Designed Curriculum and Local Culture: Acknowledging the Primacy of Classroom Culture

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ABSTRACT: One of the primary challenges facing designers today is how to design curricular innovations that are appealing and useful to teachers and at the same time bring about transformative practices. While we as a learning sciences community are relatively adept at facilitating innovative case examples, we need more empirical work that examines how curricular innovations become implemented across multiple classrooms. In this paper we examine a series of four teachers implementing our technology-rich, project-based curriculum. We then analyze and discuss each of the four cases across two themes by (a) examining how the project-level question was contextualized to meet local needs and (b) examining the cultural context that surrounded the implementation of the curriculum. Our interpretations suggest that contextualizing the curriculum is ultimately a local phenomenon that arises as a result of a number of factors, including students' needs, students' goals, teachers' goals, local constraints, and teacher's pedagogical values. These cases illuminate the importance of school and classroom cultures in the learning process. Ultimately, curriculum designers need to acknowledge that their designs are not self-sufficient entities; instead, during implementation, they become assimilated as part of the cultural systems in which they are

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INTRODUCTION

As a field, the learning sciences have become adept at producing small-scale, relatively focused curricular projects that work well within particular contexts. By working with smaller numbers of students and teachers, researchers have provided valuable data concerning how learning occurs, the strategies that teachers use in supporting their students learning, and how to design effective learning systems in K-12 contexts (Barab et al., 2001; Cobb, 1999; N. Sabelli and C. Dede, 2000, unpublished manuscript, available at http://www.virtual.gmu.edu/SS_research/cdpapers/integrating.htm). However, over the past few years there have been calls to move beyond these useful "boutique" projects to examining the interplay among curricular interventions, local systemic factors, and widespread curricular implementation (Roschelle & Jackiw, 2000). By understanding these relationships, designers should be in a better position to develop and build curriculum interventions that not only enable local success, but are scalable to meet the needs of a much broader audience.

A few projects, most notably the Jasper project and Star Legacy projects have supported wide-scale dissemination and produced products that can be implemented in a variety of contexts (see also, WISE, HiCe, Globe, Kids as Global Scientists, this issue). However, researchers on many of these projects have consistently cited a common problem. As the Cognition and Technology Group at Vanderbilt reported, teachers often "maladapted Jasper to old ways of doing things" (Schwartz et al., 1999). Therefore, the question still remains: How do we design educational interventions that are appealing to teachers and easy to implement, yet still promote teachers using progressive, reform-minded pedagogical approaches? This is one of the primary challenges facing researchers and developers in the learning sciences today (N. Sabelli and C. Dede, 2000, unpublished manuscript, available at http://www.virtual.gmu.edu/SS_research/cdpapers/integrating.htm).

This study examines these issues through four case studies of teachers implementing an interdisciplinary, technology-rich, project-based environmental science unit. The curriculum, the ActiveInk Air Quality module, was designed by a unique corporate–university partnership consisting of educational technology faculty, science educators, instructional designers, and K-12 teachers. In these case studies, we examine how this curriculum was used by four teachers within the constraints of their own classrooms. Specifically, we examine (a) the ways the project-level question was contextualized to meet local needs, and (b) the interaction between the cultural context that surrounded the implementation of the curriculum and the curriculum itself. We investigated the enactment of this curriculum as it was used across a variety of ages and locations, including in two cases where the teachers were also members of the design team. Implications are discussed in terms of how researchers can develop innovative curricula that can be leveraged within existing classroom cultures, yet still provide students and teachers with meaningful and sound learning opportunities.

THEORETICAL FRAMEWORK

The role teachers play in adapting a curriculum to meet their local constraints, match their pedagogical goals, or fulfill the needs of their students is a subject of much debate (e.g., Randi & Corno, 1997; Schwartz et al., 1999). At one level, researchers need to respect the local constraints and the professionalism of teachers, and at another level the impetus underlying the development of innovative curricula is the transformation of local practices. As such, while some researchers respect the voice of teachers, others, at least in the confines of their academic conversations, view teachers as objects to be changed. Randi and Corno (1997, p. 1164) write, "this ambivalence about the role of the teacher in the implementation of curricular and instructional innovations pervades the educational literature, and models for education reform have often reflected this contradiction." They further argue that researchers are gradually shifting toward perspectives that value teachers' implementation practices, but on the whole, "teachers have still been expected to change their practices to conform to the ideas of external change agents" (p. 1180). In this way, most educational research has appreciated teachers' necessity to adapt curricula but has ultimately presumed a "one best way" of implementing curriculum and strived to preserve the integrity of externally developed educational innovation through wholecloth adoption (Barnett & Hodson, 2001).

