the*

H: [You don't have to explain it like that just put=

S_1*: =Gravity [pull*

H: [Okay.

((H writes "gravitational pull" down on the whiteboard.))

In this episode, Ms. Hill treated the whole-class discussion as a reporting activity through which each group reported the reasons for why the Sun is so hot that they came up with in small group discussions. Ms. Hill prevented students from arguing about others' ideas directly. Nor did she allow students to articulate their ideas. As a result, the whole-class discussion was just the same as the one that took place before the small group discussion. Little argumentation was elicited, and students did not interact with each other about their different opinions. The discussion lasted for about another 15 minutes, and ended the lesson. Also, as the discussion did not touch on means of knowing (e.g., "how do you know what you know"), and as Ms. Hill did not offer floors for student argumentation, the discussion became an activity of reporting and listing different ideas without an ultimate goal of reaching a consensus. Little argumentation was thus elicited from this discussion, and the classroom discourse was closed.

Epistemic Claims. An example of closed discourse for resolving epistemic claims is the claim 5th-grade students encountered in the astronomy unit when they learned about the phases of the Moon. On December 9, 2013, students finished discussion in groups, and were asked to report their findings in the whole-class setting. They came up, however, with slightly different information, and Ms. Miller tried to use it as an opportunity to open up a discussion on how to resolve different ideas. The following episode shows a complete whole-class discussion in which Mr. Miller (M) was guiding students to establish consensus as an end goal of seeking evidence for and arguing about the causal claim about the phases of the Moon.

((12/09/13 Afternoon Group))

M: All right so that brings us to the conundrum then. Because this is what scientists do, that brings us to the little conundrum if we don't all have the same information, what do we need to do?

SS: ((Concurrent responses.))

T: What do we need to do?

S_1: Look at our notes to see who has the most accurate…

M: So maybe it's not just looking at your notes. What else can you do? Because you're in a group situation now, so what else you need to do?

S_1: We could em…em…

M: Coz if you all look at your notes, and will you necessarily all come up with the same thing? Just by looking at your notes?

S_1: Not all…

M: Nah… Could… Chances are probably not, okay? Coz you're all have different interpretations. So what could you be doing?

S_2: ((Something about looking at a book.))

M: But again, same thing is going to happen. It's just another form of looking at your notes. You're in a group situation here now, coz we have all these various versions here. What do we need to do?

S_3: Making claims…

M: So how are we going to do that?

S_3: ((Something like finding and collecting evidence.))

M: All right, so what is that process called then? What are you going to do as a group, then you have to do what?

S_4: Eh, you have to look and compare the notes or something…

M: Yeah, but what are you trying, what is the end goal you have to do after you compare all those notes.

S_5: Eh…I think first of all we'll have to eliminate things that are not true…

M: Absolutely, that's one of the steps of the process. What's the whole process though that you're going to be doing?

S_6: …Comparison…Eh, as someone says something like…someone has the evidence that you both have, and make their evidence stronger, then em,

then yeah, then turn yours over, coz their evidence is stronger,

((something inaudible about facts.))

M: So what are you trying to do then, what's your end goal as you're shifting through who got more accurate evidence? What are you trying to end up with?

S_7: To determine one of them is better than the others?

M: And how are you going to do that?

S_7: Eh, like…comparing?

M: Well you're going to do some comparing yes. What else do you also have to do with the group to reach that decision of who has the most scientifically accurate relevant information.

S_8: Pick one…

M: Yeah, but what do you, what does the group have to do in order to be able to pick one, yes?

S_9: Discuss?

M: You do have to discuss, that's one of the steps in the process. But what is that end game called?

S_{10}: Compromise?

M: You have to compromise! That's right. You have to compromise. You have to come to a con-?

SS: -clusion!

M: Consensus! You already come to a conclusion.

((SS laugh.))

In this episode, the community faced a "conundrum" of having to choose between different information to determine the most accurate. Although the questions Mr. Miller used were open-ended (e.g. "What do we need to do?" "How are you going to do that?"), the I-R-E sequence prevalent in the talk shaped the discussion into finding a known, correct answer, which is the epistemic culture of a typical classroom. For example, when S_7 said they could compare to determine if one of the claims is better than the others, it was not clear what aspects of a claim S_7 thought were worth being compared, which might lead to a discussion about the means of knowing. Yet instead of building upon this idea and eliciting more of S_7's ideas, Mr. Miller gave an instant feedback ("you're going to do some comparing yes"), and immediately asked for a different answer ("what else do you also have to do"). The conversation that followed indicates that Mr. Miller was looking for the known answer of "consensus," rather than trying to co-construct a shared norm of evaluating information. More importantly, these students' short, question-like responses (e.g., S_7, S_9, S_{10}'s responses) imply that they knew Mr. Miller had an existing, preferred answer. Consequently, the discourse was closed, and contestation of different claims among students themselves hardly took place.

