Storyboarding and Upper Elementary Students' Conceptions of Magnetism

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Abstract

This paper session will chronicle design-based studies being done to build local theory around ways to orchestrate upper elementary students' conceptual encounters with abstract, often invisible, science phenomena. Interested in both the process and products of learning we explore three key dimensions of interest (pieces of knowledge, evidence of conceptual restructuring, and text-graphic relationships). We present some early evidence of knowledge in transition and document the various ways upper elementary students use storyboarding to reason deeply about magnetism. Finally we suggest ways to tailor learning environments so that the pedagogical power of text and graphics can be leveraged more effectively. Our work begins to highlight the critical connections between the authentic revealing of students' conceptions, abstract reasoning, and learning environments.

Purpose of the Work

This paper session will chronicle work being done to help combat the proliferation of "reasoning thin" (Duschl, 2008) elementary science curricula. Exploratory studies are being done around the use of student storyboarding (sequenced graphical representations and text) as a tool to promote the "deep learning" of elementary school science. Too often elementary science instruction overemphasizes concrete and hands-on activities, skirting or even ignoring the more abstract "invisible" aspects of observable phenomena (Metz, 1995). In this paper we will illustrate how a small-scale design-based research (Brown, 1992; Cobb, et al., 2003) study is being used to build local theory around ways to orchestrate elementary students' conceptual encounters with abstract, often invisible, science phenomena. In this work we document the various ways upper elementary students use storyboarding to reason deeply about magnetism and suggest ways to tailor learning environments so that the pedagogical power of text and graphics can be leveraged more effectively.

Theoretical Framework

This study is bolstered by earlier work in several key areas: deep learning, drawing to learn, students' ideas about magnetism. The notion of "deep learning" (most often contrasted with surface learning) is not a new construct (Marton & Saljo, 1976; Ramsden, 1992). Deep learning is often characterized as integrated, reflective, and complex. Surface learning, on the other hand, is sometimes seen as an accumulation of unconnected information; a type of knowledge is pieces (diSessa, 1988). Novices often remain at the surface levels of learning while experts often demonstrated more useful integrated knowledge structures.

The practice of storyboarding comes out of the film, animation, and radio industry but in recent decades computer design and programming design have leveraged the power of storyboarding to shape and communicate ideas (Jones, 2008; Katterfeldt & Schelhowe, 2008). Madden, Chung & Dawson (2008) have implemented storyboarding techniques to help children develop their own technologies. It is apparent this tool has real value for a host of learners, yet educational research on the benefits of storyboarding as an advanced organizer and visual narrative learning tool remains sparse. We feel that the process of storyboarding is an opportunity for conceptual exploration and analysis, and serves as a communication tool for the individual, as well as a group (Reeder, 2005).

Storyboarding may also facilitate multiple levels of meaning making (e.g. mental model building and metacognition) because of the integrative and discursive nature of combining text and graphics (Lehrer, Schauble, & Carpenter, 2000; Truong, Hayes, & Abowd, 2006; White & Frederiksen, 1998). Khan (2007) and Coll (2005) discuss mental models as a way of organizing information about the world and identifying causal relationships. Students' require ongoing experiences and opportunities to reflect and manipulate their understanding of phenomena if they are going to be better prepared to apply and further their new thinking. The storyboarding process meshes well with our desire to cultivate students' "conceptual encounters" with the invisible (Shepardson & Britsch, 2006) but the product of learning becomes intertwined with the process of learning. In our work we look for evidence of conceptual restructuring (Carey, 1985), with particular interest in text-graphic relationships.

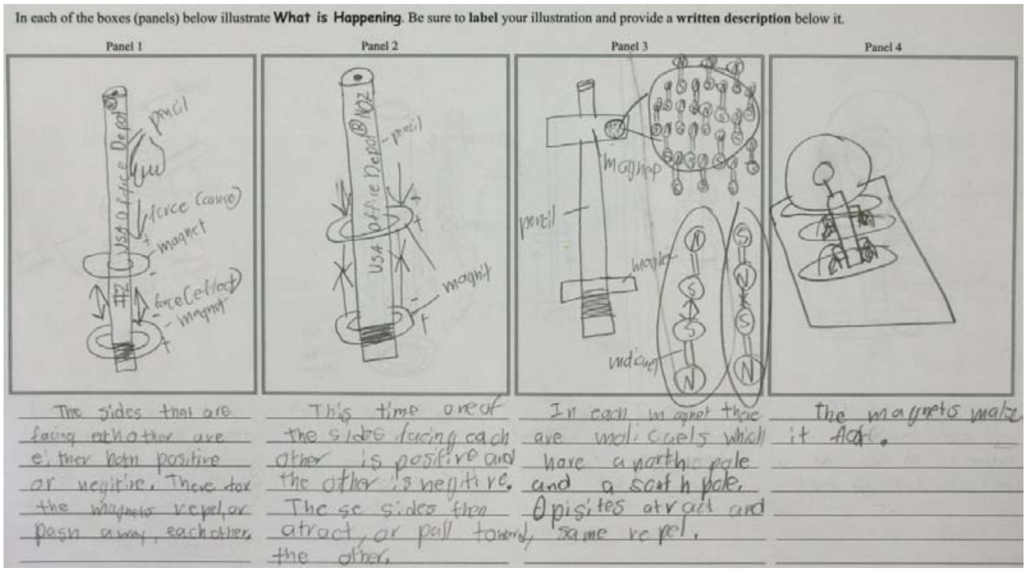
We believe that storyboarding, when combined with thoughtfully scaffolded instructional sequences, represents a powerful pedagogical strategy to support student "deep thinking" about hard to learn physical science concepts such as magnetism (Borges & Glibert, 1998; Constantinou, Raftopoulos, & Spanoudis, 2001; Sederberg & Bryan, 2010). The research base on students' understandings of magnetism is relatively thick, and a complete look at it is beyond the scope of this paper session; below we capture some of these relevant ideas uncovered in earlier work:

