AC 2011-1602: NOVEL CURRICULUM EXCHANGE RESEARCH-BASED TEACHER PROFESSIONAL DEVELOPMENT STRATEGIES TO SUPPORT ELEMENTARY STEM CURRICULUM

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Novel Curriculum Exchange —Research-based teacher professional development strategies to support Elementary STEM curriculum

Abstract

This paper reports on professional development strategies to support elementary STEM curriculum, for presentation in the K-12 Division Novel Curriculum Exchange. This paper presents the strategies developed and deployed as part of a two-year NSF project supporting enhanced elementary STEM instruction through student-generated graphics. All of the schools that participated in the study were currently using existing high-quality inquiry-based curriculum kits plus science notebooks. Over the course of the project, in collaboration with the teachers, the researchers developed graphic-enhanced instructional strategies that were then shared with the teachers through workshops and one-on-one instruction. These best practices were then incorporated in a web site for wider dissemination. The presentation will focus on the best practices in teaching and learning using the STEM curriculum, as captured on the project web site.

Introduction

For the past two years the Graphically Enhanced Elementary Science (GEES)[1], an NSF-funded initiative, has pursued the creation of teacher professional development materials through research in student and teacher scientific representational practices during STEM-based elementary technology and science instruction. Many elementary schools make use of inquiry-based science kit curriculum[2-4] that supports standards-based STEM instruction. The professional development was designed to enhance the use of these high-quality curriculum materials. Through multiple modes of data collection—including classroom observations, photographing student science notebook pages, and teacher and student interviews— a research-based strategy to enhance student learning around core STEM concepts has emerged. A recognition that professional development is cumulative and reflective, a number of cycles of formal workshops, classroom observations, interviews and analysis of student work took place over the two years. A general timeline of activities is presented below (Figure 1).

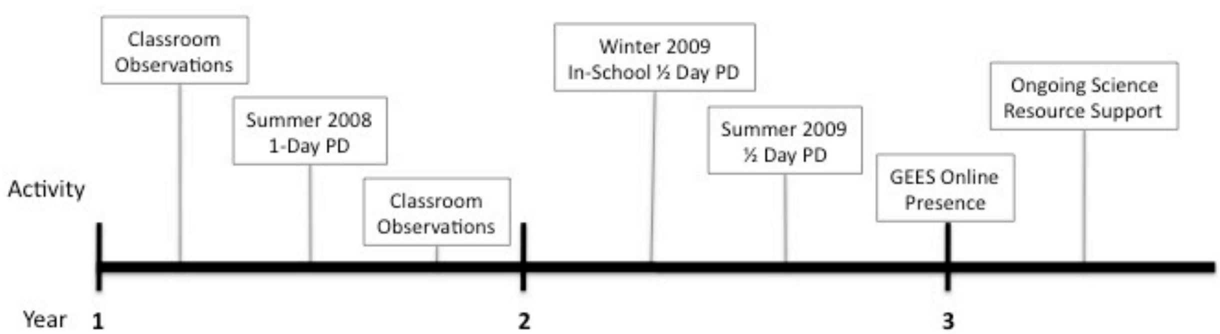

Figure 1: Professional Development Timeline

Over the course of these sessions, ideas surrounding the importance of graphics, inquiry and problem solving, and national science standards tied to elementary STEM content were introduced and expanded upon. Techniques of how to integrate graphics within the STEM curriculum were shared and practiced in the classroom. As a result of these professional development initiatives, an online presence showcasing tailored content for teachers, the professional development community and educational researchers on how best to integrate graphic-modeling tools, has been published. In order to develop effective professional development, recursive and reflective long-term engagement with teachers was central; as it informed both the practitioner and research community as to what is necessary for effective teacher development around effective use of STEM curriculum.