Summary

In this section, I describe what classroom instruction looked like throughout the school year, focusing particularly on the claims students encountered or the questions for which they were asked to make claims. Three interrelated patterns were revealed in my analysis. First, the contestability of the claims students encountered were low, meaning that they were not framed in arguable ways. Second, the resources available to students for resolving these claims were limited. Third, the classroom discourse, through which these claims were discussed, contested, or resolved, was not open enough for productive argumentation. These patterns may potentially account for the lack of change in students' use of inscriptions in their written arguments described in the previous section.

CHAPTER 5

DISCUSSION

This study explores what inscriptions elementary students use as evidence in their written arguments in which they justify their decisions they make about a socioscientific issue, how they use inscriptions in their arguments, and how science instruction may play a role in that use.

This chapter is organized in two sections. The first section focuses on the use of inscriptions in students' written arguments. I discuss the potential evidentiary values of photos and drawings in the arguments and what this means to everyday encounter with science. I then address the importance of differentiating two types of cognitive endeavors: justification of decisions versus evaluation of scientific explanations. I also discuss why and how school science could be responsive to such differentiation by linking the two. The second section turns to findings of classroom instruction. I first address the need for designing contestable claims about which students could legitimately argue in the classroom and the importance of providing relevant resources. I then address an ongoing agenda in science education to organize classroom discourse that promotes productive argumentation with evidence.

Use of Inscriptions in Written Arguments

The Potential Evidentiary Values of Photos and Drawings

Elementary students in this study had a strong preference of citing photos and drawings as evidence over other types of inscriptions. It suggests that they may see photos and drawings as having at least as much evidentiary strength as diagrams and tables, which may be seen as more traditional scientific evidence. This raises an important question: to what extent and under what circumstances can photos and drawings be treated as evidence?

Photos and drawings as evidence have long been well justified in sociology of knowledge, anthropology, and educational research (e.g., C. Goodwin, 1994; Latour & Woolgar, 1979; Pozzer-Ardenghi & Roth, 2010). Lynch (1988), in particular, discussed the juxtapositional relationship between photos and diagrams and viewed the latter as “a schematic representation of what can be seen” in the former (p. 208), suggesting it is not that photos are non-scientific, but just that they are raw data that need to be transformed, translated, or superimposed upon (Latour, 1990). Likewise, drawings could be seen as a form of graphic representations and, moreover, a conscious selection and amplification, of the real world (Latour, 1999; Lehrer & Schauble, 2012). Scientists use photos and drawings as evidence throughout the processes of making them, reproducing them, and negotiating meanings about them. In science classrooms, discussions about the meanings of photos and drawings can lead to productive learning (e.g., Enyedy, 2005; Medina & Suthers, 2013; Schwarz, Schur, Pensso, & Tayer, 2011).

This study has a fundamental difference from these previous studies in that it focuses on the evaluation of given evidence, rather than the production of new evidence. What then distinguishes the use of evidence here is that students did not have the opportunity to discuss, negotiate, or argue about the meaning of a photo or a drawing with peers as scientists usually do. More specifically, when students encounter a photo of, for example, coal-burning power plants in Ukraine that emit black smoke into the air, they hardly open up discussions about what it means with others but credit or discount its facial meaning (i.e. Coal-burning power plants pollute the air) in its full sense. In this sense, photos become both an uncontestable claim itself and the evidence for this claim.

From a descriptive perspective of public engagement with science (Feinstein, 2011), I argue that there is nothing wrong with using photos and drawings as evidence. First, photos and drawings are more closely related to the reality they represent than diagrams and tables (Pozzer & Roth, 2003). As the aim of carrying out the task was to recruit some kind of science to justify a decision, they may very well meet it. Photos, the most frequently cited, are especially useful because they "passes for incontrovertible proof that a given thing happened" and thus have "a more innocent, and therefore more accurate, relation to visible reality than do other mimetic objects" (Sontag, 2001, pp. 5–6). Moreover, when students learned science during the school year, they often faced photos and drawings that teachers provided in the classroom (e.g., the picture books about food chain, the drawings of the phases of the Moon). It is then not surprising that they tended to use them in their arguments.

