

TEACHER CHOICES ABOUT INSCRIPTIONAL AND TECHNOLOGICAL PRACTICES WHILE ENACTING INQUIRY SCIENCE

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Abstract: Science teachers are being asked to create constructivist learning environments in their science classrooms where students engage with the tools and processes of inquiry. In addition, teachers have an increasing level of accountability to national, state and local science standards and the standardized test designed to measure student achievement on these standards. How teachers ask students to use scientific inscriptions and technology can be a key indicator of the type of inquiry science occurring in the classroom. This study examines how two 5th grade teachers, in very different contexts, create learning trajectories for their students using Kids Inquiry in Diverse Species (BioKIDS), and inquiry-based technology-rich curriculum. The results indicate that attempts at inquiry science pursue a variety of goals shaped by teachers' choices about emphasis in two key areas, authenticity and the processes of science.

Introduction

The National Research Council's (NRC) National Science Education Standards (1998) and the American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy (1993) are the foundation of the call for classroom science in schools to be more inquiry based. These documents recommend students construct their own knowledge by engaging with the tools and processes of working scientist while investigating phenomenon in the world around them. The specific activities students need to participate in are:

“...making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results.”
(NRC, 2000, p. 23)

While these activities are clearly part of the scientific lexicon, studies of scientists engaged in inquiry in situ indicate scientific knowledge building is based on discourse within a community of practice (Latour, 1987; Lemke, 1990). The NRC's definition of inquiry mentions but does not emphasize communication as the driving force behind knowledge building in science. Knowledge building, while relying on the activities of inquiry science, is grounded in a context of inquiry that consists of rhetoric, representation and modeling (Lehrer, Schauble, & Petrosino, 2001). Discourse between

scientists, both in person and through publications, forms the foundation of scientific practice (Lemke, 1990; Roth & Lawless, 2002). Scientists tend to take these rhetorical skills for granted and thus they are not an explicit part of science practices suggested in the standards. How teachers can translate the discourse of scientific inquiry into science learning environments is a significant challenge engaging the field of science education.

Efforts to understand the development of science learning environments have been predominantly based on social constructivist models of teaching and learning (Bransford, Brown, & Cocking, 2000; Vygotsky, 1978). In particular, legitimate peripheral participation, suggests inculcating students to the cultural norms of a community, like the community of scientists (Lave & Wenger, 1991). A community of practice (J. S. Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Wenger, 1998) emphasizes students acting like scientists, and emulating the practices of science to become participants in the culture of science. A community of learners (A. L. Brown et al., 1993) includes specific consideration of learning *about* science while engaging in the *doing of* science. In a community of science learners classroom students work together not just to understand science content, but also the structure of science as a discipline. The shift to more community oriented models of the classroom has shifted the teacher more explicitly into a facilitator, or “more knowledgeable other” in the classroom (Palinscar, 1998; Putnam & Borko, 2000). Teachers are now in the challenging position of having to create learning environments that support students engaging in knowledge construction through inquiry science. Understanding how teachers attempt to meet these varied goals will allow researchers and designers to build better supports for teachers’ classroom enactment.

The shift in understanding learning to a cognitive perspective has transformed how teachers are being asked to teach and how researchers view classrooms. Teachers have been moved into the role of facilitator of individual students’ knowledge construction (Bransford et al., 2000). Research is beginning to define how new views of learning and teaching play out in classrooms for teachers and students. Much of this research focuses on how communities in classrooms can take up aspects of communities of practitioners. Cobb and his colleagues have done intensive and longitudinal studies of how classroom norms in mathematics develop over time (Cobb, McClain, Lambert, & Dean, 2003; Cobb, Stephan, McClain, & Gravemeijer, 2001). Ball & Bass (2000) investigated how students developed a classroom knowledge base and used it as a basis for discourse in mathematics. Roth & Lawless (2002) found that focusing on discourse patterns in a classroom could help students develop competent use of writing and abstract symbols in science. Two elements have been isolated as important to developing communities of science and mathematics discourse: inscriptions (Bowen & Roth, 2002; Cobb, 2002; McClain, 2002; Roth & McGinn, 1998) and technological tools (Koschmann, Myers, Feltovich, & Barrows, 1994; Linn, 1998; Means, 1998; Sandoval & Reiser, 1998; Songer, 1998).

Inscriptions are representations of data (e.g. data tables, graphs, or charts) used by scientists to present data as evidence supporting specific claims. Inscriptions allow scientist to represent their data in a way that supports the claims they wish to make in a form that is clear, focused, and can be transported or transformed easily. Inscriptions are

critical to the way scientist work and build knowledge in their communities (Bowen, Roth, & McGinn, 1999). Students need to engage in similar practices if they are to gain experience with the authentic tools and processes of science.

The use of technology is intimately connected to inscriptional practice in science. Scientists use technology to collect, organize, analyze, display, and communicate data. Research based inquiry science curricula reflect this interdependence as many have rich technology components as integral parts of their learning environments (Krajcik et al., 1998; Linn, Clark, & Slotta, 2003; Reiser et al., 2001). These curricula integrate learning activities with learning technologies to create environments for students investigating diverse content including biology (Sandoval & Reiser, 1998), environmental science (Means, 1998), chemistry (Wu, 2003), and physics (Roschelle, Kaput, & Stroup, 1998).