Context of Professional Development

This project was funded by the National Science Foundation under the Discovery Learning K-12 program to create professional development materials for elementary science education. We recognized that an important first step was going to be understanding the curriculum as written by the developers. It was immediately understood that the science kit curriculum specified in the school district in fact had a broad STEM content, including covering many technology, modeling, and engineering design activities. It was also recognized that it would be important to not only understand the curriculum as written, but also understand how teachers enacted the curriculum in their classrooms. We had reason to believe that differences in teacher training, and experience and attitudes towards STEM would result in differing approaches to instruction, and that direct observation of classrooms would be the best way to understand and document these instructional strategies. In the first six months the research team spent time observing classroom instructional practice using a structured but flexible observation protocol (see Appendix).

Many of the state mandated kits included content that covers process skills, STEM content and habits of mind[5, 6] associated with abstract science concepts as well as technological problem solving and pre-engineering (e.g., motion and design, magnetism and electricity, and sound). By the time elementary students complete Grade 5 they will have covered sixteen topics—each topic being covered over a 3, 6 or 9 week period depending on grade and other instructional demands. We chose to focus on eight kits that exemplified the range of activities covering aspects of the physical, biological and pre-engineering sciences. In the early elementary grades students covered Changes STC™, Sound Insights™, Human Body Fossweb™ and Soils STC™, while in the late elementary grades students were introduced to Animal Studies STC™, Magnetism and Electricity Fossweb™, Landforms FOSSweb™ and Motion and Design STC™[2-4]

Teachers navigate these topics and concepts using a combination of inquiry-based science, mathematical application, technological design and problem solving. For instance, in the early grades students' explore the physics of sound (e.g., vibration, pitch, timbre and volume) by creating instruments (drums and kazoos) to distinguish between the various properties of sound. As well, students are engaged in properties of matter investigating concepts of phase change, and design and construct projects (e.g., a technological device to minimize ice from melting). In the later grades students study the physics of motion (e.g., friction, gravity, potential and kinetic energy), incorporate technological design to test vehicle performance under certain design constraints (comparing rubber band energy to energy harnessed by sails). Finally, they are engaged in inquiry exercises to investigate weathering properties associated the formation of the Grand Canyon. In many instances students are engaged in investigations that meld concrete observations and technological design with abstract science concepts, conduct experiments to highlight science processes that are both visible and invisible, and collect data to guide iterative design.

Students utilize the science notebook to document their inquiry and design investigations. The notebook is a learning tool used to record student thinking, provides a chronological account of the investigations, and supports student reasoning and reflective practice as they engage in evidence-based arguments. Student predictions, observations and meaning making are documented in written and graphic modes (Figure 2). The science notebook is also a valuable tool for teachers to provide feedback on student understanding.