Critical here, remarkably, is not whether photos and drawings should be used, but what support school science could provide for students to critically think of the evidentiary strengths and limits of photos and drawings and, more importantly, encourage them to negotiate and argue about the use of photos and drawings in the classroom. And to argue further, photos and drawings, like other types of inscriptions, do not intrinsically have evidentiary power. Due to their nature of raw data, moreover, it is arguable that these two types of inscriptions are not as saliently linked to a claim as diagrams and tables. Thus, school science should guide students to consider how a certain inscription could possibly be used in relation to making a particular claim, which is regarding the rhetorical reference to inscriptions as discussed in the next section.

Justifications of Decisions vs. Scientific Explanations

Another finding of the written arguments is that students tended to merely point to an inscription without any further articulation. In line with Sandoval and Millwood (2005), there are three possible explanations. From a normative standpoint, it may be the case that elementary students' ability to argue with evidence is limited, and pointing is the simplest way of using an inscription in an argument. Highlighting, in contrast, requires that students not only understand specific information within an inscription but also know how to articulate its relation to a claim, and it may be just difficult for students of this age. Yet it may also be the case that students see the inscriptions I provided as self-evident, without need to further describe them or interpret their meanings. Or, alternatively, students may find it unnecessary to describe or further articulate the relevance of an inscription because "they may not have perceived a rhetorically relevant audience for their work" (Sandoval & Millwood, 2005, p. 49). That is, as the written argument task was framed as a school-based, paper-and-pencil task, students may have perceived the goal of doing it as finding the right answer and showing it to the teacher. If this is the case, students' job was to find out an inscription or a set of inscriptions that matches the decision they made, and as the teacher (or me as the researcher who administered the task) knew the right answer beforehand, it was not necessary then to interpret the specifics of inscriptions or how they could serve as evidence in an argument.

I align more with the third explanation, and argue that the framing of the tasks greatly matters in how to interpret the results. One of the reasons is that, in my study, students also tended to assert that an inscription “shows” a claim without explicating how. Assertions were the second frequent way of referring to an inscription as shown in the results. This result is inconsistent with Sandoval and Millwood’s (2005) study, in which assertions did not stand out as a heavily used way of reference. To interpret this, one should first keep in mind the difference between tasks in the two studies. In Sandoval and Millwood’s (2005) study, the aim of the written argument task was to construct a scientific explanation about complex phenomena such as natural selection. In my study, on the other hand, the aim was to justify a decision about everyday life. To justify an already-made decision, one may recruit science in his or her arguments not because of the factual base it provides, but because of its value-laden aspects, such as the objectification of the natural world (Lemke, 1990). In other words, students may co-opt science in their arguments to rhetorically persuade the audience, or to reframe the focus of the focal issue against the opponent (Nielsen, 2012b, 2012c). In these cases, even though the arguments may not necessarily be scientific, they are functional.

In terms of the written argument tasks administered in my study in particular, I explicitly framed the aim of these tasks, as stated in the instruction and the questions, as making and justifying a personal decision. Further, as I administered the tasks in students’ regular classroom setting with their teachers’ presence, it is likely that they perceived the tasks as normally school-based. Consequently, students may neither feel obliged to describe the content of a cited inscription to a distant audience nor perceive the need to explain how the inscription is related to a particular claim. What students needed to do was simply to recruit an inscription in their arguments by either including it in the texts (i.e. pointing) or claiming its role as evidence in its own terms (i.e. assertion).

This situation mirrors the classroom instruction these students experienced. In the lessons I described in the previous chapter, students encountered scientific claims that described or explained the natural world (e.g., what causes dawn and dusk, how hot is the Sun). What they needed to do was to construct or evaluate scientific explanations, instead of justifying a decision. The activities in which students participated, moreover, were school-based tasks: they got a claim that had already been made, and were asked to seek proof for it; or they were faced with a question for which they knew there was a right answer, and were asked to find it (i.e., to make *the* claim about that question). Their performance in the written tasks and in the classroom tasks was thus consistent: to show the teacher an answer without a need to articulate its relation to the question.

