Activity in Pervasive Computing Project-Based Science Classrooms

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Project-Based Science (PBS) is an educational paradigm supported by recent developments in learning and motivation theory that suggest learning may be facilitated through meaningful and inquiry-oriented activities (Blumenfeld, et al., 1991). Project-based science learning environments produce communities rich with activities that enable students to explore and construct understandings and meanings in science. These socially-situated activities lead to the development of a unique culture with its own set of values, meanings, and practices presumably centered around learning and doing science (Latour & Woolgar, 1979; Lave & Wenger, 1991; Ruopp, 1993). In PBS classrooms, students actively construct their knowledge during projects consisting of: 1) a question or problem that serves to organize and drive activities; 2) a series of products that address the question or problem; 3) students engaging in authentic investigations; 4) communities of students, teachers, and members of society engaging in discourse about the problem as well as collaborating together; and 5) the use of cognitive tools, including portable computers, Internet information and communications, modeling and simulation software, page layout and presentation tools, and hypermedia construction kits.

The use of these tools, like all technology, is socially-situated and becomes embedded in cultural practices (Bruce & Rubin, 1993; Pea, 1994; Pfaffenberger, 1992; Riggins, 1994; Rogers, 1995; Sheingold, Hawkins & Char, 1984). Examining the interaction of the technology with the situation in which it is used is crucial since technology is necessarily embedded in social practices and it acquires new and unexpected shapes as it is re-created to conform with the goals and norms of the people who use it. The tools help define what practices are possible and contribute to the system of values and meaning making within the culture. Activity is shaped through the use of tools and technologies, and in classrooms, learners become active participants in the culture by using the technologies. As the community adapts to the methods and uses of these tools (and adapts the tools to the community's particular needs), the cultural practices and values change.

In this paper we examine the cultural practices in a PBS classroom during one project where students routinely use computational media tools to produce a World Wide Web resource about toxins found in water. Specifically, we examine 1) The influence technology has on the goals of the classroom, and 2) The role technology plays in sustaining the activities which reflect the developing classroom values. These questions focus not on the technology, but on the technology in use, in a situation-specific set of social practices around learning and doing science. The long-term concern of this research is on the changes in the social context and how the technology is used and assimilated within the culture to sustain cultural values and science learning.

Method

We employ an ethnomethodological approach to data collection and understanding the classroom practices (Whyte, 1984). For the past two-and-a-half years, the first author participated as a technician, researcher, and software designer in a PBS environment in which three high school science teachers, with the assistance of the Hi-C research group at the University of Michigan, designed and implemented a three-year, project-based science curriculum called Foundations of Science (FOS) (Huebel-Drake, et al, 1995). One class of 25 students is the focus of research from their first year in high school (in FOS I) through the first half of their third year (FOS III). During this two-and-a-half year time period, daily and weekly field notes, artifacts from the environment, video tapes of classroom sessions, and interviews with students and teachers have shaped our understandings of the activity systems present in this community. In this paper, we describe a recent project in FOS III and provide a brief analysis to explicate the various roles and values present among teachers and students and how the use of technologies are socially-situated in this PBS learning environment.

Context

At Community High School, all Freshman, Sophomores, and Juniors take Foundations of Science I, II, and III respectively. These classes meet once a day for 50 minute time slots five days a week. The teachers clearly state that the FOS curriculum is based on project-based science, integrates earth science, biology, and chemistry, provides opportunities for authentic, local science projects, and includes routine use of computational media. The curriculum ranges from very traditional science instruction (lectures, required reading, de-contextualized lab work, worksheets, and exams are provided) to open-ended, artifact-centered, long-term, inquiry-based units.

The Room. This school year, the FOS III class meets in room 317, a room rich with computational media technology and constant activity around the tools. The room is wired with Ethernet at every table, there are two printers (one laser, one color ink-jet), two digitizing scanners, three publicly-accessible Macintoshes along one side of the room (one with A/V capabilities), and two locked computer cupboards – one on wheels – containing about 40 color PowerBooks total. An ISDN line connects the school-wide Ethernet to the Internet through the University of Michigan Digital Library project. In addition, on the LAN lie several local servers with student storage space and an Internet server providing World Wide Web and FTP services for the students. In cupboards, students can find CD-ROMs, a digital camera, a video camera, and a video microscope. Despite all of this computational technology, room 317 also has attributes commonly associated with traditional science classrooms. A blackboard and a dusty overhead projector are the only shared writing surfaces, cupboards along the side of the room hold balances, hot plates, glassware, microscopes, and thermometers. A television, VCR, and videodisc player on a cart are also prevalent fixtures. Three islands along the center of the room hold power, gas, as well as Ethernet outlets. Students sit at large tables, each with four chairs, set up in six blocks centered around the islands.