Technological Innovations

Technological innovations are frequently thought of as novel technological artifacts—that is as objects that incorporate new knowledge. However, processes such as instructional approaches can be considered technologies as well (Bijker, Pinch, & Hughes, 1987; Shapin & Shaffer, 1985). Such processes are often referred to as "soft technologies" within the field of instructional technology (Heinich et al., 1999). Instructional processes like problem-based learning, project-based learning, or educational games can be considered soft technologies because they are novel processes with embedded knowledge about learning, instruction, and behavior. Thus, instructional innovations that are based on these processes can be seen as technological innovations.

Recently, educators have begun to examine in detail how technological innovations are deployed and implemented within social settings. For example, using a Social Construction of Technology framework, Avery and Carlsen (2001) analyzed the design, content, and use of technological innovations over time. Researchers from this tradition (e.g. Kline & Pinch, 1996) have studied how the meaning of an innovation is interpreted by social groups (interpretive flexibility), how the negotiation of the meaning of an artifact stabilizes (closure), and how social groups interact with technology and appropriate technologies in everyday use. By studying the lifecycles of technologies from design to utilization, researchers can gain a sense of how tools are appropriated in action, and the interrelationships between technological innovations and culture.

Makers and Users

As Lindsey (2000) suggests, traditional distinctions such as the *users* of an innovation and *makers* of an innovations disintegrate when one actually examines how technologies are implemented. Lindsey (2000) writes, "Users often do unanticipated things with a technology, and the technology may have a different role in a person's life than for which it was designed" (p. 4). For example, Avery and Carlsen (2000) as part of their Environmental Inquiry project brought science teachers together to form a community of practice around the development and implementation of an inquiry-based science curriculum. As a part of their study, they examined how makers and users of the curriculum differed in terms of how they implemented the curriculum and reconfigured their classroom environments. Based on a series of case studies, Avery and Carlsen argued that users may be just as likely to implement and reconfigure their classroom environments with the same rigor as the makers. Hence, the makers of the community became users, and the users became so familiar with the interworkings of the program that they began to redefine the program and the community, in effect, making the community. Thus, Avery and Carlsen (2001) found that all of their teachers negotiated the meaning of innovations, vacillating between roles as makers and users.

If technology users are ultimately also remakers of that technology, then we can expect that teachers would reshape curricula as situations dictate. As professionals, teachers are not only justified in adapting curriculum to local constraints, but also in an ideal position to repurpose curriculum (Luehmann, 2001; McLaughlin, 1976). The teachers typically better understand their students' needs and how to conform the curriculum to the day-to-day realities of their particular school and classroom than does a designer. Consistent with this view, Randi and Corno (1997) argue that

> What have often been documented as teachers' adaptations of innovations may have been teachers' innovations created in response to the contexts in which they work. We suggest that part of what teachers learn as they teach is to synthesize new ideas from instructional models they imitate. That is, teachers infer new knowledge and invent new practices based on instructional models introduced by researchers and others. Classroom innovations are thus co-constructed and socially derived.

In this way, teachers' adaptations of innovations are not phenomena to be avoided, but rather an ongoing process to be supported. As such, the goal of instructional designers might be not how to create "teacher-proof curriculum" or to even understand teachers' adaptations of curricula so that such repurposing of curricula can be avoided. Instead, designers might reconceptualize "implementation" as a process of supporting teachers in contextualizing curricula to meet their local needs (McLaughlin & Marsh, 1978). This could be done by providing teachers sufficient guidance to use the curriculum in useful ways and supporting their inquiry into their evolving teaching practices while using the curriculum (Luehmann, 2002).

Supporting Teachers' Use of Innovative Curricula

Several programs whose designs are based on the learning sciences research tradition have abandoned conventional "implementation models" and reconceptualized their role as one of supporting teachers in contextualizing curricula to meet their specific contextual needs. This section outlines some recent approaches.

Flexibly Adaptive Curricula. One such attempt to support teachers in adapting project-based curricula is the Star Legacy project (Schwartz et al., 1999). Star Legacy is a software shell that John Bransford and his colleagues at the Cognition and Technology Group at Vanderbilt (CTGV) designed in response to their findings from the Jasper project (CTGV, 1992, 1993). CTGV found that teachers frequently felt lost using the Jasper curriculum, did not know how their daily activities related to one another, or understand how their activities were leading toward the completion of the project goal (Barron et al., 1995). In response, CTGV developed the Star Legacy learning cycle which consists of problem-solving steps common to problem or project-based curriculum, such as identifying challenges, generating ideas, or going public with students' thinking. The Star Legacy provides a map for students and teachers, that scaffolds their progress through the curriculum, which in turn, can promote the learning processes characteristic of well-designed project-based learning units.