Linking Explanations to Decisions

The differentiation between scientific explanations and justifications of decisions raises a significant issue for science education. Although constructing scientific explanations and making arguments about complex phenomena of the natural world have become a focus in the science classroom, students rarely engage in justifications of decisions. As Berland and Reiser (2009) pointed out, students consistently use evidence to make sense of scientific phenomena and articulate their understandings, yet not to persuade others of their understandings. Persuasion and justification are both social activities that entail not just empirical but also rhetorical use of evidence. School science does not emphasize this. And, even when school science does emphasize justification, as enacted in some recent studies (Christodoulou & Osborne, 2014; Ryu & Sandoval, 2012), it was justification of scientific claims and their explanations, not of socioscientific decisions.

The results of unchanged use of inscriptional evidence before and after science instruction geared towards coordination between claims and evidence require explanations. The most obvious explanation may be that students were simply doing two different tasks in the tasks and in the science instruction: justifying a decision in the former, and evaluating scientific claims and constructing scientific explanations in the latter. Further, while students learned about science like astronomy and energy in the classroom, they encountered socioscientific issues like GMOs in the tasks. The lack of social aspects in both the form and the content of classroom activities may result in the stability of students' use of evidence in the tasks.

My study thus highlights the need for school science to link scientific explanations to justifying socioscientific decisions. As NGSS expects that students be able to critically consume scientific information when they leave schools, school science is obliged to explore ways to reframe science in the classroom for its everyday usefulness. Although we always hope that students use science to make everyday decisions, I do not argue that there should be a normative expectation that people ought to rely *only* on science to make decisions. As competent outsiders, people well educated in science should be able to identify and make use of scientific information when relevant (Feinstein, 2011). I further argue that relevant scientific knowledge may underlie socioscientific decision-making, and we should expect students to take that into account, even if their ultimate decisions are not scientific. Understanding how scientific knowledge can be brought to bear when thinking about SSI may help students make more informed decisions in their everyday life. School science should thus explicitly link scientific explanations to socioscientific decision-making, and help students identify the relevance of science not just in explaining phenomena, but also in solving everyday problems.

Epistemic Culture and Learning Environment

This study analyzes a school year of science instruction in the classroom. During this year, I worked closely with the three science teachers on seeking teaching materials, designing learning activities, and most importantly, ways of organizing classroom discourse in order to promote argumentation. From the analysis on the written argument tasks, our collective work did not yield differences from the pre- to the post-task.

It should first be noted clearly that I do not intend to draw causal relations from classroom interactions to the results of written tasks. I argue, nonetheless, that how students interacted with the teachers and among themselves in the science classroom played a role, from a perspective of causal processes (Maxwell, 2004), in how they use inscriptions as evidence in their written arguments, which is mediated by how they participated in the epistemic culture (Knorr-Cetina, 1999; Ryu & Sandoval, 2012).

Claim Contestability and Resource Availability

This study analyzes all the major claims students encountered in the classroom in a school year of science instruction. Two types of claims were identified: disciplinary claims were regarding scientific facts per se, while epistemic claims regarding what counts as reliable knowledge or evidence. As shown in the previous chapter, these claims, be it disciplinary or epistemic, were not contestable in that the involved knowledge was fixed, and the discussions were framed by teachers as either finding the right answer or reporting on different ideas without a need to reach a consensus.

Previous studies have argued that claim contestability matters in how students perceive learning science and what resources they could make use of (e.g., Radinsky, 2008; Watson, Swain, & McRobbie, 2004). Reviewing relevant literature, Manz (2014) frames argumentation as a process of "participation in contesting and stabilizing both what is known and how it is known" (p. 21). Manz further proposes that we should support teachers to recognize and frame "productive moments of uncertainty" (p. 28). This study confirms this view. Without such uncertainty, it is not quite likely that students would confront conflicting ideas and argue about them.

With this being said, though, what does a contestable claim for elementary students look like exactly? Research has argued that the introduction of SSIs is an effective way of problematizing science content and opening up opportunities for argumentation (for relevant reviews, see Cavagnetto, 2010; Sadler, 2009). Although this study did not use SSIs as a source of target ideas during instruction, the results in the written tasks show that SSIs are not necessarily effective in eliciting a range of disagreements. For example, few students in the GMO task chose to eat GMOs or to support the GMO industry. This was the case perhaps because, as previously discussed, it was framed as a justification of decisions without rhetorically relevant audience. In the classroom, on the other hand, discussions about GMOs may potentially be productive because it could be framed in different ways, as illustrated in previous studies (Albe, 2008; Ekborg, 2008; Nicolaidou, Kyza, Terzian, Hadjichambis, & Kafouris, 2011). Most of these studies, however, took place in upper secondary levels. Future research should thus discuss what specific SSIs are suitable in different levels of science education.