- Magnets are attracted by a type of gravity- Barrow (1987) [grade 2]; Borges & Gilbert (1998) [grade 12]
- Poles are only on the ends of a magnet- Barrow (1987) [grades K-3]
- Magnets work by pulling (pulling model)- Erickson (1994) [grade 4]
- There are charges circulating there is a magnetic field- Borges & Gilbert (1998) [grade 12]
- Electrons in one, protons in the other makes magnets attract- Barrow (1987) [grade 6]

Materials & Methods

Context and Sample

The research being reported here represents the two iterations of our storyboarding about magnetism instructional sequence. While the first study and its implications on our learning environment will be described, in this paper priority will be given to the second study. Working with a convenience sample of 25 academically gifted (AG) 5th graders (8 female and 17 male) from a public school in central North Carolina, we engaged participants in a brief (75 minute) but carefully structured instructional sequence. Seating in groups of three or four, students shared materials and engaged in exploratory tasks, observing each, and storyboarded “What is happening?” in a series of successive panels. Figure 1 shows the results of this process.



The sides that are facing eathother are e;ther both positive or negitive. There for the magnets repel, or pash away, eachother.

This time one of the sides facing each other is positive and the other is negitive. These sides then atract, or pull toward, the other.

In each magnet there are molicuels which have a north pole and a south pole. Opisites atract and same repel.

the magnets make it [illegible].

Figure1. An example student generated storyboard.

For Panel 1, the group was given two doughnut magnets and a pencil; the bottom magnet was affixed to the bottom of the pencil and the student places the free magnet on the pencil and observes and explains what happens. Next, students removed the doughnut magnet, flipped it over and placed it on the pencil again and each student continued their storyboard. Next, a researcher led a brief (10 minute) whole group discussion about "What is happening?" in the first two panels. The discussion included terms, definitions, explanations regarding magnetic forces (attractive & repulsive), magnetic waves, magnitude of forces/waves, charges associated with magnetism, and relevant images (e.g. investigation objects, vectors, and waves). Following this discussion, students were given the opportunity to re-represent "What is happening?" in Panel 3. Next, the researcher introduced students to magnetic levitation (maglev) technology via a brief video segment and explains that a model of this maglev technology has been built for them to explore. Each group is given a partially built maglev model (that used clay, magnets, and a pencil) and asked to storyboard "What is happening?" in Panel 4.

Data Sources and Analyses

Students completed their storyboards individually. These written artifacts (both graphic and text) were the primary source of data for this exploratory study. In this work we approach our analyses and descriptions of student work in a manner similar to that of Gobert and Clement (1999) in their work around student-generated diagrams of plate tectonics. That is, we are equally interested in the process and product of science learning; using storyboarding as a tool to make students’ reasoning and progressive model construction visible (Larkin & Simon, 1987; Schwartz, 1993).

The first level of analysis used the *Structure of Observed Learning Outcomes* (SOLO) taxonomy (Biggs, 1999; Biggs & Collis, 1982). To aid our analyses we built out the SOLO taxonomy to include conceptions specific to our magnetism scenarios (table 1 below).

Table 1

The content specific SOLO taxonomy used in the first level analysis

Level	**Description**	**Sample Student Responses**
Prestructural	The task is not attacked appropriately, the student hasn't understood the point, or question is reworded.	Panel 1: The bottom magnet is glued to the pencil.
Unistructural	One aspect of the task is picked up and used .	Panel 3 image only depicts magnetic attraction or repulsion (not both).
Multi-structural	Several (two or more) aspects of the task are learned but are treated separately.	Panel 3: *In panel 1 when they repelled it was a push. In panel 2 when they attracted it was a pull.*
Relational	The components are integrated into a coherent whole, with each part contributing to the overall meaning.	Panel 3: *There are two different poles on a magnet and the same poles repel and opposite poles attract. The further apart the magnets are the weaker the force.*
Extended Abstract	The integrated whole at the relational level is reconceptualized at a higher level of abstraction, which enables generalization to a new topic or area, or is turned reflexively on oneself .	Panel 4: *To get the pencil to stay all the magnets have to be repelling pushing the pencil upward keeping it in place just like the train floats above the track.*

According to this system, *Prestructural* responses indicate no understanding. The two “surface level” responses (*Unistructural* and *Multistructural*) suggest an understanding of ideas or facts. In contrast, the two “deep level” responses (*Relational* and *Extended Abstract*) suggest a change in the quality of responses; they are, in essence, cognitively more robust. At this level of analysis, students’ graphical representations and written descriptions were analyzed together but each panel was scored separately.