Classroom teachers must take all these components - inquiry, community, discourse, inscriptions, and technology - and develop them into a learning trajectory (Cobb et al., 2001) for their students. The shift toward more inquiry based science teaching combined with a philosophical move to a community of learners model has been difficult for teachers (K. S. Davis, 2003; Marx et al., 1994). Through their enactment teachers' must not only adapt the curriculum activities to fit the local context (Barab & Luehmann, 2003; Marx et al., 1994; Squire, MaKinster, Barnett, Luehmann, & Barab, 2003), but they must also adapt the technology itself (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Lin, 2002). Teachers' difficulties with meeting new challenges posed by constructivist models of teaching are not unique to science education.

Science education researchers interested in teacher learning are beginning to examine how research-based inquiry-science curricular materials get taken up and enacted by teacher (Crawford, 2000; Keys & Bryan, 2001; Roth, 1995; Tabak, 2002). It is research with teachers in classrooms that will help illuminate how success can be achieved in a variety of contexts and constraints. We know teachers can have success in a variety of contexts and within a variety of constraints (Songer, Lee, & Kam, 2002). A clear understanding of how teachers enact curriculum within local constraints is what Richardson (Richardson, 2002) suggests is missing from the current understanding of teaching, specifically "a theory of teaching focused on the act of teaching" (p. 3). This study is aimed at addressing the key issue at the center of research on teaching – what does effective constructivist teaching look like in action? This question is addressed in the specific context of the teaching of inquiry science.

This study investigated the choices teachers' make when developing a learning trajectory during the enactment of an inquiry-based biodiversity curriculum in fifth grade. The overall question used to organize the study was:

How do teachers choices about technology, scientific inscriptions and constraints they encounter shape a learning trajectory for sixth grade students learning inquiry science in the context of biodiversity?

The participants in the study were two teachers engaged with the enactment of an inquiry-based technology-rich science curriculum in substantially different contexts. I examined their practice to get insight into the larger analytical tensions they grappled with during enactment. The intent is to help teachers and researchers move beyond one idealized version of inquiry science (Songer, Lee, & McDonald, 2003) and develop a more nuanced view of how inquiry can succeed in a variety of contexts.

Theoretical Framework

This study is grounded in a theoretical framework based on the concept of communities of learners (A. L. Brown et al., 1993, Bransford et al., 2000). In a community of science learners students engage in the doing of science while at the same time stepping back and reflecting on what they are doing – i.e. learning about science. In a community of learners students develop rich conceptual understandings of science content and processes through both the *doing of* and *learning about* science.

Doing science is defined by the NRC (National Research Council, 1998) in terms of the activities of inquiry and focuses on the tools and process of working scientists. If teachers are to engage students in the authentic practices of science, however, a shift in emphasis is required based on the illumination of science practices by research in the social studies of science (Latour, 1987; Lemke, 1990). This work indicates that science is a community process of knowledge building where scientists use inscriptions and rhetoric to support claims they make about the nature of the world (Roth & Lawless, 2002). Translating communities of science practice into classroom communities of science learners is a significant challenge for teachers and an growing area of research in science education.

Lehrer, Schauble, & Petrosino (2001) suggest inscriptional practices and scientific argumentation as the foundation of experimentation in science:

“We suggest that three related aspects of science – namely, rhetoric, representation, and modeling – must be well established in the background context if experimentation is to be a meaningful activity for students, rather than a disembodied method” (p. 251-252).

Students in science classrooms must engage in scientific argumentation to construct both individual and community understandings (Roth & McGinn, 1998). Framing science as a rhetorical activity does not alter the activities of scientific investigation described in the standards, but instead changes the focus from science as a method to the establishing norms in a community that reflect the discourse of science knowledge building (Roth & Lawless, 2002). Similar work in mathematics has shown that supporting the establishment of classrooms norms (Cobb et al., 2001) and classrooms shared knowledge base (Ball & Bass, 2000) can create a more powerful learning community for students.

Scientific rhetoric is fundamental to inquiry science and inscriptions are fundamental to rhetoric, then technology is a core support for the collection data and creation of

inscriptions from that data (Latour, 1987). If communities of science learners are to reflect scientific practice then the use of technology becomes an important component in inculcating students to the tools and processes of science. What requires more consideration is how technology interacts with inscriptional practices to support scientific rhetoric.

Professional science is dependant on rhetoric supported with inscriptions created with increasingly sophisticated technology. How do these practices translate into a learning trajectory for students? A teacher must make choices about how inquiry science is enacted in her classroom. What choices does a teacher do when confronted with the task of creating a learning trajectory where science learners construct knowledge around specific content goals? How does she make choices about what questions students can investigate, what data students should collect, what they should do with the data and how they should communicate their findings? Teachers are increasingly being held accountable to specific content standards (American Association for the Advancement of Science, 1993; National Research Council, 1998). The various ways teachers address this multifaceted challenge while allowing students to engage with the processes and tools of science is a critical area for science education research.