As a software package, Star Legacy is unique in that it is designed to promote reflection by recording students' reflections, predictions, and activities as they work through the curriculum. These reflections are recorded as legacies in the system for the students themselves, other students, and teachers to examine. For example, a student new to Star Legacy might read the reflections of a student who has completed three learning cycles to develop a better picture of how learning occurs through extended interaction with the curriculum. Similarly, teachers can read the reflections of other students and teachers to better understand the experiences and challenges associated with tackling novel curricula. In general, research conducted on teachers' use of Star Legacy has reported positive findings in using implementation histories to promote successful implementation (Schwartz et al., 1999). Star Legacy is one instantiation of a flexibly adaptive design which, through its open ended and easily adaptable structure, allows each classroom to implement it in a unique way that responds to local needs such as classroom pace or student ability and interest.

Educative Curriculum. Another response to the need to support teachers in enacting reform-based curriculum is the use of what Ball and Cohen (1996) refer to as educative curriculum. The goal of educative curriculum is to design materials that support teacher learning as well as student learning through content, pedagogical, or pedagogical content knowledge supports (Shulman, 1986). As opposed to many other forms of professional development or support such as summer workshops, teacher supports offered through educative curriculum are available to teachers as they are actually engaged in enacting a reform-based curriculum. Examples of these supports include sample questions teachers can use to probe student understanding, descriptions and explanations of possible student responses, strategies and rationale for different ways to foster inquiry, and supports for enriched content understanding (Singer et al., 2000).

Schneider and Krajcik (2000) defined a set of design principles for educative curriculum based on literature on teacher knowing and learning, observations of teachers' previous experiences with a particular curriculum unit, as well as recommendations by Ball and Cohen. With these principles in mind, these researchers observed and interviewed three teachers with varying degrees of experience (1, 7, and 17 years) with respect to the use and effect of the educative materials intended to support teachers' enactment. This study found that all three teachers used and found value in the educative supports, but to varying degrees. In each case, aspects of classroom practices could be directly attributed to specific components of the educative teacher supports.

Though much is needed to be learned about the design and potential effectiveness of materials used to support teachers' enactment of reform-based curricula, it is encouraging (and perhaps intuitive) that initial research efforts have found that learning supports designed with the teacher in mind can lead to enhanced thoughtfulness and effectiveness of teachers' enactment. Improved practice is a promising outcome from materials that seek to enhance content understanding, increase access to valuable teaching strategies and perspectives, and most importantly, support the orchestration and facilitation of a specific lesson for a specific grade level, highlighting common student misconceptions and useful strategies.

Community Models of Learning. Another approach to supporting teachers in using curricula is through the development of professional communities who are focused on improving their teaching practice (Thomas et al., 1998). For example, in the Inquiry Learning Forum (ILF) project, teachers can work together in collaborative groups designing and adapting lessons or entire curricula to meet the local needs of these teachers (Barab et al., 2001). Originally, the ILF was designed around the metaphor of allowing teachers opportunities to visit one another's classrooms, critique one another's teaching, and participate in a supportive community of practice. However, Barab and colleagues (Barab et al., 2001;

Barab, MaKinster, & Scheckler, in press) found that teachers wanted a place to share resources (such as curricula and lesson ideas) and learn from the successes and failures of their colleagues' implementation of various curriculum materials. The researchers found that teachers' desires for professional development were located strongly in local teaching needs such as developing confidence and expertise in their subject matter as well as responding to unique demands related to student demographics, parental pressures, or school culture. Thus, the emphases in the ILF have moved from one of visiting one another's classrooms, to one where teachers can collaboratively create curriculum and study how common curricula are used in various classroom contexts.

Similarly, Avery and Carlsen (2001) developed the Environmental Inquiry Community of Practice (EI COP) for teachers to explore inquiry teaching through participation in a community of practice. Drawing heavily on the work of Lave and Wenger (1991), Avery and Carlsen describe how the EI COP is a community of practice designed to support members in moving from legitimate peripheral participation to core participation. The EI COP "brings together scientists, educators, staff, and secondary school teachers in a collaborative effort to create an environmental science curriculum that is sociologically authentic" (Avery & Carlsen, 2001, p. 12). In short, all EI COP participants are committed to teaching with the EI curriculum in their classrooms and then participating in seminars and discussions (both online and face-to-face) critiquing their practices. As such, the EI COP program attempts to leverage teachers' natural inclinations to customize curriculum to their particular needs and foster a community where examining teachers' practice will lead to better understanding of science education issues, including how to implement the EI COP curricula.

