

# **Examining Science Inquiry Practices in the Elementary Classroom through Science Notebooks**

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## ***Abstract***

Current research and reports on classroom practice indicate an ongoing need for professional development in elementary science education. The purpose of this research is to investigate the efficacy of science notebook analysis as a vehicle for informing this professional development, with a particular emphasis on guiding teachers in using student-produced graphics more effectively. A purposeful sample of 32 science notebooks from a single elementary school were analyzed for graphic content based on a research-based taxonomy. The results of the analysis show a non-uniform distribution of graphic production across stages of the inquiry. The graphics produced were also largely teacher-driven and represented concrete, macro-scale, real-time phenomena. The paper concludes that this analytic approach has considerable value in informing elementary science professional development.

## ***Subject/Problem***

Elementary science education has come under increased attention as educators, researchers, and policy makers have coalesced around the notion of the important foundational role elementary science plays in later success in STEM education (Duschl, Schweingruber, & Shouse, 2007). This focus reaffirms how critical a role thoughtful and sustained professional development plays. Unfortunately, the goals of inquiry-based science, as outlined by the national standards (AAAS, 1993; NRC, 1996) and more recent national committees on K-12 science education (Duschl et al., 2007), are often at odds with the realities of elementary teacher preparation and development. Reform-based practices require rich understandings of the nature and practice of science along with core content mastery, which are often not strengths of elementary teachers (Enfield, Smith, & Grueber, 2008). Research has shown that elementary teachers often hold naïve views of the nature of science (Ackerson, Abd-El-Khalick, & Lederman, 2000) that influences their approach to teaching in the classroom. This, combined with weak content mastery (Smith & Neale, 1989), often results in instruction that does not mirror reform-based goals. Evidence of this can be seen in the 2005 NAEP results that show roughly one-third of fourth grade students score below the Basic designation on the test (Grigg, Lauko & Brockway, 2006)

Several research groups have begun to explore the use of science notebooks in conjunction with science investigations (Klentschy & Molina-De La Torre, 2003; Saul & Reardon, 1996) and how student work in the notebooks potentially provides powerful evidence of inquiry practices. These written and drawn artifacts provide a permanent record that the teacher can use for ongoing formative assessment of the students' development of science concepts (Alonzo & Aschbacher,

2004; Saul & Reardon, 1996) and has potential to inform prescriptive approaches for improving inquiry-based science instruction through professional development. While individual researchers have noted in their work the great power of graphics to reveal what students know about science (Lehrer & Schauble, 2002; Wu & Krajcik, 2006), more mainstream texts on elementary science instruction with notebooks (Campbell & Fulton, 2003; Harlen, Elstgeest, & Jelly, 2001) is only the beginning of how this evidence might provide guidance for the design of professional development.

The purpose of this research is to investigate the efficacy of science notebook analysis as a vehicle for informing elementary teacher professional development, with a particular emphasis on guiding teachers in using student-produced graphics more effectively. Initial work by the research team (Wiebe, Madden, Bedward, Carter, & Minogue, 2008) has pointed to the potential of notebook analysis to better understand the arc of learning that students are experiencing when using science notebooks in conjunction with science kits. When triangulated with classroom observations (e.g., Minogue, Madden, Bedward, Wiebe, & Carter, 2009), a picture of the influence teacher instructional strategies have on the notebook more clearly emerges. This work will look at this investigative process in more detail.

### ***Design and Procedure***

#### *Study Context*

This study is set in a U.S. urban/suburban public elementary school with approximately 325 students in grades K-5. Students receive daily instruction in science throughout the year and teachers are expected to use science notebooks as they deliver science instruction via district-adopted kit-based materials (NCS DPI, 2000). While many of these teachers have received district sponsored professional development on the use of these kit-based materials and/or science notebooks, such training is not mandatory or uniform. During the Spring of 2008, three researchers conducted multiple (3-6) classroom observations of each of the six teachers during their science periods. In each instance the observer recorded the date, time, science kit being used, and qualitative field notes regarding what transpired during each session. Attention was given to capturing the words and actions of both the teacher and students and no structured data collection process was employed. Additionally, the research team critically examined each lesson in a sample of four kits, one per grade level, highlighting key teacher background information and creating potential science notebook entries for each day. The resulting material, called "roadmaps," includes specific notations for pre-, during- and post-investigation. The roadmaps helped the team understand the kit structure and systematically look for opportunities where graphic production could potentially enhance learning. At the school where our observations took place, each grade is assigned 4 science kits, 1 per quarter. With the day-to-day time constraints that all elementary schools face, we estimate conservatively each kit was covered in approximately 15 40-minute science lessons. This represents the times when notebooks and graphics could be leveraged.

#### *Notebook Sampling*

A type of purposive sampling, typical-case sampling (Teddlie & Yu, 2007), was used to acquire notebooks. Two teachers from each grade selected between 2 and 12 notebooks per class, exemplifying a cross section of student ability. Every page of student work in the science notebook for the entire year was photographed and catalogued. This resulted in 32 notebooks: 15 from boys, 15 from girls, and two that could not be attributed to a gender. All told, 1195 pages

were photographed. For this presentation, only data from the second-grade classrooms will be reported.

*Procedures*

Using semiotics as a methodology, external graphic representations were defined with regard to their relation to the real world (Lemke, 1998; Peirce, 1960; Scheiter, Wiebe, & Holsanova, 2008). Semiotics is an approach that can be used to more rigorously analyze the relationship between the elements (i.e., signs) that make up a graphic, the instructional context in which they were created, and other relevant characteristics of the learner. These characteristics were used to derive a graphic type for each science notebook entry deemed a graphic. Important characteristics include the scale of the representation (macro being what can be seen in a single, unaided view), the temporal dimension (real-time, faster, or slower), and the text-graphic relationship. While semiotics is often used to analyze graphic artifacts as an end unto itself, the goal with this work is to inform future creation of graphics by students.