The Unit. During the second unit for the FOS III students, entitled "Is My Drinking Water Safe?," students worked alone or in pairs for six weeks to investigate a single water pollutant of their choice and answer 11 questions posed by the teachers that covered issues in social, chemical, health, and ecological areas concerning the pollutant. Students were to use a range of resources to conduct the research, including the World Wide Web, library materials, information from local and government ecological and conservation organizations, guest speakers, videos, laboratory experiments, and lectures provided by the teachers. Students were at first required to develop a project plan for their work using PlanIt Out, a software package developed by the Hi-C research group specifically for the FOS program to help students create project plans and track progress, with a final product consisting of a report in HTML format to be published in the school's World Wide Web site. Other required activities included peer evaluations of report drafts as well as critiques of pages found on the Web.

Data - A Chronology of Major Events

Introduction to the project

The "Is My Drinking Water Safe?" project began with a short introduction by the teacher during which he handed out a project description sheet and laid out the goals of the project. His primary message to students was that they were to make a community resource for people who want and need fairly non-technical information about water pollutants. In addition, the teacher stressed the use of content knowledge on chemical structure and bonding that the students covered in the first FOS III unit, knowledge about ecology that these students covered in projects in FOS I and II, and the importance of gaining new skills by using the classroom computers for project planning, Web searching, and Web page building. At the end of class, the teacher handed out a "Home Toxics Survey" that students were to fill out by surveying common household products.

On the second day of the project, the teacher lectured on the use of the LAN for storing files on the network server, discussed issues about toxins in the environment and human health, and discussed a sample Web page report written by one of the pre-service student teachers in the FOS program. Unfortunately, since the school's ISDN line had gone dead earlier that day, the preservice teacher attempted to access the Web via a standard modem connection, which prompted a class discussion about when and how students were expected to access the Web. The sample report followed the project guidelines: it had eleven sections corresponding to the questions the teacher posed for the students, it had a drawing of the chemical structure of the pollutant, and, at the end of the report, it had links to two places on the Web.

The third day of the water pollutant unit marked the first time this school year that students were required to use the classroom computational media. After a brief demonstration by the teacher (using his PowerBook connected to a TV) during which he showed PlanIt Out, students formed eleven groups of two and checked out the

PowerBooks. At the same time, a second FOS program teacher wrote critical events and dates for the project on the blackboard (e.g. a field trip and due dates for evaluation worksheets and the final report). Using PlanIt Out, students began to enter the events and dates given to them by the teachers.

The ISDN Line is Down - The Next Nine Days

During the next nine days, the school's ISDN line remained inactive, so the FOS III teacher postponed most of the pollutant research. Instead, the class discussed the home toxics survey, and watched and discussed several documentary videos, including one on disposal of toxic waste and one on a well known book that, in the sixties, was a diatribe on the use of pesticides. The class took a field trip to a local wastewater treatment plant and at the teacher's request, pulled out their PowerBooks once to adjust the dates in PlanIt Out . Again, for this activity with the computational media, the new tasks and dates were written on the blackboard and students entered them into PlanIt Out.

Several times during this nine-day period, the teacher suggested to students that they could start researching their toxin "the old fashioned way" by going to the library and using materials there. Also, the classroom had sets of materials from local and national ecology groups with information many of the students may have found useful. Nevertheless, none of the groups began their research until 12 class sessions after the project introduction, when the ISDN line came up and students accessed the Web via their PowerBooks.

The ISDN Line is Reactivated - Research Time

The day the ISDN line was reactivated, a new vitality was apparent in the room as students came between classes, during lunch, and after school to access the Internet for various reasons. The FOS III class began to take on a different intensity than in previous weeks as social interaction increased dramatically: small groups formed to discuss their water toxins and ad hoc problem solving groups formed while using ClarisWorks and the Internet. For several class periods, students used Web sites recommended by teachers in a class handout, and compiled information about the water pollutants they chose. Some students attempted to use Web search engines but expressed frustration at not being able to find useful information. The teacher circulated around the room assisting with computer functions, science content knowledge, and Web resource use. After three days of research time in the class, the teacher, realizing that some of the chemical concepts in the resources were beyond the students' understandings, spent an entire period using the blackboard and lecturing about chemical bonding and naming.