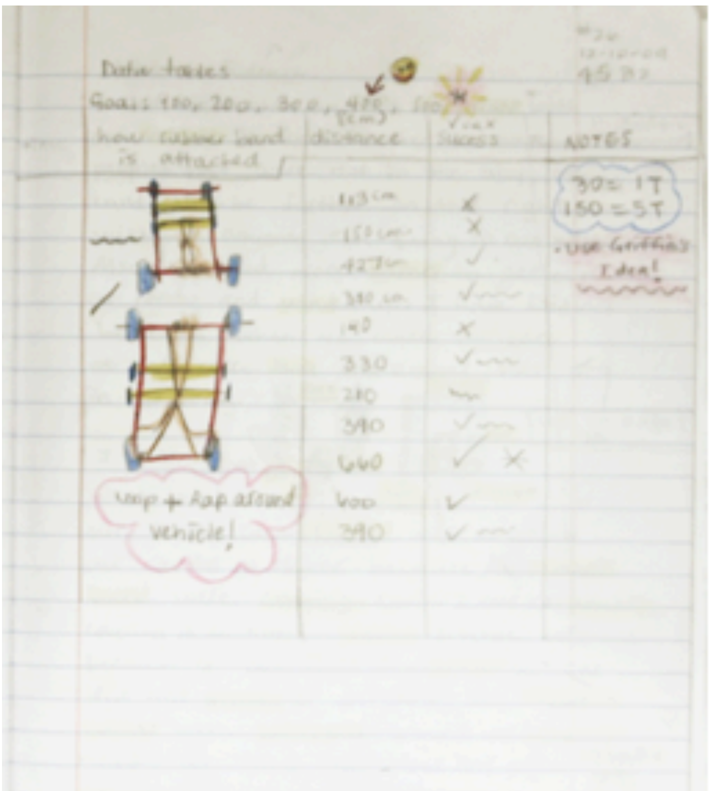

Figure 2: Testing the effects of transforming rubber band energy

Pre-Professional Development

We observed elementary teachers from one area school for six months during their STEM instruction. An observational protocol was designed to record teacher pedagogical practices, the use of graphics during student science investigations and aspects of scientific and technical discourse (e.g., how graphics were leveraged during whole-class and individual sense making) (see Appendix).

Summer Professional Development – Year 1

Prior to the following academic year, teachers from six area elementary schools were invited to participate in a one-day workshop where we solicited and shared some of our preliminary ideas around how more effective use of student-produced graphics could enhance their existing STEM-based curriculum. After presentations covering STEM content, interactive notebooks and inquiry science, we engaged teachers in a lengthy brainstorming session on the role and use of graphics in elementary grades. By the end of the activity, teachers became more aware of the cognitive role of graphics (e.g., Venn diagrams, concept maps, and KWL and tables) along with traditional data driven graphics (e.g., pie charts and bar charts). During this session, the research team began to seed ideas about student abstract reasoning on concepts surrounding the "invisible" (Figure 3).

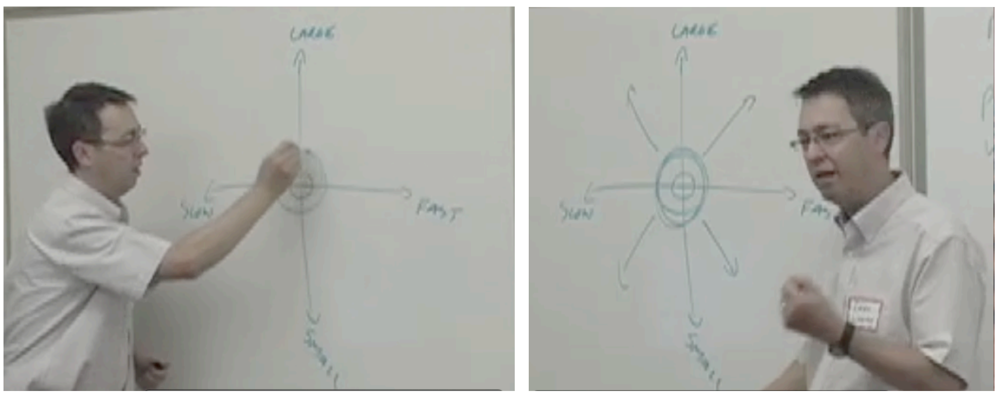

Figure 3: Discussion about the invisible world

> The direct observable world really dominates the graphics in this area right here. But what we want to explore today is how do we move out from that direct observable world to that invisible world of things that are happening so *slow* that we can't see them within a reasonable amount of time. Let's say within a classroom period, or so *fast* that we can't see them at all, or so *small* that even with the aid of a microscope we still can't see them, or so *large* that they are bigger than what we can take in within a single view. (Author, during the workshop)

In the afternoon teachers were grouped by grade to integrate the morning's activities and develop science notebook entries that reflected the integration of these common graphics and phenomena around the invisible. By having teachers share their notebook entries with the remainder of the group, it highlighted the beginnings of a STEM concept progression from Grades 2-5. Many elementary teachers teach in a particular grade for many years without a clear understanding of what the previous grade has taught or how best to prepare students for the following grade. As well, these STEM kits provide an (overly) abundant amount of information that becomes difficult for teachers to navigate pedagogically. Due to time constraints—the early grade classes receive 25-35 minutes with this kit curriculum 3-4 days a week, while the upper grades might receive 50-75 minutes two times per week—teachers are forced to make decisions on what content to cover over a typical 9-week instructional sequence. Hence, having teachers develop full notebook entries gave them an opportunity to discuss and share decisions on what core content provides the best opportunities for students to experience, thematically, larger conceptual ideas that span multiple grades. Teachers held onto their entries and used it as the basis for their future planning sessions. In the following example the teacher describes a student scenario using their notebook to record their observations (Figure 4).