Productive moments of uncertainty created by presenting contestable claims are not enough—it is not easy also to envision how elementary school science could support contests in these moments in order to make them “productive.” In the 6th-grade classroom in this study, for example, the two claims about epistemic standards were potentially contestable in that they were not regarding factual knowledge, and there was not a fixed and singular standard of evaluating claims and evidence. Yet, there was still little argumentation among students in the discussions. A major reason here was that students did not have enough epistemic resources. In a week of discussions about how to prove a claim is accurate, students hardly used resources outside of their prior understandings about science. As a result, not only was the process of reaching a consensus difficult, but the outcome of that consensus (i.e., the final worksheet about claim evaluation) also was not aptly shared and used in the group activities that followed. Science educators and researchers have reported on a lack of relevant resources in teaching SSIs (e.g., Cross & Price, 1996; E. G. Pedretti, Bencze, Hewitt, Romkey, & Jivraj, 2006; Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006). This study extends this point and highlights a need to coordinate between contestable claims and relevant epistemic resources.

Further, if we agree that school science should provide students with a variety of epistemic resources in order to support their argumentation about not just what is known but also about how it is known and about how a socioscientific decision is made and could be justified, what kinds of epistemic resources could there be? This is an open question to which this study does not provide a solid answer. Yet within an overall frame of public engagement with science, this study addresses the importance of understanding children's ideas of what counts as evidence. As science knowledge is inevitably subordinate in socioscientific issues (Nielsen, 2012c), it is critical to develop detailed accounts of how children make sense of what resources in their daily life count as "scientific" and what do not. School science, accordingly, should provide a repertoire of resources available to students and help them identify what is relevant to their own everyday judgments and decisions.

Opening Up and Substantiating Classroom Discourse

Analysis on classroom discourse in this study opens up another line of discussion. The initial rationale for working with teachers on organizing classroom talk was that as teachers constantly press for norms such as reaching a consensus, convincing each other, using evidence in support claims, students would appropriate them in collective argumentative discourse as well as in individual argument making (see Ryu & Sandoval, 2012). As I did not find significant differences in the written argument tasks at the individual student level, how classroom discourse was actually organized in the school year of science instruction opens an interpretive window into the causal processes.

As shown in the previous chapter, the classroom discourse was nearly closed, be it about disciplinary or epistemic claims. The closed nature has two meanings here. First, it means that the discourse was not open to argumentation. In the discussion on "why is the Sun so hot," for example, Ms. Hill explicitly stopped students from elaborating on their ideas and commenting on those of others. The discussion thus became a reporting activity without an ultimate goal of reaching a consensus. In Mr. Miller's epistemic talk, although there seemed to be a conclusive consensus at the end, it is salient that he was waiting for a preferred answer. Students perceived the aim of talk the same way, instead of feeling a need to legitimately argue for their proposed solutions (or against others' proposals). As the discussions were framed as a school-based task, it is not surprising that students did not have opportunities or feel encouraged to argue with each other.

Second, the discourse was closed in the sense that discussions on epistemic claims were greatly delimited from those on disciplinary claims and from subsequent activities of learning. Epistemic talk, important for developing shared means of knowing as it was, thus became too abstract to be usable in students' individual or collective learning. The set of discussions on how to prove a claim is accurate in Ms. Hill's classroom, for example, was not embedded in evaluating or making claims about substantive science knowledge, such as the temperature of the Sun. Nor were they explicitly connected to students' individual work on their projects that followed the discussions. In consequence, although students did have a wide range of ideas about how to evaluate a claim, they talked about them in a rather abstract and distant way, and they rarely touched on them since the epistemic discussions ended.