Following the lecture, students spent a few more days using the Web, sharing information about useful Web sites, printing documents directly from the Web, compiling and creating information in ClarisWorks, and creating ball-and-stick models of the chemical structures of their toxins. As soon as one group created a physical model and captured a photograph of it for their Web page, several other groups began doing the same. The next day, the teacher made available via the network server, a ClarisWorks document he created containing pieces of ball-and-stick models already drawn for students to build their own models on-line. Several groups used this new "model maker."

From Researching to Publishing

Four weeks into the project the teacher changed the due dates a second time. The original project was to take four weeks, but with the two sets of date changes, it was extended to six weeks. These new date changes were not entered into PlanIt Out (students had not used PlanIt Out during the researching period, not even to check progress). During this week, the teacher asked for drafts of each group's current work. One of the pre-service teachers used screen shots and an overhead projector to demonstrate the use of Web-It (Day, et al, 1994), a utility built into ClarisWorks for converting word processed documents to HTML-format that are published on the Web. In the days following this lecture, several groups began a process of iterative document design: writing and formatting in ClarisWorks, converting to HTML, checking the format with a Web browser, revising in ClarisWorks, converting again, and so on. Many students continued to use the Web, compile content, and address more of the eleven required questions.

During the fifth week of the project, the teacher again adjusted the project schedule and students were given a few extra days to continue building their Web pages. All but one of the groups used ClarisWorks' built-in "style rules" associated with the Web-It translator to write and format their documents. At the end of the week, students placed drafts of their HTML documents in a public folder on the server and each group chose two Web documents to peer review. Using a teacher-created worksheet, the groups conducted peer evaluations to rate each others' Web pages on a scale of 1 to 10 with comments in five categories: Organization, Explanations, Appearance, Sources, and Links. During the sixth and final week of the project, with peer reviews in hand, and additional content collected during the week, students spent lunch time and class time to complete final revisions. Groups handed in reports at the end of the sixth week of the project by placing final documents in their personal folders on the server and individual students completed project evaluation forms.

Analysis

In this unit, there were several principal goals and a range of activities enacted to attain the goals, both supported by and not supported by the computational media technologies. This analysis serves to summarize the goals and activities and to provide some insight into how the technology influenced cultural values.

Several principal goals were stated by the teacher both verbally and on his project description sheet at the outset of the project: 1) Students would produce a community resource that would fill both local and global needs; 2) Students would use prior chemistry knowledge to understand and present chemical, ecological, and health-related information about their water toxins; 3) Students would gain new publishing skills, such as project planning, Web searching, and Web page building. The relationships between these goals, the classroom activities, and the pervasive computational technology reveals aspects about how technology plays a large role in the development of cultural values reflected in the FOS III classroom.

The first goal would not have existed without the school's World Wide Web server and ISDN line, yet it became a primary driving force behind the purpose the teacher and students had for the project. Producing a community resource created the conditions under which the five aspects of a PBS project could be attained. Students engaged in the following activities: investigation on the question, "Is My Drinking Water Safe?"; production of Web documents using constructive, cognitive tools; authentic research using the a Web browser; and collaboration among students and communication with the larger community. Together, these activities suggest the cultural value that students use their scientific understanding to fulfill a community need to have a single source of accessible information about water toxins written for a broad audience. Thus, it was the availability of the school's Web server that supported the development of this cultural value of producing a community resource.

The second goal might have existed in some form in the absence of pervasive technology; however, technology may have facilitated the goal through two activities: information gathering and publishing. Access to the information on the Web gave purpose and meaning to the chemistry content learned in the first FOS III unit since students needed to assimilate the new, more authentic information with their prior knowledge while they constructed their own Web documents. In this brief analysis, we do not examine the degree to which students assimilated the new information with their previous understanding. We don't know yet to what degree building the documents influenced construction of new understanding, but it was clear that during the unit students needed to use their prior knowledge about chemical structure, bonding, and naming while building their Web documents. Because students had questions about the previously-learned chemistry concepts, the teacher interrupted their research and publishing activities to provide a lecture on these chemistry topics. Thus, the technology (Web as information source and Web as a means to publish) seems to support the value of students assimilating real-world applications with more abstract chemistry knowledge.