Design and Procedure

Context

This study was conducted with two teachers during their enactment of *BioKIDS: Kids' Inquiry into Diverse Species* (Songer & Meyers, 2001), an eight-week, inquiry-based, technology-rich biodiversity curriculum designed for 5th grade students. BioKIDS was designed to meet National, State, and local standards in biology and inquiry science (American Association for the Advancement of Science, 1993; National Research Council, 1998). BioKIDS involves students in technology supported field data collection, in-class observation of animal specimens, and research on local animal species. The curricular activities have been specifically designed to scaffold students' inquiry skills with respect to claims based on evidence (Lee, 2003). The activities use local biodiversity data gathered by students using Personal Digital Assistants (PDAs) in their schoolyard or field site. The student data is used in inquiry-fostering activities designed to guide students in the analysis of animal abundance and richness. Students are in the field observing and collecting data while also considering how their local data fits into a broader scientific understanding of biodiversity. Finally, students gather information about local species with a web-based resource of taxonomically arranged local species information accounts, the Critter Catalog. These components work together to support both the students and the teachers in creating learning opportunities around the concept of biodiversity.

Teachers

The teachers chosen for this study represent critical cases (Moschkovich & Brenner, 2000). Two teachers were chosen from a group seven enacting the BioKIDS program in the fall of 2002-03 school year. They were selected in an effort to portray the diversity of enactments that occur based on the same curriculum, in the hopes that these critical cases

might provide interesting issues for further examination. The teachers were both prior participants in BioKIDS and were both teaching 5th grade students. Specific contrasting criteria were: urban / suburban, strength of science content background, self-contained classroom / subject specific classes, and teaching philosophy. The two teachers were identified, approached by me, and consented to participate.

Mr. Denny was in his mid-thirties and had been a elementary school teacher for 12 years. He taught a mixed fifth and sixth grade class in a mid-sized, well-educated, affluent suburban town. His school was a K-8 school of choice based on the open philosophy of education (Combs, 1991), which is progressive and student-centered. He had 28 students in his class, 13 sixth graders, and 15 fifth graders. There are eleven girls and 17 boys. The school is located a short (10 minute) walk from a 52 acre undeveloped park which Mr. Denny used as a field study site. Mr. Denny was an English major as an undergraduate, and had little background or formal training in science. Mr. Denny's classroom had six computers, four that are at least two years old and two newer ones (iMacs) with Internet connections via the school network. He also had access to a computer lab in the room next door containing approximately 30 iMac computers with Internet access. He needed to sign up for this lab to use it, but seemed to have little difficult getting access to the room when he needed it.

Ms. Brooks was also in her mid-thirties and had been a middle school teacher for 10 years. She taught 5 science classes a day, two of fifth graders and three of sixth graders in an urban district. Her school was a charter school for grades four through eight, emphasizing Mathematics, Science, and Technology. The class I observed had 29 fifth grade students; there are 14 boys and 15 girls. The school is located on a major street with a small (approximately 1.5 acre) fenced-in playground behind the school. One area contains a play structure with woodchips around it, another has a basketball court, and there is also an area of open grass at the back of the playground. There are two large planting boxes in the sidewalk between the parking lot and the playground. In addition to the playground, there is a small area at the front of the school with grass, flowers and two trees. Ms. Brooks has 30 computers in her room mounted below the desks. The machines are all about two years old, and only about half of them are functioning at any given time. They are commonly missing mouse balls, will not start due to software issues, or cannot connect to the school network to get Internet access. During BioKIDS Ms. Brooks and I did the support and repair of the classroom computers.

Data

Data were collected to allow for cross case analysis of two individual teacher cases of enactment of the BioKIDS curriculum. The data were collected over the course of the teachers' ten or eleven week classroom enactments and consisted of: (a) interviews with teachers prior to the start and after the completion of the curriculum; (b) audio recordings from a lavalier microphone of the teacher during classroom enactment; (c) my fieldnotes from observations of lessons; and (d) audio recordings of informal meetings between the teacher and me. Secondary data included student pre/post tests with multiple choice and open-ended questions and samples of student work used to indicate student learning. In addition there were fieldnotes for all of these days of enactment and student artifacts.

The student artifacts included student notebooks from Ms. Brooks' class and student produced artifacts ranging from written reports to Hyperstudio stacks from Mr. Denny's students.

Analysis

The primary data analyzed for this study were the interviews, informal meetings with teachers, and enactment data from the two classrooms as represented in the fieldnotes and audio of the teachers. Analysis was based on guidelines from Miles and Huberman (1994). A detailed description follows, but the steps of analysis can broadly be characterized as: (1) preliminary elaboration of fieldnotes, (2) generation of initial codes, (3) transcription of selected audio to further elaborate fieldnotes; (4) coding of fieldnotes / transcription; (5) development of conjectures and modification of codes, (6) testing of conjectures against the corpus of data, (7) general themes developed based on conjectures, (8) detailed narrative written to exemplify themes, and (9) themes revised and clarified with input from participants and other researchers.

The data were coded in units of analysis representing complete ideas ranging in length from a short sentence to a short paragraph. More than 2300 units were coded from the transcripts and fieldnotes of 37 days of enactment. Each unit was coded with at least one code representing the analytical value of that unit. For example a unit might be coded as representing a teachers choice about a content goal (e.g. understanding the concept of richness) for the students. A total of 43 codes were used representing teachers' choices about authenticity, science content, inquiry process, use of inscriptions, use of technology, and constraints.