This study thus joins the ongoing agenda on promoting argumentation in science education. These findings suggest that argumentation can hardly be promoted without some goal that stretches beyond arguing per se. Reaching a consensus or convincing a peer, to name but two options, has to be a legitimate and consistent goal that is shared within the learning community (Berland & Lee, 2012; Kolstø, 2000; cf. Garcia-Mila, Gilabert, Erduran, & Felton, 2013). This study also confirms, nonetheless, that there is a tension between these goals and more traditional goals of individual sensemaking and learning (Berland & Reiser, 2011; Jiménez-Aleixandre et al., 2000). That is, even when teachers explicitly teach students to argue and emphasize the social aspects of argumentation, it is likely that students would take it up as a school-based task of learning knowledge and performing skills. This tension thus challenges us to explore how argumentation, as a new form of discourse set in the classroom, is related to other goals.

Further, discourse about epistemic understanding and practices should always be embedded in substantive topics of science, as in the discussion about "backing up your claim" and "providing justification" in Ryu and Sandoval's (2012) study, which was embedded in inquiries about magnetism and electricity. If it is too abstract, students may not find it useful in their learning. As NGSS proposes 8 scientific and engineering practices (e.g., developing models, planning investigations, interpreting data) and assumes that these practices are integrated with crosscutting concepts and disciplinary core ideas (NRC, 2011), this study urges us to consider ways of organizing science teaching to meet the expectations. Argumentation, if taken up within a cohesive framework of legitimately contesting and stabilizing what we know and how we know it, could be a connective discourse that draws scientific practices, domain-specific knowledge, and relevant resources like inscriptions, together (Sandoval, Xiao, Redman, & Enyedy, 2015). The integrative framing and organization of school science could help students identify science as relevant and useful in their everyday life.

Limitations and Future Directions

This study has several limitations that call for future research. First, I presented the written argument tasks in a particular way: Students were asked to make a decision first, and then use given inscriptions as evidence to support that decision. This raises a question of whether such frame primed students to justify an "existing" decision rather than to make sense of available evidence first, which may then affect how they organize their arguments. Future research that manipulates different ways of framing the task may be productive in understanding students' rhetorical aims and their performances.

Second, the analyses of the written arguments reflected my biased perspective of what was important. In accord with my research questions, I only examined students' use of inscriptions, and ignored other aspects of their arguments. Although I did not find significant changes between the pre- and post-tasks, a more comprehensive and nuanced look into the written arguments may reveal new findings of theoretical importance. For example, I discussed that students might merely point to an inscription or assert that it shows a claim without further articulation because they did not perceive a rhetorically relevant audience for which they needed to make articulations, but I did not analyze how they attended to potential audiences in their arguments (e.g., using "you"), as certain linguistic markers may reveal students' "recipient design" and further, their rhetorical aims (Sacks et al., 1974). A normative lens into coding these data, such as the validity of inference (Kuhn et al., 1995; Schauble, 1996), may also provide different and analytically meaningful measures of students' written arguments.

In terms of classroom instruction, my collaborative work with the three science teachers could be viewed as a "weak intervention." Although I tried hard to communicate with them with regard to what to bring to the lessons and how to organize the discussions, there were so many factors beyond my control that affected their teaching in a day-to-day manner. The teachers, on the other hand, also tried hard to explore novel ways of teaching to meet NGSS with a lack of key resources (e.g., curriculum materials, teaching manuals, formative assessment tools). Consequently, they did not always enact what we planned or designed to do in the classroom. It is thus difficult to discern the causal links between classroom instruction and students' performance of written arguments. For example, even though I argue that the task difference (i.e., justifying socioscientific decisions vs. constructing scientific explanations) accounted for students' unchanged performance from pre to post, it may as well be the case that more productive learning that aims at scientific explanations could facilitate students' justification of decisions regardless of the task difference. My current analysis did not discern these two potential reasons. Future research could implement a more systematic and "stronger" design approach to examine how various aspects of instruction affect students' understanding and use of evidence in argumentation about socioscientific issues.

APPENDICES

A. Energy Task

When you grow up, there will be many times when you will asked to make a decision about something that matters to you or to your community. In these situations, you will be asked to consider many different sources of information and ideas. The following paragraph describes such a situation. Please read the paragraph below and answer the question that follows. Like many real-life situations, there is no single, clear right or wrong answer. Instead, you try to come to the best decision you can, based on the information you have.

