Children's Use of Inscriptions in Written Arguments About Socioscientific Issues

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Abstract: Engaging with science in everyday life typically occurs in the context of socioscientific issues, situations where science can play some role in helping people come to some judgment or decision. Such issues often require the interpretation of inscriptions (graphic representations of information) to evaluate claims. Research on socioscientific reasoning has shown that students often do not use relevant science or subordinate it to personal or social concerns. Research has not yet looked explicitly into how students interpret different types of inscriptions as potential evidence for use in socioscientific reasoning. This study compares upper elementary students' use of scientific and editorial inscriptions in their arguments about socioscientific issues. Using a pre/post design, we investigate students' use of inscriptions before and after a semester of science instruction focused on the coordination of claims and evidence.

Introduction

Engaging with science in everyday life often means being put in a position of having to evaluate claims. This includes not just deciding whether or not to believe a claim, but also judging its relevance to the issue at hand. Being scientifically literate, therefore, entails becoming a competent outsider to science that identifies personal relevance of particular scientific claims (Feinstein, 2011). Yet to complicate matters, in science-related issues people might encounter (e.g. What to do about climate change? Should I buy organic foods?), arguments for or against a particular position combine scientific and editorial claims. Educators have long wanted school science to prepare students to engage with science productively, but we have little evidence this happens. A good deal of research on science-related issues (i.e. so-called socioscientific issues) has explored questions around when and how students use relevant scientific knowledge to reason about an issue. Yet, one's knowledge on a topic is very often insufficient to contribute to a reasoned judgment. The problem becomes, then, how do students evaluate claims they encounter about which they know little? What do they think counts as evidence?

Socioscientific issues (SSI), those where science can inform the judgments or decisions we have to make in such fields as energy use, the environment, or health, are an arena in which students' thinking about evidence can be linked with their daily life. We hope students use scientific knowledge to help them come to reasoned arguments and decisions (e.g. Kolstø, 2001; Zeidler, Sadler, Simmons, & Howes, 2005), yet studies show students 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). Further, it is only natural that in everyday situations science serves merely to frame the focus of seeing while values play a more significant role in reasoning (Nielsen, 2012a, 2012b). This view opens the possibility that students make judgments about the appropriate role of scientific knowledge in SSI.

This study explores the bases on which students might make such judgments, by focusing on a neglected yet critical aspect of SSI reasoning: the use of inscriptions as evidence. Inscriptions are graphical representations of information, such as photos, diagrams, graphs, tables, etc., mobilized in support of arguments (Latour, 1990). In science, inscriptions are a crucial means for representing the world and supporting or refuting explanations about how it works. In the classroom, as in the science lab, they mediate efficient communication, foster evaluation of scientific knowledge, and support conceptual understanding (Cobb, 2002; Roth & McGinn, 1998). Yet little is known about how students use inscriptions in SSI, even though when we face science in our daily life, we encounter inscriptions often simultaneously. For instance, a news article about hybrid cars may contain a diagram of CO_2 emissions by gasoline-powered cars and a photo of horrible traffic on a California freeway. A picture of a peaceful river farm may be attached to the grocery shelf as advertisement for organic foods. How do students perceive the role of these different inscriptions in reasoning about energy use or organic foods? Do they interpret such images as evidentiary, or as evocative of particular feelings or ideas?

To approach these problems, three research questions guide this study. First, what inscriptions do elementary-aged students use to argue about a SSI? Second, how do they use these inscriptions? Third, how appropriately do they use these inscriptions? Using a pre-/post-test design, we find patterns in which students use different types of inscriptions, in varying ways, to support their decision-making at the beginning and the end of a semester of instruction geared towards coordinating evidence and claims. We discuss potential implications for science teaching that fosters scientific argumentation and productive engagement with socioscientific issues.

Methods

Participants

This study took place in a public university laboratory school located in a large, ethnically and economically diverse city. The student population was 36% Caucasian, 28% Multiethnic, 20% Latino, 9% Asian, and 7% African-American. One intact 5th-grade classroom was recruited for this study, involving 2 science teachers and 56 students aged 10-12 (30 boys, 26 girls). Students of this age have basic knowledge of science yet declining interest (Osborne, Simon, & Collins, 2003), and SSI addresses this very feature by approaching everyday situations, thus makes the sampled classroom analytically informative.