Vignettes

To understand the findings from this study it is important to get a sense of the differences between the two teachers' enactment of the BioKIDS curriculum. In the following section vignettes are presented representing each the enactment in each of the two classrooms. The vignettes are chronological with dates of direct quotes from teachers in brackets following the quotes. The direct quotes are linked together with text written for these vignettes based on fieldnotes from the teachers' classrooms. The vignettes highlight incidents that represent the choices teachers make about the goals of their enactment as that is the focus of this paper. Mr. Denny's vignette shows his focus on having students provide input and direction to their own investigations. He also emphasizes observation and identification of organisms when his students are in the field.

Mr. Denny

Mr. Denny and I met for his initial interview. I asked him about BioKIDS, his plans for this year and how it would be different from the previous spring.

"I would much rather see the kids, if they're really passionate about one subject or one idea, let them pursue that and through pursuing that they'll

learn how to write well and learn how to research, gathering information and then making decisions based on information.” [09.15.02]

The spring of the 2001-02 school year he participated in the BioKIDS program and agreed to follow the written curriculum closely for purposes of my colleagues research on curricular supports for claims and evidence. In the fall of the 2002-03 school year he was going to do BioKIDS, or more accurately an exploration in biodiversity based on BioKIDS, his way. He emphasized going out to Riley Park, which he will use as a study site for the class and described his hopes for his students during their study of biodiversity in Riley Park:

“gather information, organize data, make some conclusions based on your data, use technology to help you gather and sort and present data, practice some research skills and certainly in the context of doing all of that you're going to be doing a lot of reading and writing.” [09.15.02.]

Mr. Denny started the first day of BioKIDS by walking to the meeting area at the front of his room:

“Today we are going to Riley Park for a BioKIDS experience. Riley Park is going to become like our lab, like you have a science lab upstairs. So, today were going to go there as a class. My expectation is that we just kinda walk around, familiarize ourselves with the park. We have an aerial map of what it looks like. And I would like to get you guys to the point where you just feel comfortable with the main trails in this park. It is not huge, but it is somewhat confusing, because there is a maze of trails in there. My intention is to be out there every Monday for the next seven to eight weeks, alright.” [09.16.02]

Then he asks students about vocabulary and defines key terms, specifically biodiversity, abundance, and richness. While talking with his students he is writing these terms on the board.

Mr. Denny tells me he sees himself as a facilitator of students' interests. I am interested in how he plans if the curriculum is so dependent on students and what they want to learn? How does he organize what students do in the classroom?

“I come up with an idea or situation through what I've heard them interested in, I'll do some initial organizing and exposure, then I'll turn it over to them, see their reaction and then I'll go from there. That's what my jumping off point is and then I kind of use the kids almost like leap frog. I know after Monday they're going to come back and have ideas about what they're interested in and then my job becomes taking those ideas and helping the kids to formalize them more.” [D.09.16.02]

The students have just finished their lunch and Mr. Denny calls them into the front of the class to go over their goals for their time in Riley Park. He did not have them carry

anything for recording fieldnotes. However, on returning to the classroom he is debriefing their experience and setting expectations for the curriculum and he brings up the topic of a field notebook.

“These are like reflective journals or maybe what you can think of as a field journal.” [09.16.02]

He mentions that the students will use CyberTracker, a tool used by field biologists that can also help support them when they are collecting their field data at Riley Park.

“OK. Well it's a little more than just using the palm pilot, I'm glad you've been exposed to it, but its also using a program on the palm pilot that will help you when you're out in the field, out in Riley Park, take useful notes.” [09.16.02]

The following week as they prepare for their next field site visit, Mr. Denny asks students to move beyond talking about a species or group of animals they are interested in and toward an investigation in biodiversity. To facilitate this he turns the class to the list of groups they have formed based on their interests. Mr. Denny asks everyone to make a final choice of which group to join. After some changes by students many of the vertebrate groups have disappeared from the list. This is likely because Mr. Denny has discouraged studying them as they are difficult to find and count. The final list of groups includes: trees, spiders, insects (or arthropods), fungi, and one student interested in birds.

The following week before the field visit he encourages students to make more detailed notes about the environment surrounding the specimens they find in the field.

“Insect people, I want that you do, when you find an insect, I know like Scott's group did a good job of this. Take some notes about its environment. Where do you find it? On the ground? On the tree? Maybe what kind of tree. Under debris, in the sunshine, OK.” [09.30.02]

It is also on this third field visit day that Mr. Denny starts to talk more specifically about making drawings of the animals, particularly of the insects and spiders groups are finding in the field, as a way to gather more information in their fieldnotes. Mr. Denny says their up close examination of the animals will help them identify the animals for later study. The students have one more of field site visit on Oct 7th.