Based on the results of this first level analysis, second level analysis was conducted in order to generate more nuanced data regarding students' scientific reasoning using graphics and text. In this 2nd level analysis we looked specifically at three *dimensions of interest*. These include: *pieces of knowledge*, evidence of *conceptual restructuring* (Carey, 1985), and *text-graphic relationships*. More precisely for the first dimension, we identified key terms (e.g. pole, attract, repel, field, force) and symbols (e.g. N, S, +, -, vectors) of interest and did frequency counts, cataloging the “pieces of knowledge” students held. We also looked for evidence of “restructuring” (Carey, 1985) and placed students on a continuum (from “no” to “weak” to “strong”). This judgment was made by looking across individual student’s panel. It was a holistic score that tries to capture each student’s conceptual moves, the durability of ideas, the uptake and use of our graphic tools. Finally, we examined and began to describe text-graphic relationships using the following scheme.

Table 2
Our look at text-graphic relationships

Relationship	Description	Example
Incompatible	text & graphic contradict each other; message is inconsistent	The student illustrates how 2 donut magnets placed over a pencil remain at a distance from one another. The labeling includes the word repelled pointing to the floating magnet. In the students supporting text they state "The first donut magnet is glued to the pencil and is not [a]ffected by gravity [while] the second magnet is dropped down [on] the pencil [is] [a]ffected by gravity.
Compatible	text & graphic communicate the same idea or concept	The student illustrates two donut magnets placed over a pencil that remain at a distance. The use of arrows and labeling word "push" illustrates the donuts are being repelled from each other is reinforced by the incorporation of like charge symbols (+) facing each other. In the student's supporting text they state, " In panel 1 when they repelled it was a push, in panel 2 when they attracted it was a pull. This is shown in the picture above."
Complementary	text & graphic work together to fill out or complete a narrative of the phenomena, mutually supplying each other's lack	The text states, " I think the magnets used [generate] a magnetic field to attract and repel." In the student's graphic representation they draw the first magnet floating over the second magnet, incorporate a Magnifier Tool to illustrate how magnets are made up of mini magnets, and draw a series of wave lines to show the resulting magnetic field. The students reasoning of magnetic field is captured graphically while their written text, though incomplete, is supported by their graphical representation.

Results

Despite the potential of storyboarding, the bulk of the students in this study showed evidence of "surface learning". That is, the results of our first level analysis (using our SOLO taxonomy) suggested that 78% of the panels (viewed collectively) showed "surface" thinking/learning about our magnetism scenarios. Most responses lacked coherence, the integration of key concepts was not common, and knowledge remained fragmented.

Our second level findings point to the prevalence of knowledge in pieces (diSessa, 1988). For example many students were able to recite the "opposites attract" rule (56% made explicit references to it) but few demonstrated the ability to integrate this knowledge with the ideas of polarity or the interaction of magnetic fields, remaining stuck at the "rule level". Our results also showed that only 3 students (12%) showed no restructuring while the remaining 22 students (88%) showed weak restructuring. In regard to text-graphic relationships, 13 (21.33%) of the student generated panels were deemed *incompatible*, 48 (64%) were *compatible*, and 14 (19%) were *complementary*.

We believe that useful ideas did not make it onto the students' storyboards; future iterations will capture all modes of communication (i.e. discourse and gesturing). We also suspect that constraining students' peer interactions impoverished their written products. As a result we are considering the influences of taking more of a situative participatory approach to the design and assessment of our learning environment. This approach would assume that knowledge is co-constructed as learners interact with the materials, cognitive tools, domain specific language, and each other (Hickey & Zuiker, 2003). Our presentation will consider the constraints and affordances of storyboarding uncovered thus far and point to future iterations of this sort of learning environment.

Significance of the Work

We feel our work makes theoretical and methodological contributions to teaching and learning environments by challenging long held assumptions about children's ability to reason abstractly. At a minimum, we demonstrate that storyboarding can be used as a rather robust formative assessment tool; indicating what pieces of knowledge students bring to the experience and giving some insight into the durability of these ideas. Further, our design studies are providing early evidence of *knowledge in transition* (Smith, diSessa, & Roschelle, 1993). Storyboarding appears to be an innovative way to make students' meaning making more visible. As part of the learning environment, storyboards may be help mediate students' thinking about concrete experiences and abstract phenomena, ultimately paving the way for more robust conceptual encounters with the invisible. The exploratory work presented here begins to highlight the critical connections between the authentic revealing of students' conceptions, abstract reasoning, and learning environments and should appeal to the diverse interests of the AERA community.

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