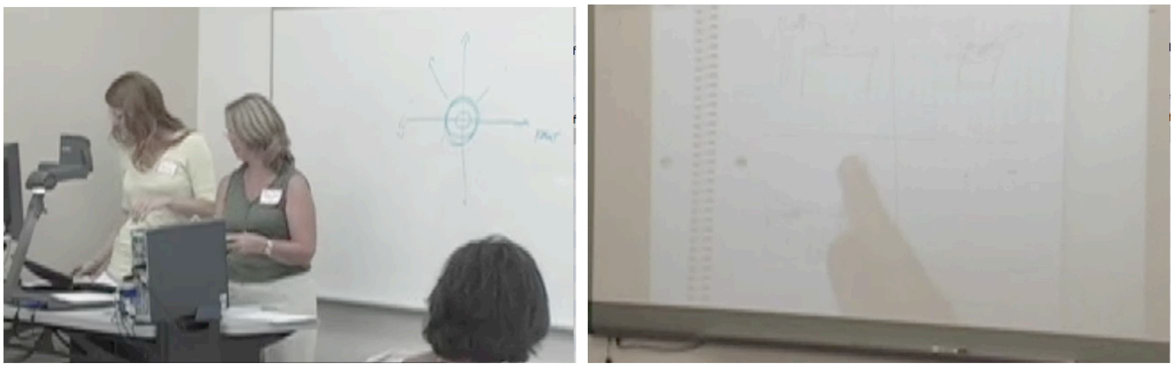

Figure 4: Teacher notebook entry and explanation on sound

> Sometimes children may be at stations…with their notebook…and actually record what they did at each center. On this one you have a tuning fork showing that the sound came from the table …[in another case] they [student] hit the drum with a stick or here they have their hand on a CD player [where] they felt the vibration. (Teacher, during the workshop)

Winter Professional Development – Year 2

For the next 6 months, we again visited science classrooms to observe some of our pedagogical tools in action with the STEM curriculum. As a result of these observations, half-day and small group sessions were designed to encourage further use of graphics during instruction. There was a more explicit attempt at modeling the use of graphic tools with core STEM concepts that were often abstract and invisible (e.g., friction, erosion, gravity, phase change, sound waves). Our techniques can be a challenge for teachers who are not accustomed to incorporating graphical modes of representation, as it exposes STEM concepts that are not always highlighted through verbal or written forms. It was also an opportunity to introduce the importance of considering how unifying STEM conceptual ideas can help organize instructional delivery (NCDPI, 2004). For instance, the role of form and function in understanding skeletal aspects of the human body, observing patterns to help explain sound propagation, and designing and testing models (e.g., Kinex cars) to explore ideas of force and load. The challenge remains how to support teachers and students in reasoning about abstract concepts that are visually beyond human perceptual frame both in terms of geometric scale and rate of change (e.g., dissolved sugar in solution or geologic time).

Summer Professional Development – Year 2

The six participating schools were invited to a half-day session where they were introduced to our revised graphic-modeling tools in support of abstract STEM concepts. In this session we were explicit in organizing the STEM content to illustrate how our graphic tools can support big conceptual ideas in STEM across the elementary grade levels. The use of these foundational images (graphic-modeling tools) in conjunction with stated STEM concepts would facilitate student sense-making within and across the elementary grades. The aim was to assist teachers in developing a school culture whereby they would instill a common graphic language that overtime the students would recognize and deploy. These graphic-modeling tools would be placed in the classroom as part of a graphic wall to support student meaning-making. Figure 5 is the proposed 24 x 36 poster teachers could print and hang on the wall.[1]