Setting

The two teachers of the sampled students were participating, with the other teachers at their grade level, in the second year of an ongoing "work circle" (Shrader, Williams, Walker, & Gomez, 1999) with researchers to develop practices to help students coordinate claims and evidence across the curriculum. In science, this included learning routines of productive science talk (Michaels & O'Connor, 2012). Teachers organized projects and short-term group work to encourage students to share their ideas and work toward consensus explanations for the science topics under study.

Measures

We used two written tasks as pre-/post-test design to measure participants' performance at the beginning and end of the fall semester. In each task, participants individually read a single-paragraph scenario of a socioscientific issue (alternative energy use in one task and genetically modified food in another). The scenario presents a dilemma about which participants have to make a personal decision. We oriented participants to personal decision making because it represents how people commonly encounter and use science in everyday life. Participants were then asked to write down their decision and explanation, using inscriptions provided.

Each scenario includes 8 inscriptions participants may use to support their written response. Four are scientific inscriptions: 2 tables and 2 diagrams. Tables refer to the arrangement of information, mostly numbers, in rows and columns. Diagrams refer to graphs, models, or maps. Four editorial inscriptions include 2 photos and 2 drawings. Inscriptions were selected by reviewing a variety of news reports related to the topic of each scenario. Each inscription includes its original caption from the source article to help students comprehend the information it conveys. We divided inscriptions into scientific and editorial because students use both scientific and editorial resources to reason about SSI (Albe, 2008; Wu & Tsai, 2007), but it is not yet known whether or not students prefer one form over the other, or if they choose different kinds of inscriptions to support different types of claims. Finally, we chose 2 inscriptions for each type (8 in total) because it is an amount that is feasible to handle yet maintains enough variation.

Procedures

We administered the pretest early in the fall semester (i.e. mid-October 2013) and the post-test following the semester (i.e. late January 2014). Presentation of tasks is counter-balanced: participants are randomly divided into two groups in each class, with half of them completing the energy use task as the pretest and the GMO task as the posttest, and the other half completing the tasks in the opposite order. This counter-balancing mitigates potential effects from task ordering or difficulty. Twenty-seven students completed the energy task at pre-test, then the GMO task; 29 completed the GMO task first, followed by the energy task.

We gave oral instruction to participants prior to the test. 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 testing, but they were allowed to ask us any questions regarding task comprehension.

Analysis and Findings

In what follows, we present our findings of content analysis on the written tasks. For descriptive purposes, we show separate data in each task as well as combined data to delineate a comprehensive picture of students' pre-to-post performance.

What Inscriptions Do Students Use?

For the first question, we counted the frequencies of students' citing each inscription. As we predefine 4 types of inscriptions and distinguish scientific ones from editorial ones, we documented how often they use each type, and specifically, which they use the most. These frequencies depict a general picture of students' use of inscriptions in the task, and in particular, whether students tend to use inscriptions that are more relevant to everyday life (e.g. photos, drawings). The 56 students cited the given inscriptions 117 times in the pretest (63 in the energy task and 54 in the GMO task) and 127 times in the posttest (64 in the energy task and 63 in the GMO task; see Table 1). Across both tasks, 31% of cited inscriptions in the pretest and 32% in the posttest were scientific. As a group, students were more likely to use editorial inscriptions than scientific ones in both the pretest, χ^2 (1, N=56) = 10.470, $p < .01$, and the posttest, χ^2 (1, N=56) = 9.646, $p < .01$. Thus, students preferred editorial forms of evidence to scientific ones, which suggests an orientation to the problems that is more social, in which the relevant science is subordinated to other kinds of concerns (e.g., economic, moral, etc.).