After a two-week hiatus from field visits due to a scheduling change, Mr. Denny feels the weather is too cold and also that students have had adequate time in the field for data collection, so there are no more field site visits. The class begins independent work on their BioKIDS projects. He begins class by reading through the drafts students have submitted describing the project they plan on doing to represent their learning during the field visits:

“An orb weaver, Bill and I are planning to do a report on orb weavers. Great. That's I think Fernando. You guys today can use the computer lab

and get on there and use the Critter Catalog. I will pick seven spiders. I will study each of them and then write the basic information about them.” [10.28.02]

“I will measure the abundance of box elders and sugar maples and at the end I will compare the numbers and see which has higher abundance. Nice, Henri.” [10.28.02]

During their individual work a number of students are having difficulty as they did not collect specific data, but made observations and collected specimens. One of the difficulties with the specimens is that most student groups (e.g. fungi group, spider group, and insect group) are having difficulty identifying their organisms specifically enough to find more information about them:

“If you can’t figure out what kind of spider that spider is then you could study another spider. That’s fine, OK... The problem is there’s so many insects that, arachnids, insects, arthropods, whatever you want say, that nobody knows them all and I don’t know that even Hank [BioKIDS field biologist / entomologist] would know them so you could be doing a, what I’m asking you to do is find a similar spider, get as close as you can and study that. OK, yes and that’s fine. You know it’s a spider right? You can certainly find a spider that looks similar to it.” [10.28.02]

After class Mr. Denny mentioned something he saw going differently from last year and in particular how the end of the unit was shaping up differently this year.

“I’m finding is, is that the variety of the ways the information is presented is going to be pretty cool and that level at which there, and this is what my thought is, that level of detail for each project is going to be much deeper and in the end I would like to, to pull them together and maybe focus more than, because right now, I think last year they got a bigger picture idea. This year they’re getting more in-depth into one individual and I’d like to tie them all in at the end and look more at abundance and richness, you know. If your Cardinal eats beetles and there’s no beetles, you know.” [10.28.02]

The inability of the students to find information about the individual animals they found in the field continues to cause frustration. Most of them end up researching their animals at the group (e.g. funnel-weaver spiders) level which is more general. Mr. Denny asks them to work with this more general information for their final projects. He most often asks them to find information about their animal or plant through Internet or library source books and asks them to prepare a report based on that information.

“Well I would suggest this, you have, you have some trees that you found, right? You could find information on those, on the Internet. You could look them up in a tree book. I have many, many different books over here on trees. All right. You could write up a report on those. You could do a

picture of those, however you're going to share your information.”
[11.11.02]

As students come to Mr. Denny with difficulties he continues to act as facilitator and guide to help students get some form of a final working product.

“All right, well you have box elder, you have sugar maple. You could, if nothing else, you could take this, type it up. Edit it, type it up, OK. How about that lad, that's something you could work on.” [11.11.02]

The final projects ranged in scope and presentation medium. Steven completed a fairly detailed map of the trails in Riley Park. Gretchen and Marion created a video about the fungi they found in Riley Park, identifying some and just showing some to the camera. Carl, Peter, and Hector each made Hyperstudio™ stacks with information about funnel-weaving spiders. Octavia and Isabelle collaborated to make a book of trees including information about the trees found on the Internet, picture of them from Riley Park and collected leaf samples. The projects, regardless of medium and type of organism, were descriptive reports on animal or plant groups whose members could be found in Riley Park.

Ms. Brooks

Ms. Brooks and I talked after school the day prior to her starting the curriculum. I asked her about plans for BioKIDS and the types of outcomes she is interested in. She is going to add an optional activity included in the curriculum about connecting biodiversity to a local environmental issue.

“I was going to try and find out, and it was something I was thinking about when I was seeing about the brownfields was there's a couple of areas. We've got a couple right around the school over here. I think on the other side of that house there's an empty lot. We could maybe even look into it or we could even compare our schoolyard to that lot... because the people that live in that house, this year their son is enrolled in our school.”
[09.17.02]

Brownfields are areas with commercial or hazardous waste on them and often appear as abandoned lots. They are a significant problem in Urbanarea as there are a large number of sites and no money in the city coffers to clean them up. As it is a problem in Urbanarea and there is access to some in the immediate vicinity of the school it seems a logical choice for a jumping off point for a connecting BioKIDS to a local issue.

Ms. Brooks was interested in her students learning the content and process of science and saw BioKIDS as a way to do that in an interesting and engaging way. She is primarily interested in preparing her students for taking the standardized exams. One of which, the Midwestern Assessment Program (MAP) is a high stakes test linked to school success and can lead to reorganization and closure of schools receiving failing grades.

“So I mean the [Urbanarea Public Schools] curriculum’s all spelled out. I mean as far as the skills we’re teaching the standardized tasks so I don’t have a whole lot of choice in some of those other matters. You know I’m teaching so that they are successful on the MAP, and that’s it.” [09.17.02]

In the past Ms. Brooks has participated in other curriculum units designed by the University of Michigan through the systemic change initiative she is a part of in the Urbanarea Public Schools. As one of a series of curricula, BioKIDS was designed with the standards and pacing guide of the school system in mind, and thus it is aligned well with these goals. She also expressed interest in having students collect and analyze data and improve their critical thinking skills.