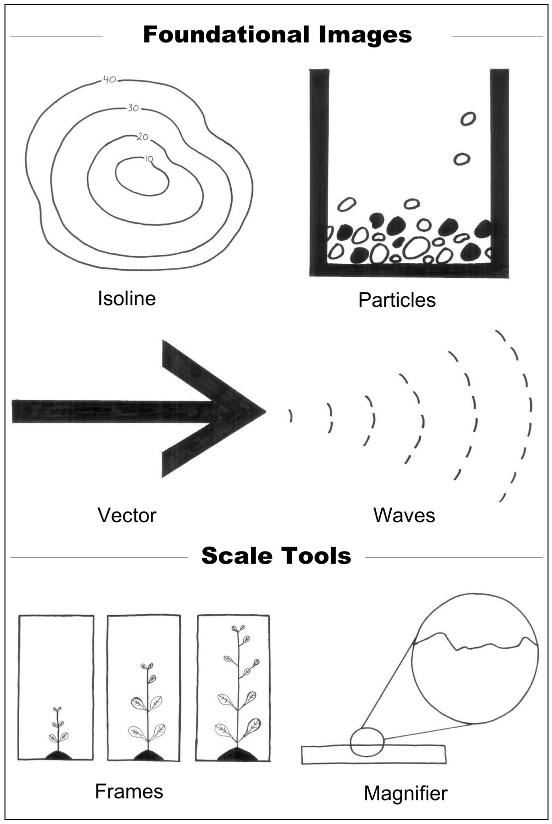

Figure 5: Foundational Images Poster

At various times throughout the year, we solicited feedback from teachers after classroom instruction or during one of their formal planning periods:

> Researcher: How have graphics helped students during their investigations?
>
> Teacher: [During predictions] it helps them visualize what [ideas they can test] and be able to really see in their minds what they plan to do rather than just listing out [procedures] like a grocery list….[and] they are able to see, okay I want to set the vehicle up this way, put the washer here and this is the plan for this investigation.
> … When they do their conclusions they have to look back at their predictions and say was it correct or was it not correct or was it partially correct. And what evidence specifically from the data or their observations support or doesn't

support them. Then they get to reevaluate at the end, they can't change it but they get to reevaluate [their prediction] (Figure 6 & 7).