Table 1. Frequency and percentage of types of inscriptions cited across Energy and GMO tasks

	Diagram	Table	Drawing	Photo	Total
Pretest	30 (26%)	11 (9%)	35 (30%)	41 (35%)	117
Posttest	31 (25%)	15 (12%)	26 (20%)	55 (43%)	127

More specifically, in the energy task, students frequently cited: 1) a drawing portraying nuclear reactors as green leaves with the title "Nuclear Energy Clean Air" (14 times in the pretest), 2) a photo of working coal-burning power plants in Ukraine (18 in the posttest), and 3) a photo of nuclear reactor explosions in the 2011 earthquake in Japan (13 in the pretest and 14 in the posttest). In the GMO task, on the other hand, students frequently cited a line chart (i.e. diagram) that illustrates the increasing rates of inflammatory bowel disease after GMOs were introduced in U.S. public diet (16 in the pretest and 18 in the posttest). Often cited was also a photo in which a little girl was holding up a sign during a street protest against GMO. Overall, Table 1 shows students tended to use photos the most, and tables the least, perhaps because they viewed photos as more common in and relevant to their everyday life. A semester of instruction did not change such perceptions.

How Do Students Use Inscriptions?

To understand how students deploy specific inscriptions within an argument, we adapted a coding scheme developed to categorize levels of "rhetorical reference" to inscriptions of data (Sandoval & Millwood, 2005). These levels range from less to more appropriate, from a scientific perspective, kinds of 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) *assertion*, asserting an inscription "shows" or "support" a claim without explaining how (e.g. "I would vote for the coal power plant because it seems safer as shown in image #5 compared to image #8."); and 4) *interpretation*, explicating how specific features of an inscription relate to a claim (e.g. "In picture 2 it states that the rate of inflammatory desease has increased a lot since before GMO started. It pretty much doubled since GMO, and if it keeps up, our community will be full of desease."). A sufficient use of inscription should involve as much interpretation as possible.

The level of rhetorical reference is coded for each citation of an inscription. The scale of these levels is ordinal, so we cannot simply create a sum of scores for each participant. Instead, there are two ways to use this scheme to understand students' references to inscriptions. At the aggregate level, we computed the frequencies of each type of reference across the corpus of written responses (see Table 2).

Table 2. Frequency and percentage of rhetorical use of inscriptions

	Pointing	Description	Assertion	Interpretation	Total
Pretest	65 (56%)	25 (21%)	15 (13%)	12 (10%)	117
Posttest	49 (39%)	28 (22%)	37 (29%)	13 (10%)	127

Chi-squared tests indicate that students were most likely to merely "point" to particular inscriptions, $\chi^2_{pretest}$ (3, N=56) = 61.427, $p < .001$, and χ^2_{posttest} (3, N=56) = 21.756, $p < .001$.This echoes Sandoval & Millwood's (2005) earlier claim that students may see data as self-evident, with no need for interpretation. Compared with those of the pretest, on the other hand, the percentage of pointing decreases and that of assertion increases, both in a notable way, in the posttest.

We also computed ratio scores of the four levels of rhetorical reference for each student (e.g. one used 5 inscriptions: 60% pointer, 20% description, and 20% assertion). Non-parametric correlations show that, in the pretest, only the level of interpretation is significantly correlated with scientific types of inscriptions ($r = .247$, $p < .05$). Though quite mild, this might suggest that students see the scientific types of inscription as more open to interpretation, and thus more in need of being explicitly justified in relation to their claims. The percentage of scientific inscriptions does not significantly correlate with any level of reference in the posttest.

How Appropriate Is Students' Use of Inscriptions?

The third question focuses on the functional role of inscriptions in relation to their content. We anticipated two major functional roles, varying by the type of inscription: eliciting values or emotions vs. providing data. For instance (from students' responses), a claim, "The nuclear power is so dangerous, people will get injured or killed, like in [a photo of nuclear reactor explosion in Japan]," was coded as eliciting emotions or values, for the photo is used to show the horror of a nuclear accident. To be clear, it is not that such a photo is not evidentiary; the value of such images is exactly that they show quite viscerally a risk of nuclear energy. Yet, such an image is used, in this case, to elicit an emotion rather than to convey evidentiary information. An example of providing data is: "It also looks as in [a diagram that shows the increasing rates of inflammatory bowel disease after GMOs were introduced in U.S. public diet] that GMO foods are possibly causing inflammatory bowel disease." The inscription provides data to support the causal claim.

Our assessment of appropriateness entails an explicit correspondence between contents and functions; that is, using scientific inscriptions to provide data about the state of the world, and using editorial inscriptions to elicit values, emotions, or moral concerns. Taking up this stance, we counted as appropriate all instances where a claim corresponded to the inscription cited as evidence, shown in Table 3 for both tests.