“I think what [the BioKIDS curriculum designers] have going here, the kids really have to think. I mean they’re working on the critical thinking skills. They’re observing and looking at things more critically and having to analyze it.” [09.17.02]

She mentions that about midway through the curriculum most of the students will be participating in a field trip to a camp about an hour north of the city. She has made this trip in the past to allow inner city students an experience in the country. She has never viewed it as an explicit science learning opportunity. In the context of BioKIDS, however, she sees possibilities for connecting the experience at the camp with the activities students are engaged with in school. She begins by talking about what students have done in the past while at camp and how it could connect to BioKIDS.

“They saw frogs and they were small things that were camouflaged in the woods and they were just maybe on walks or hikes or going from one program to the next and it was the young ones that were spotting things. So you see it might be interesting to see if we can take the CyberTracker with us.” [09.17.02]

While the use of CyberTracker to collect data at the camp is interesting to her, she is particularly interested in having students use their data in addition to the field data they collect at the school to aid in their investigation of biodiversity.

“I would like to look into that because as I was reading the first activity they need to research, make some comparisons between that and [the data they collect] on the CyberTracker.” [09.17.02]

Ms. Brooks chose to augment the first curricular activity by spending more time developing a schoolyard map and making it into an interdisciplinary activity with the Mathematics teacher, Ms. Dunn. Students will spend the first day measuring the perimeter of the schoolyard and the remainder of the week in the classroom adding detail, color, and scale to their map.

“We have a couple of tasks today before we go out and get started... with collecting some of our data and that is we need to select a group name for

our team, so our team name and we need to go outside and map out the area that we're going to do our field research in and that area is our schoolyard." [10.01.02]

Ms. Dunn puts particular emphasis on scale as this topic is covered in the MAP. The next three days of the class are to be spent either outside measuring the schoolyard with a trundle wheel (day 1) or determining an appropriate scale and completing and coloring the schoolyard map (days 2 & 3). Students work in groups and complete one map per group. Ms. Brooks used the mapping exercise to set the frame for the remaining learning the students were going to do around biodiversity.

The day after student complete their maps, Ms. Brooks opened class by reorienting the students to the map and its relationship to the schoolyard. She then worked with the students to divide the schoolyard into zones A - E to assign one zone per group in the class.

"We need to divide up our schoolyard into zones then we need to assign zones to each group and we need to go outside and start collecting some data for our zones. So that we have a little better idea of what our school looks like, what that school map looks like, we need to sort of section it off or look at it in terms of how is each group going to collect data from one particular area in our schoolyard." [10.07.02]

After dividing the schoolyards into zones Ms. Brooks asks students to go outside in their groups and make some observations while sitting silently and listening:

"OK so our job is to go into our zones... you're go into your zone and I'll call time then you'll close your eyes for two minutes and watch my second hand and then I'll call time again and you'll open your eyes and we're going to come back into the building to write down our observations." [10.07.02]

After the silent observation students collected data on the habitats in their zone using a worksheet from the curriculum. After class Ms. Brooks mentioned she wants students to focus on data collection in the next couple of days, as she wants to make sure students have data rich enough to make comparisons.

The following day students are preparing to head into the field to collect habitat data about their zones. Ms. Brooks walks them through the details of the sheet and lets them know that they will each have a role when they are out in the field. As they continue to walk through the worksheet she makes clear the roles the students will be playing while in the schoolyard collecting habitat data:

"OK so it's telling you about all the different things, all the responsibilities you have as a field biologist." [10.08.02]

After class when we are talking, Ms. Brooks compares an investigation from the recommended textbook for sixth grade science and the biodiversity investigation in BioKIDS.

“...sometimes I don't see how some of the investigations...in their textbooks actually are teaching the concept.” [10.08.02]

After students returned from camp they used the skills in data collection with CyberTracker to collect the data in their own schoolyard. The data is considerably different from the data collected at Camp. The camp is significantly more biodiverse than the schoolyard. Ms. Brooks wants to have students be able to make data comparisons between the Camp Lake in the Woods data and their schoolyard. She is specifically interested in them making comparisons so they can begin to make claims about the differences in biodiversity.

“All right, we're changing gears a little bit here but since you went to camp with us you had an opportunity to use the Palm Pilots and the CyberTracker program and we have that data and what we thought we'd do today, since we have the whole group, is use the CyberTracker, the Palm Pilots to go outside and have you collect some data in your zones so that we can come back and take a closer look at the two different habitats.” [11.05.02]

When the students are in the field Ms. Brooks emphasizes the purpose of the data collection:

“OK so now we're looking for evidence remember and it's going to ask you how you saw your evidence.” [11.05.02]

Ms. Brooks intended the data collected to be evidence used later to make claims about the biodiversity of schoolyard zones. This data collection is a foundation for the later analysis where students will create inscriptions from that data when analyzing the schoolyard zones.

The final activity of the unit involves the analysis of their schoolyard data to determine which zone is most biodiverse. The students receive spreadsheets with the data they collected using the CyberTracker software. Ms. Brooks moves the students through the activity of representing their data in graphs and then making claims about the biodiversity of the zones. The first step in this process is to make the question, and the form of their hypothesis, explicit.