Choosing a Power Plant

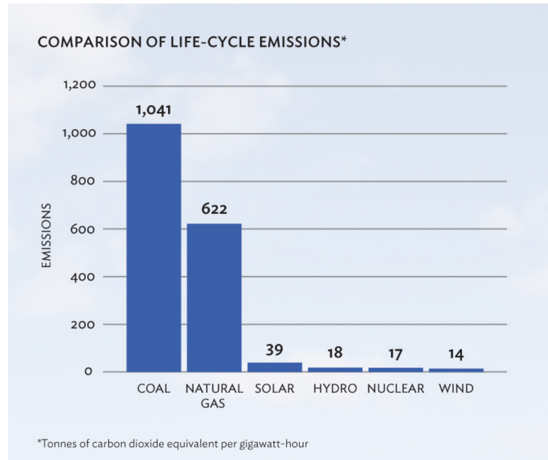
Triveca is a large city (about the size of San Diego) located next to the Gray Mountains. This city receives all of its electricity from a coal-burning power plant. Some citizens emphasize that burning coal is relatively inexpensive and safe, while nuclear power plant produces radioactive waste and has risk of accidents. Some other citizens, however, argue that a nuclear plant would supply all the needed energy and eliminate all of the coal-burning air pollution. A group of scientists are debating on this problem as well, but they are in disagreement on several major technical issues.

If you lived in this city, which type of power plant would you vote for? Explain why you would vote this way as fully as you can. Use as many of the images on the following pages as you think will help you make the best case possible for your position. Be sure to write down the number of an image when you use it, and say how each image you use is related to your argument.

Your Decision: (Which type of power plant would you vote for?)

Your argument: (Why do you make that decision? How would you argue for it?)

1. Advertisement about coal-burning power



2. CO_2 emissions of different energy uses

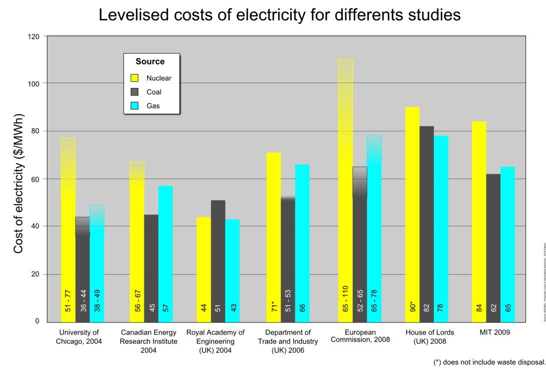
Table 1 | **Health consequences of the Chernobyl accident in the first 15 years**

Cause	Condition	Morbidity	Mortality
Whole-body irradiation	Acute radiation sickness Delayed consequences (for example, myleodysplasia)	134 ?	28 3–11
Fallout	Thyroid cancer Other cancers	~2000 in those exposed as children No evidence of significant increase; needs study	10–20
Fear; social consequences of response to accident (for example, forced relocation, job loss)	Environmental stress disorder	Uncertain, but large	Contributory factor to an increased mortality (for example, through increased smoking and alcoholism)

3. Health consequences of the Chernobyl nuclear accident in the first 15 years

4. Advertisement about nuclear power

5. Working coal-burning power plants in Burshtyn, Ukraine



6. Costs of electricity in different studies by different power sources
(yellow = nuclear; black = coal; blue = gas)

Table 3. Contributions of Coal-Fired Power Plants to Selected Hazardous Air Pollutant Emissions

Hazardous Air Pollutant	Percentage of Point Source Emissions
Acid Gases (hydrochloric acid and hydrofluoric acid)	76%
Arsenic	60%
Beryllium	28%
Cadmium	30%
Chromium	20%
Cobalt	34%
Lead	15%
Manganese	11%
Mercury	46%
All Non-Mercury Metal HAPs Emitted by Coal-Fired Power Plants	25%

Data obtained from USEPA, 2007

7. Influence of Coal-fired power plants on different air pollutant emissions

8. The 2011 earthquake in Japan caused nuclear reactor explosions.

B. GMO Task

When you grow up, there will be many times when you will asked to make a decision about something that matters to you or to your community. In these situations, you will be asked to consider many different sources of information and ideas. The following paragraph describes such a situation. Please read the paragraph below and answer the question that follows. Like many real-life situations, there is no single, clear right or wrong answer. Instead, you try to come to the best decision you can, based on the information you have.