In addition to these characteristics, the stages of scientific inquiry that these graphics served was determined based on the context of the notebook entry and knowledge of the science kit lesson plans. The graphics were coded as happening either before, during or after the science investigation. An equally important reflective activity was whether the graphic was a re-representation of content that was originally represented either elsewhere in text or in another graphic. Finally, the graphics were coded based on whether they were teacher-driven (e.g., black line handouts) or student-driven.

The coding of graphics was done by two raters. To ensure greater inter-rater reliability of results, pilot coding was performed first on one notebook per grade. Comparison of the pilot coding between the two raters was then used to resolve differences in application of the coding scheme.

***Analyses and Findings***

Table 1 shows the results of the science notebook coding previously described. A Pearson’s Chi-squared test was used to determine the significance (alpha = .01) of the distribution of counts across categories. Of particular interest is that the distribution of graphics between the three phases of investigation was significantly different from a uniform distribution across the three phases. Similarly, the distribution between Macro-scale drawings and the other scale representations was also significant as was the distribution between Real-time scale and the other temporal scales. Graphics that re-represented ideas or data originally recorded in text or graphic form was also significantly under-represented. Finally, the distribution between Teacher Driven and Student Driven (and Student-Teacher Driven) graphics was significantly different.

Table 1. Results of notebook coding

Graphic Representation	Investigation Stage			
	Pre	During	After	Unknown
<b>Text-Graphic Relationship</b>				
Drawing-driven	38	99	0	7
Text-Driven	37	135	37	2
Balanced	16	197	3	0
Unknown	1	0	0	11
Totals	92	431	40	20
<b>Spatial Organization</b>				

1-dimension	16	21	22	2
2 or more dimensions	72	358	7	7
Unknown	4	52	11	11
<b>Totals</b>	<b>92</b>	<b>431</b>	<b>40</b>	<b>20</b>
<b>Scale Representation</b>				
Macro	64	354	20	8
Macro-micro	2	14	0	0
Macro-molecular	13	7	6	1
Micro	1	7	2	0
Molecular	2	0	0	0
Super-Macro	5	7	0	0
Unknown	5	42	12	11
<b>Totals</b>	<b>92</b>	<b>431</b>	<b>40</b>	<b>20</b>
<b>Drawing's Temporal Representation</b>				
Real-time	36	212	15	6
Slower than real time	0	0	0	0
Faster than real time	0	0	0	0
Not applicable	50	178	14	5
Unknown	6	41	11	9
<b>Totals</b>	<b>92</b>	<b>431</b>	<b>40</b>	<b>20</b>
<b>Re-representation</b>				
Yes	3	21	1	0
No	84	404	37	11
Unknown	5	6	2	9
<b>Totals</b>	<b>92</b>	<b>431</b>	<b>40</b>	<b>20</b>
<b>Driving Force of Notebook Entries</b>				
Teacher-driven	63	397	36	9
Student-driven	3	19	1	0
Teacher-Student driven	26	14	3	5
Unknown	0	1	0	6
<b>Totals</b>	<b>92</b>	<b>431</b>	<b>40</b>	<b>20</b>

The analysis of graphics produced by students in their science notebooks as part of inquiry activities with the kits provides considerable insight as to when the science notebooks were used and how both the kit curriculum materials and teacher instructional strategies guided the production of graphics. As indicated by the data in Table 1, classroom observations, and other analyses of the notebook contents, the science notebooks were not consistently used throughout the kit-based science activities, though the research team saw opportunities to do so almost everyday. The preponderance of use was during the investigation portion of the inquiry and the graphics produced by the students were used to represent phenomena visible by the student at a real-time, macro scale. Opportunities were missed to use science notebooks during pre-investigation to textually and graphically organize concepts related to the investigation, to construct graphic models representing the concept or phenomena to be investigated, and to make predictions based on their initial understanding of the concepts. Similarly, there were many possibilities to use graphics to re-represent and synthesize ideas and observations in the after-stage. Here graphics could again be used to represent revised models and/or predictions about the investigated phenomena.

Many of these models representing the phenomena would require moving the graphics beyond visible, macro-scale, real-time observational records that dominate the graphic representations.

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They would, instead, need to represent more abstract ideas that encourage deeper more reflective thought about the science concepts under study. While models are often not formally introduced until later grades, more abstract representations, such as vibrations or sound waves were seen in a few second grade notebooks. We suggest that effective use of graphic models would be facilitated by the use of *master images* (Mathewson, 2005)—robust canonical representations of scientific phenomena—that students could use throughout a kit and across grade levels. It is believed that introduction and scaffolding by the teachers could make such imagery much more common.

### **Conclusions**

Despite being in its early stages, the research effort described here is already providing much needed information regarding the complex relationships among teachers' science pedagogy, kit-based science curricula, science notebooks, and student cognition. We put forward a rather robust graphics taxonomy that was used to generate empirical evidence regarding the way in which graphics are being used during kit-based inquiry investigations. Perhaps more importantly, our analyses revealed that the pedagogical power of student-generated graphics is not being harnessed at all stages of the inquiry cycle. We believe this work is directly in line with recent calls to critically examine current K-8 science curricula and teaching practices (Duschl et al., 2007), helping to inform these elementary science teacher professional development efforts.

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