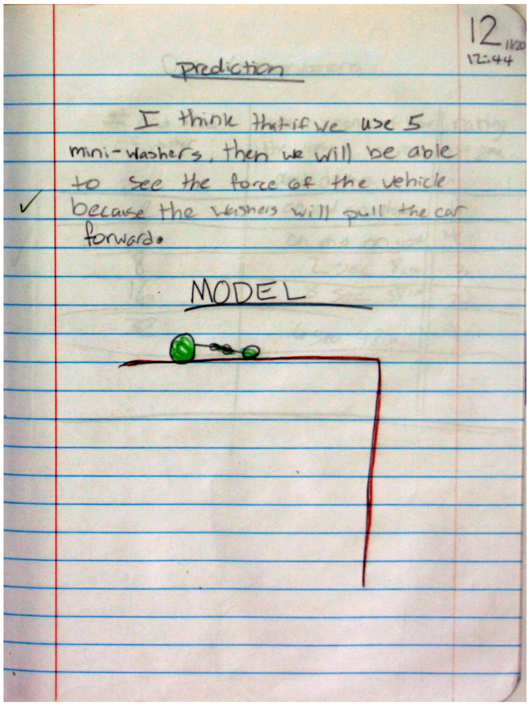

Figure 6: Student Prediction

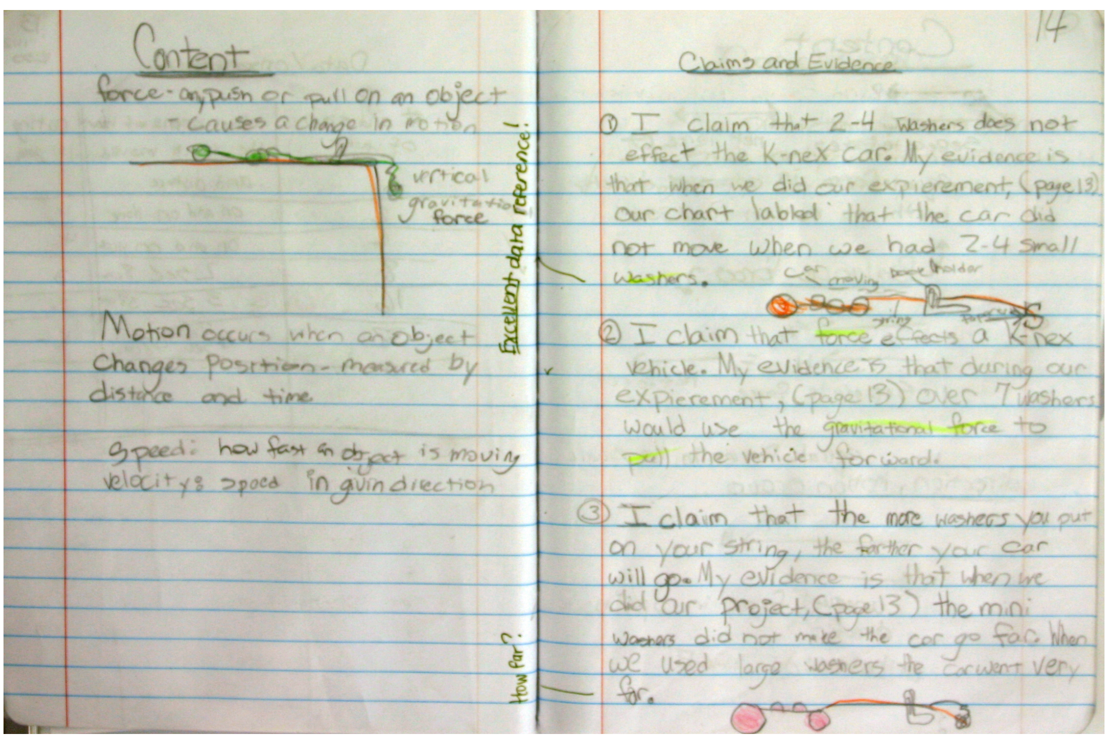

Figure 7: Student Claims and Evidence

Despite working with these teachers over the past two years, there remained an additional need to assist teachers in the use our graphic-modeling tools, especially when it came to representing abstract/invisible concepts. The following is a response from a Grade 2 teacher after the second year of professional development:

> My suggestions would be to provide more examples of the use of graphics, some introductory lessons to give the students a firm understanding. As I do feel that those who are not able to physically write down what they were observing could use these graphics in place of writing. The introductory lessons along with a multitude of examples before using them in the actual science lessons could possibly lend for more independent use of the graphics. (Teacher, during a classroom interview)

Even though the research team modeled many examples across several grades, not all teachers were comfortable moving forward with our graphic-modeling tools.

Current work: Professional Development – Year 3

As a result of our face-to-face professional development and ongoing feedback from teachers, we created an online professional development site (http://gees.ncsu.edu), which demonstrates modeling techniques suitable for elementary science curriculum across Grades 2-5 (Figure 8)[1].