Genetically Modified Organisms (GMOs)

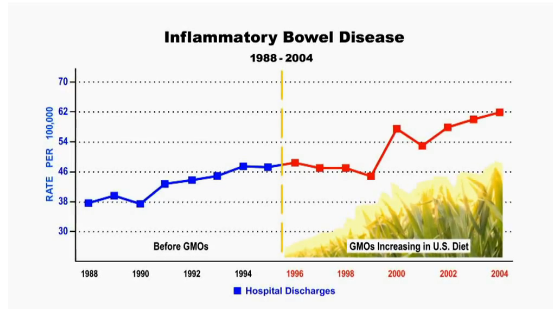
All living things are made up of cells, and inside every cell are bits of stuff called genes. Genes are the code that tells living things how to grow and how to function. Scientists have learned how to change the genes in some plants, and this way they can change how the plants grow. Living things that have had their genes changed are called "genetically modified organisms" or GMOs, for short. Some people say that growing GMO crops, like corn, can help more crops grow by making them more resistant to pests, disease, or severe weather. They also say it might help people by getting rid of genes that cause food allergies. Other people, though, say there are risks to the environment from GMOs, since GMOs can invade areas where wild plants grow, or they might breed with wild plants and change them in unexpected ways. Both of these problems might threaten biodiversity by destroying wild plants. These people also suggest that new genes put into GMOs might cause new, unexpected allergic reactions in some people. There is no clear agreement among scientists about whether or not we should grow GMO food crops.

Will you buy GMO foods on a regular basis? Explain why you would decide this way as fully as you can. Use as many of the images on the following pages as you think will help you make the best case possible for your position. Be sure to write down the number of an image when you use it, and say how each image you use is related to your argument.

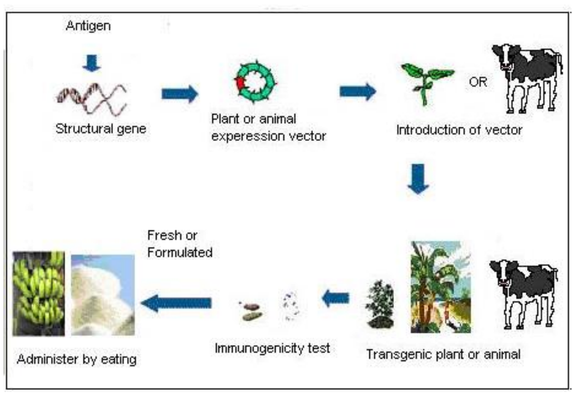
Your Decision: (*Will you buy GMO foods on a regular basis?)*

Your argument: (Why do you make that decision? How would you argue for it?)

1. Non-engineered tomatoes suffering from blossom end rot.



2. The rates of inflammatory bowel disease, which causes many chronic diseases, have been increasing drastically since GMO was introduced to public.



3. Strategy model for production of genetically-modified edible vaccines

4. A little girl holds up a sign during a protest against GMO business in Los Angeles.

5. FDA approves the first genetically-modified flu vaccine

Table 8: Seed contamination in U.S.: contaminated seed samples/samples analysed

	maize	soybean	canola
analyser organisation-A	3/6	3/6	6/6
analyser organisation- B	5/6	5/6	5/6
TOTAL	8/12	8/12	11/12

source: Bulletin of UCS, 23 Feb. 2004

6. Genetically modified seed contamination in the U.S.

Country	Total GM Crop Farm Income Benefits, 1996–2008, in Millions of U.S. Dollars	Average Yield Increase of GM Crops	
		Corn	*Cotton*
United States	$23,268.7	5%	9.6%
Argentina	$9,227.3	7.8%	28.6%
China	$7,599.0	n/a	9.5%
India	$5,142.0	n/a	54.8%
Brazil	$2,820.6	n/a	6.2%
Canada	$2,070.5	5%	n/a
South Africa	$506.9	15.3%	24.3%
Paraguay	$503.2	n/a	n/a
Australia	$224.1	n/a	n/a
Mexico	$91.1	n/a	11.8%
Philippines	$88.3	24.1%	n/a
Bolivia	$83.4	n/a	n/a
Spain	$77.0	7.4%	n/a
Uruguay	$53.3	6.3%	n/a
Romania	$44.9	n/a	n/a
Colombia	$13.9	n/a	5.7%

Sources: PG Economics, "Focus on Yields," October 2009, at *http://www.pgeconomics.co.uk/pdf/focusonyieldeffects2009.pdf* (January 12, 2011).

7. Genetically modified crops: Yield and production impacts

8. GMO's threats to biodiversity

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