“So our class hypothesis – [starts reading from a BioKIDS worksheet] using the habitat data that your class collected for each zone, determine which zone you think will have the highest bio-diversity of animals. Think about which zone offers homes for the largest number of animals or abundance and the greatest number of types of animals, which is richness

[done reading]. So take a minute there with your group to make that hypothesis and give two reasons why you made that choice.” [11.06.02]

The next step asks students to create data tables by transferring data from the summary sheets onto worksheets that are part of the curriculum. Then they will graph this data and begin to think about what conclusions the data will support.

“OK so what we're going to do is take the information from our data summary reports and we're going to put together a data table.” [11.06.02]

“Here's our data table, but we need to use our summary reports to get our information for those tables then we can use the information from our tables to make some graphs.” [11.06.02]

When students are asked to support their claim about which zone is the most biodiverse with the evidence from their data, Ms. Brooks returns them to the core components of biodiversity and reminds students their claims should take these into account. In the end, the students' work with their CyberTraker data represents the primary summative activity for their study of biodiversity. The remainder of the time spent on BioKIDS was 5 class periods from 11 November to 20 November working on individual animal research and sharing this research within small groups.

Analytical Tensions

Tension – [Physics] A constrained condition of the particles of *a body* when subjected to forces acting in opposite directions away from each other, thus tending to draw them apart, balanced by forces of cohesion holding them together.

-Oxford English Dictionary 2nd edition [emphasis added]

The results of this study are framed in the form of tensions to emphasize that teachers are being pulled in different direction along different axis during their enactment and must make choices that have trade-offs. The learning trajectory the students experienced is a direct result of how the teachers made choices about where they felt equilibrium lies within each tensions at a given time. These equilibrium points charted over time represent the learning trajectory. The key part of the definition “a body” – that is the tensions exist within a single construct. The concepts of authentic learning and authentic science are different components of the same construct, namely authenticity, and no enactment however much it is more of one is ever without the other. Each individual choice a teacher makes more clearly defines the learning trajectory and thus where that particular enactment falls along the tension. All teaching is a balancing act where priorities are weighed with the understanding that all choices lead to trade-offs and compromise. The forces both external and internal on these teachers can be quite large and where they feel at equilibrium defines not only this individual learning trajectory, but also them as teachers.

Two tensions emerged regarding teachers' goals while enacting BioKIDS. The first tension deals with how teachers view authenticity. The second tension was related to teachers' choice of emphasis between the processes of natural history and natural science. These tensions describe analytical dimensions of enactment that emerged illuminating the struggle teachers engage with while creating classroom communities of science learners.

Authentic Learning and Authentic Science

Authenticity in teaching science has two distinct components - supporting students as they pursue their personal interests toward unique understandings of content and supporting the development of students' understandings of the unique culture and practices of science. A teacher may have students engage with a question of interest and facilitate the pursuit of an answer without consideration of the particular processes or content the student will learn. A teacher may also engage students in simplified or scaffolded versions of the processes and content of science without concerning themselves with the inherent interest these processes and content have for students. Striking a balance between these, or not, is one of the key decisions a teacher makes to define the culture of a classroom and the students' learning trajectory. Teachers more focused on *authentic learning* are facilitators, allowing students to initiate the choice of content or approach to content which interests them and then assisting students with formalizing their interests into a curricular structure, one tailored to the individual student and their interests. Teachers more focused on *authentic science* attempt to development of a community of practice, where students are engaged in the culture and practice of science including the tools, techniques and methods scientists use when engaging with similar content area problems. Teachers make choices about the content and approach to content, if somewhat broadly defined, and students work toward answering questions the teacher has selected to drive intellectual engagement with the content.

Natural History and Natural Science

Webster's defines *natural history* as "a work dealing with the properties of natural objects, plants, or animals; freq. implying a popular rather than a strictly scientific treatment of the subject." While *natural science* is "[a] science, as biology, chemistry, or physics, based chiefly on objective quantitative hypotheses." The contrast between the two key components of this tension is subtle but critical in terms of the goals of the activities students engage in and the way the activities are portrayed as part of the endeavor of science. This tension is also suggested in the change that occurs as students move from elementary school science to high school science (middle school, as always, is a varying hybrid of these two). Elementary students usually engage in *natural history*, describing the world and its wonders without explicitly analyzing its nature based on goals of describing larger patterns or abstracted rules. High school students, however, tend to use "the scientific method" to address problems, generate hypotheses about how the world works, and endeavor to collect data to support or refute these hypotheses. The fundamental difference between natural history and natural science is that one favors description and observation, and the other favors data and analysis.

A learning trajectory reflecting the values of natural science will have student making observations, writing in their notebooks, and perhaps collecting specimens for

identification. A learning trajectory reflecting the values of natural science will have students collecting numerical data allowing for analysis and comparison, representing their data (with an inscription of some kind), and building an argument or claim and supporting it with these data. These key constructs are differentiated primarily by differences in the intent and focus of the activities students are engaged in, the difference between descriptive and analytical goals.

Discussion

The results of this study indicate that inquiry science curricula designed with flexibility in activities and activity sequences allow teachers to pursue their own learning goals for students. In particular this study has implications for how authenticity is considered in inquiry science and also how the tension between natural history and natural science plays out over the course of K-12 science education.