Third, each new skill the teacher stated for this unit was based on the accessibility and design of computational media in the classroom. For this teacher, the presence of PlanIt Out meant students would gain skills in project planning and management, the presence of the Web meant students would gain skills in searching and accessing authentic information, and the presence of ClarisWorks with Web-It meant students would gain design and publishing skills. Each of the skills, with the associated classroom activities, are discussed individually below.

Planning

Planning and management skills are crucial for success in inquiry-based activities commonly found in PBS environments. During the second FOS III unit, the teacher had the explicit goal of having students plan their project using PlanIt Out. However, the teacher specified the dates and tasks associated with completion of the project and asked students to insert these benchmarks into their PlanIt Out plans. The only time students referred to their plans was when the teachers asked them to change due dates, so the classroom did not adopt the value of planning. This may be due to several factors, including: 1) the teachers gave the students the due dates and tasks rather than having the students generate and control them; 2) the students may not have had the need to plan because of the small size of each workgroup and the ease of communicating with one partner over the relatively small number of activities (e.g. searching, evaluating, writing); and 3) the design of PlanIt Out or the lack of routine use of the tool may have contributed to the absence of explicit student planning. Teachers enacted the activity of planning, but the value was not adopted by the culture.

Information Finding

Information finding skills are an important aspect of inquiry-based activities. Technology allowed students to gather information, but the Web was not the only resource available. For some of the selected toxins, information was available in other classroom resources. The Web was the most widely used means for gathering information – every group used it routinely; nevertheless, use of Web search engines was not routine even though they were available. Most groups used Web resource sites given to them by the teacher. The value of finding information was pervasive, but the value of learning to conduct searches was not. This may be due to: 1) Web resource sites were given to students, so they didn't need to learn to search; 2) learning to use search engines wasn't an explicit activity and it wasn't supported through instruction; and 3) the design of the search engines may not have supported successful searching (students who did attempt searches exhibited frustration at not finding useful information), and students found the lists given to them by the teachers to be a more efficient means of getting information. Web-based information access was valued, although finding authentic information through search engines was not a pervasive activity in this culture.

Web Page Design and Publishing

The skills of producing artifacts representing students' understandings include the ability to compile, represent, and structure information from diverse sources. On the project description sheet and during the demonstration of the teacher-produced Web page, the teacher provided the format students should follow. This format included the following: Title, Introduction (Questions 1 and 2), Body (Questions 3 through 11), Conclusions, and References. An analysis of the student reports has not been completed to determine if students followed this format, but as students used ClarisWorks with Web-It during their page production, formatting was facilitated by the tools. Students used the style rules and automatic heading levels provided through the software while the skill of writing HTML was not needed since Web-It automated the process. The project description sheet also specified that students should incorporate a three dimensional representation of their chemical and diagrams or photos explaining the effects of the pollutant in the body. Access to Web sites with such images, tools such as ball-and-stick kits, and a digitizing camera facilitated the incorporation of multiple representations in student reports. Thus, the cultural value of structuring content and building multiple representations is supported by the community and, in fact, encouraged by the computational media tools.

One other aspect of publishing includes the process of review and revision, and many groups conducted review and revision in their own writing processes. Although this was not a stated goal at the outset of the project, the teacher did encourage peer reviews of Web documents by organizing a peer review session. The peer review was facilitated by the classroom network server which allowed students to easily share electronic versions of documents. The teacher provided a worksheet for reviewing documents and students spent a few class periods afterwards revising their documents. Although peer review was not a stated goal, students found the activity valuable. The teacher attempted to instill the values of peer review and revision in the classroom, but they did not become pervasive activities throughout the project (perhaps because the teacher and students did not see the need until the end of the project).

Concluding Remarks

Understanding how computational media is socially-situated in classroom contexts provides insight into the roles technology plays in the development of classroom culture. In the FOS III classroom, we saw students participating in activities associated with project-based science environments, many of which were encouraged or facilitated by the pervasiveness of classroom technology. In some cases, the goals, (such as producing a community resource, integrating practical applications with prior science knowledge, and structuring, representing and formatting information for a Web document), the classroom activity and the corresponding value systems were supported primarily through access to the computational media. In other cases, the goals, (such as project planning and management), and the corresponding cultural values did not catch on and were not supported by the technology. The relationship between the adoption of cultural values and technology that enables or encourages the values needs further examination. For example, the values may not have been adopted because they weren't supported by the technology, or the technology may not have been adopted because the values to support its use were not present, or both. It is important to better understand the cultural context (the relationships between goals, activities and tools) that supports students' inquiry-based science learning so supportive activities and technological tools may be designed to facilitate desired learning processes.

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