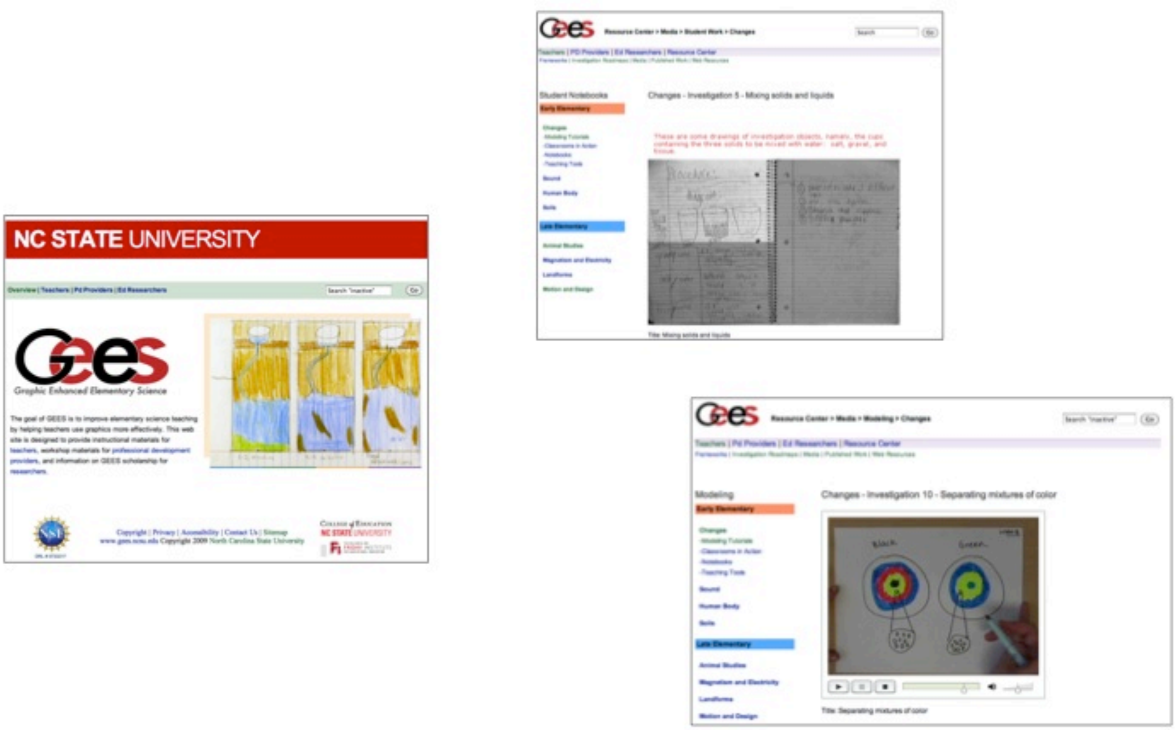

Figure 8: GEES Website (http://gees.ncsu.edu) Screen Captures

Lastly, fieldwork is underway with several area elementary teachers to extend pedagogical practices. The focus is to capture additional student-teacher interactions and conduct student interviews on their meaning-making capabilities with graphics. This a crucial step to confirming the efficacy of our approach on impacting student learning around key elementary grade STEM concepts.

Conclusion

In order to encourage pedagogical best practices using high quality elementary STEM curricula, teachers need to be part of a research & development team that is innovating not just with the writing of the curriculum, but also in innovative instructional delivery. In the case of our project, teachers needed to experiment with our graphic tools, share their understanding, and at times modify their approach. They need to be supported in the classroom, given opportunity with peers to share ideas and increasingly rely on virtual resources to compliment and develop their pedagogical strategies. Similarly, the providers of professional development (the researchers in this case) need to reflectively make use of ongoing classroom observations and teacher feedback to modify their support of teachers. The communication between practitioner and researcher must remain open and continuous if thoughtful innovations around STEM teaching and learning are going to take hold in the classroom. Rather than focus on writing new curriculum, this project chose to support effective teaching practices around existing high-quality curriculum materials. Through such a professional development strategy, this project has been able to innovate in the use of student-generated graphics to support the use of models and modeling in science, technology and engineering—central components to learning in these disciplines.

References

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5. AAAS, American Association for the Advancement of Science. *Benchmarks for science literacy*. 1993, 2009 March 6, 2000 [cited 2009 June 5]; Available from: http://www.project2061.org/tools/benchol/bolframe.html.
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Appendix - GEES Classroom Observation Protocol

DESCRIPTIVE INFORMATION:

Researcher:

Teacher/Grade: School:

Condition: *Control/Experimental (highlight one)* Materials:

Date: Start time: End time:

Number of Students: # Males: # Females:

Classroom Set-up (describe or sketch set up below):

DIALOGUE BETWEEN RESEARCHER AND TEACHER:

I. LESSON INTRODUCTION

Instructions: Provide a brief description of how the lesson started and mark whether each of the indicators was present or absent.