Authenticity and Accountability

This research contributes to the ongoing dialogue on creating communities of science learners (Krajcik et al., 1998; Linn et al., 2003; White et al., 2002). The majority of research on communities of science learners focuses on how teachers can engage students with the tools and processes of science (Lehrer et al., 2001). This work indicates that for a complete understanding of authenticity in communities of science learners we need to better understand the role of authentic learning.

For authentic learning to be taken seriously as a key component of science learning it must be better defined and assessments must be developed to evaluate student abilities. A teacher must pay attention to the knowledge and beliefs their students have in order to plan effective instruction (Bransford et al., 2000). This study indicates that it is also critically important to pay attention to the students' interests and questions about content and processes in science. By doing this and providing flexibility within the curriculum we allow teachers more choice about the balance between authentic learning and authentic science. Adding what amounts to flexibility in content taught is in direct opposition to essentialist conceptions of education e.g. (Hirsch, Kett, & Trefil, 1988), and rigidly systematic methods of teaching (Slavin & Madden, 2001).

Creating curriculum to support this flexibility poses challenges. In most school systems there is not the time, resources, or structure to allow students to engage in independent inquiry about science. One possibility is for curriculum designers to develop alternative paths within the curriculum, each of them leading to different sub areas of the topic being studied. The flexibility would allow a teacher to manage different paths through the content for different students and increase the authenticity of the learning. Students on different paths, and thus answering different questions within the broader content framework could allow for more discussion of the relationship between questions, claims, and evidence. In this way inquiry science curriculum with an explicit authentic learning component could contribute to students understanding of the context of inquiry science (Lehrer et al., 2001; Roth & Lawless, 2002).

Given the current policy environment with emphasis on accountability, however, it is not possible to argue for educational changes without measures to support their value for learning. Assessment measures must be developed, as they are being for inquiry process skills (Songer, 2004; Wenk & Songer, 2004) that measure component skills of authentic learning and its contribution to learning science. One possible measure could target students' ability to generate scientific questions they are interested in answering.

Longitudinal View of Science Learning

The tension of natural history and natural science that emerged from the enactment of the two teachers in this study point to a larger pattern in science teaching and learning. Elementary school teachers struggle with teaching science and particularly with inquiry science (Arora, Kean, & Anthony, 2000). Elementary school science tends to be more focused on natural history, usually to the exclusion of the analysis fundamental to natural science. When students are young teachers emphasize observation and identification in large part based on Piagetian and Neo-Piagetian views of children's development (Metz, 2000). Secondary schools reverse this emphasis with students learning much of science abstracted away from the phenomenon in nature. Physics classes for high school students can be more about developing heuristics for solving mathematical problems with little regard for developing an intuitive sense of physical phenomenon. When students do engage in hands-on activities they are likely to be scripted and may even reinforce a heuristic or right answer epistemology of science (Chinn & Malhotra, 2002). Teaching students systematic ways of solving similar problems is done in the name of preparing students for college classes, which further abstract science from nature.

Piagetian views of what elementary school students are capable of are being challenged (Metz, 1995). The National Science Standards (National Research Council, 1998) are calling for more inquiry across grade levels. This study indicates that a balanced approach between observation and analysis is needed, but should evolve over a student's school career. Students in elementary school need to engage in abstraction and inference in order to understand the function and nature of scientific inquiry. Observation should still be the largest part of what students do in their early careers, but observation should be seen as a critical and early stage of a larger process. In secondary school more attention needs to be paid to contextualizing science content in real-world phenomenon that students experience. It may be that the bulk of the work that high school students do is analytical, but without experience to frame abstract concepts there is a loss not just of understanding of the content, but of the nature of scientific endeavor and knowledge. The two teachers in this study represent the fairly abrupt transition from concrete to abstract that often occurs between elementary school and secondary school. Both teachers have sixth grade students, but Mr. Denny's class was much more typical of an elementary approach to science, while Ms. Brooks' students were engaged in analysis and inference from data. What seems likely to be most effective is a blended approach to science that respects the skills of both natural history and natural science. The teaching and learning of science should evolve throughout the k-12 curriculum moving gradually from more concrete to more abstract, but never one to the exclusion of the other.

The main implications from this research are:

- Authentic learning must be more explicitly considered by both researchers and teachers.
- In order to better understand authenticity in science classrooms we need assessment tools designed to measure its components.
- Students' development of science process skills needs to be considered longitudinally as a blended and evolving mix of the skills of observation and analysis.

Conclusions

This study is part of a larger systemic effort to impact middle school science teaching in urban public schools. Creating change is difficult and requires scaling multiple curricular programs across multiple grade levels to build students inquiry skills not just over a school year but also over multiple years. This study contributes to a larger picture by shedding light on teacher enactment, the critical interpretive interface between research based inquiry curricula and student learning. Only through a deep understanding of the nuances of interpretation and enactment of curricula can research based reform programs begin to build the long term collaborative and supportive relationships with teachers needed for real reform in urban schools. This study contributes part of the answer to some of the critical questions about the relationships and resources needed for teacher to change their practice. Understanding some of the issues teachers must address during enactment also leads to questions about how researchers can help teachers take ownership of reforms and work with researchers to create a balanced fit between reform and the local context.

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