Table 3. Frequency and percentage of functional use of inscriptions (types of inscriptions : functions)

	Appropriate Use			Inappropriate Use		
	Sci : Data	Edit : Values	Total	Sci : Values	Edit : Data	Total
Pretest	27 (23%)	23 (20%)	50 (43%)	13 (11%)	54 (46%)	67 (57%)
Posttest	35 (28%)	40 (31%)	75 (59%)	11 (9%)	41 (32%)	52 (41%)

Chi-squared test on the 4 combinations of functional use in the pretest shows that students were more likely to use editorial inscriptions to provide data, χ^2 (3, N=56) = 31.479, $p < .001$. It reveals a mismatch between the content of inscription a student use and its function being deployed at the beginning of study. Yet their appropriate vs. inappropriate use in total did not significantly differ. In the posttest, on the other hand, students were more likely to use inscriptions in appropriate ways, χ^2 (1, N=56) = 4.165, $p < .05$. From Table 3, it is clear that the increase of appropriate use could be attributed to the increase of using editorial inscriptions to elicit values and the decrease of using them to provide data, suggesting students' improvement in functionally deploying editorial inscriptions in their arguments.

In addition, non-parametric correlations reveal that, in the pretest, appropriateness of functional use is significantly correlated with percentage of scientific inscriptions (r = .459, $p < .01$), which indicates that students who used more scientific inscriptions were more likely to use inscriptions appropriately. The appropriate use is also modestly correlated with the rhetorical level of interpretation (r = .283, $p < .05$), which may suggest a covariant tendency of coordinating the content of an inscription with its function and interpreting an inscription to support a claim. Counterpart analyses on the posttest, again, do not yield significant results.

Discussion

This study addresses an immediate question that has not been explored in sufficient depth in studies of SSI reasoning. That is, how do students deploy different types of inscriptions in their arguments about SSI, given that in everyday situations, SSI often come with a variety of inscriptions? Our analyses show that at the beginning of the semester, students tended to: 1) use editorial inscriptions, especially photos, more than scientific ones, 2) only "point" to an inscription without making clear how it is related to a claim, and 3) use editorial inscriptions as data to support a claim. A semester of science instruction that highlighted scientific argumentation, coordinating evidence and claims in particular, did not significantly change *what* inscriptions students tended to use, but, more or less, *how* students used inscriptions to argue about SSI.

Agreeing with Nielsen (2012a, 2012c) on SSI argumentation, we do not expect students to use only scientific inscriptions and make only scientific arguments. In everyday situations, people make decisions not about "what is true," but about "what to do," in which non-scientific considerations play a significant role. Yet we do argue that school should teach students to explicitly distinguish evidentiary demands in arguments, supporting the veridicality of claims, from other rhetorically meaningful uses of inscriptions, and to understand the strengths and weaknesses of kinds of inscriptions for supporting particular kinds of claims.

Our analyses shed needed light on children's understanding of different forms of evidence and their uses. The prevailing view in science education is that students see data as objectively self-evident, although young students are capable of learning the need to justify evidence-claim relations (Ryu & Sandoval, 2012). This study extends this work, through our contrast between scientific and editorial inscriptions. The findings we present here suggest that, students may be capable of learning to use editorial, if not scientific, inscriptions more appropriately, and to take the self-evidence of data less for granted.

This study opens up a new direction of research on public engagement with science focused on the features of potential forms of evidence and their influence on how students coordinate claims and evidence. Although our design does not enable causal inferences from classroom instruction to changes in pre-/post-tests, it takes a very first step to understanding use of inscriptional evidence in arguing about socioscientific issues. As educators become more concerned with how students warrant claims, scientific and otherwise, this study aligns with efforts to understand children's ideas of what makes a good warrant for particular kinds of claims. Because science knowledge is inevitably subordinate in socioscientific issues, by their nature, it is important to develop detailed accounts of how students make sense of what counts as "scientific" and what does not. This, in other words, is to explore children's capacity for becoming competent outsiders to science (Feinstein, 2011) by identifying relevant scientific resources and deploying them in their own everyday judgments and decisions.

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