Introduction Emphasis	Present?	Evidence/Explanation
a. Provides overview		
b. Relates lesson to previous lessons/activities		
c. Assesses prior knowledge		
d. Uses science notebooks*		
e. Uses graphics**		

*Scale: 1- Present 0- Absen t*Notebooks use will be addressed in detail later on in protocol.**Graphics will be addressed in detail later on in protocol*

II. EVENT LOG/SYNOPSIS:

Instructions: Create an event-driven synopsis for the class period describing both teacher and student actions during each event. Shorthand codes for modes of instruction and teaching materials can be found in the table below the log. Refer to graphics as Graphic A, B, etc., as these will be described in section IV of the protocol.

Event time	Teacher Actions	Student Actions

III. LESSON CLOSURE

Instructions: Write 1-2 sentences describing how lesson ended.

Event Log Coding Scheme

Mode of Instruction	Code	Materials Used	Code
Whole Class Instruction	WCI	Printed Reading Materials	PRM
Hands-on Activities	HOA	Computer or Computer Technology	CT
Lecture or Recitation	LR	Overhead projector or LCD	OP
Drill and Practice	DP	Chalkboard/Whiteboard/Chart Paper	CWC
Reading Textbook or Kit Materials	RT	Videos/Films/Music	VFM
Teacher Demonstration	TD	Demonstration models	DM
Small Group Discussion	SGD	Manipulative/hands on equipment	MHE
Cooperative Group Work	CGW	Worksheets	WS
Individual Seat Work	ISW	Science Notebooks	SN
Open Ended Inquiry	OEI		
Data Collection and/or Manipulation	DCM		
Note-taking (includes copying materials and procedures)	NT		
Homework or Class work Review/Correction	WRC		
Group Presentation (student)	GP		
Notebook Entry or Log	NE		

IV. NOTABLE DIALOGUE

Instructions: transcribe any notable classroom dialogue in the box below.

V. NOTEBOOK USE

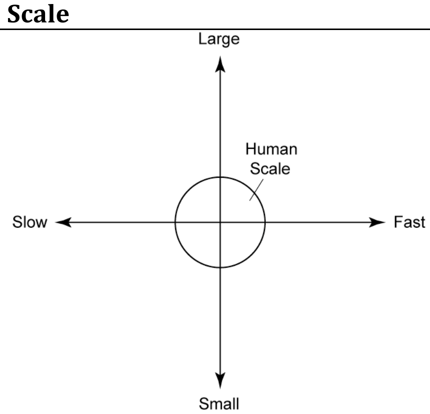
Instructions: briefly describe notebook entries. Refer to graphics as Graphic A, B, etc., as these will be described in section V of the protocol.

Notebook Use	Present?	Driver	Description of Notebook Entry/(ies)
Notebooks used before Investigation			
Notebooks used during Investigation			
Notebooks used after Investigation			

Present/Absent Scale: – Present, 0 – Absent Driver Codes: T – teacher, S – student, B – balanced

VIa. PICTORIAL GRAPHIC CODING

Instructions: Identify scale, provide a brief description, and thumbnail sketch (if possible) of any pictorial graphics presented or created in the lesson.

ID:	Scale	Description	Thumbnail Sketch
		Choose one: O Teacher Driven O Student Driven O Balanced Describe Graphic: Describe Graphic:	

VIb. DATA-DRIVEN GRAPHIC CODING

Instructions: Identify graphic type, provide a brief description, and thumbnail sketch (if possible) of any data-driven graphics presented or created in the lesson.

ID:	Graphic Type	Description	Thumbnail Sketch
	OChart OTable OBar Graph OHistogram OFlow Chart OTimeline OVenn diagram OLine Graph ODouble Bubble OKWL O Stem and leaf plot OOther (describe)	Choose one: O Teacher Driven OStudent Driven O Balanced Describe Graphic:	