Summary

This study involves four teachers using a newly designed technology, project and inquiry-based curriculum in four very different settings. We had the unique opportunity to examine how both designers and nondesigners of a flexibly adaptive curriculum implemented it in their classrooms. Furthermore, this curriculum was designed based on very specific and reform-minded pedagogical, curricular, technological, and social commitments. Given these commitments we were very interested to see to what extent the teachers and students adapted the curriculum to their own classroom culture and to what extent this curriculum resulted in reform-minded teaching and learning. This study builds on the frameworks and understandings of previously published projects, and provides a significantly more detailed examination of how the ActiveInk Air Quality curricular innovation was implemented across multiple classrooms.

CONTEXTS AND METHODOLOGY

Participants

In this study, we examine a technology-rich project-based science curriculum being used in four unique settings. Based on convenience sampling, four classrooms were selected for this study. Two of the participating teachers also significantly contributed to the development of the ActiveInk curricula, and the other two were teachers with whom the researchers had few to no prior relations. One of the classrooms was in a middle school, two were in high schools, and the fourth was in a university, a class specifically intended for preservice teachers. Because the cases are so divergent, we used a qualitative case study approach designed to illuminate the uniqueness of each case, and reveal sources of variance and invariance across the cases (Stake, 1983).

Settings

Case 1: Rural High School. Luke teaches science at a medium-sized rural county high school. He has a master's degree in Hydrogeology and has taught high school physics, chemistry, and environmental science for 7 years. Luke was also a member of the ActiveInk curriculum design team. He agreed to use the ActiveInk curriculum in his class because he hoped that it would offer his students more experience using computer-based learning environments and the chance to study the chemistry involved in the production of ground-level ozone. Luke used the ActiveInk curriculum for four 85-min class periods in his environmental science course. This class was composed of 14 students, mostly juniors and seniors. For the most part, these students were not in the "college-bound" or "honors" track, and Luke described them as "not among the strongest science students he has." Luke was particularly excited to see how this group would receive the ActiveInk curriculum.

Case 2: Suburban High School. Susan teaches earth science, environmental science, and beginning chemistry at a large suburban high school. She was concluding her second full year of teaching and was not involved in the design of the ActiveInk curriculum. Susan's reasons for choosing to use the ActiveInk curriculum in her classroom included her view of the curriculum as an excellent set of resources that her students could use as well as a way to integrate technology into her teaching. Susan was also strongly interested in trying something new that pushed her teaching as she felt frustrated at what she perceived to be a negative attitude toward curricular innovations from other members of her school faculty. Within the Air Quality curriculum in particular, she was most interested in having the students use the ozone modeling tool to examine the formation of ground level ozone and have the students present their work to each other and their parents at the conclusion of the unit.

Case 3: Large University. In contrast to the other settings, this case took place within the teacher education program at a large Midwestern university. The ActiveInk curriculum was used with 14 students in a senior-level capstone course for elementary science concentration students. This course integrated biology, chemistry, physics, and meteorology, focused on the earth as an energy system, and encouraged students to critically examine the impact that humans have on the environment. Roger taught the lab section of this course, and his lessons usually aligned with the corresponding lecture section. He was a 4th year doctoral student in science education, this was his first time teaching this particular course, and he was a novice in using technology-enhanced curricula. Roger expressed concern that many elementary teachers do not have a strong foundation in science content. His goal for the ActiveInk Air Quality module was to provide a meaningful learning experience through which his students could learn science content, participate in an inquiry-based curriculum, and reflect on how they might use this type of technology in their own classroom. The class was divided into two sections, and each section used the curriculum during two 2-h classes. The students worked in pairs, each at a different computer, and a 1/2-h debriefing discussion followed the unit.

Case 4: Middle School. John is a student teacher at Junior School which is a small, private "alternative" middle school, populated mostly by the children of university professors. For 2 weeks, John used the Air Quality curriculum in his middle school science classroom. John is the de facto technology teacher at the school and was excited to use a web-based curriculum. He was interested in trying ActiveInk because it would provide his students with an opportunity to use technology and build on earlier work they had done exploring environmental education issues.

Curriculum

The ActiveInk Network is an e-learning portal where teachers, students, and parents can explore interdisciplinary projects that promote critical thinking skills and allow students to engage in authentic scientific investigations. The ActiveInk technology platform and curricula are designed to support project-based and inquiry-based environmental science. Each curricular module is centered around a driving question and leads to the construction of a tangible and shareable artifact, such as an ozone action plan for their community (see Figure 1). Each project is comprised of four to six challenge questions that students address in order to complete the project. Each challenge has a set of web-based tools and resources that students can use to answer the challenge question and any other questions that arise (see Figure 2). Available tools include an ozone level simulation that displays ozone levels under variable environmental conditions, chat applets, discussion threads, and brainstorming tools. As an inquiry curriculum, the questions and tools are designed to serve as the central focus, and resources are meant to be accessed only when needed. Resources range from narrative cases of patients suffering from ozone to Shockwave animations of

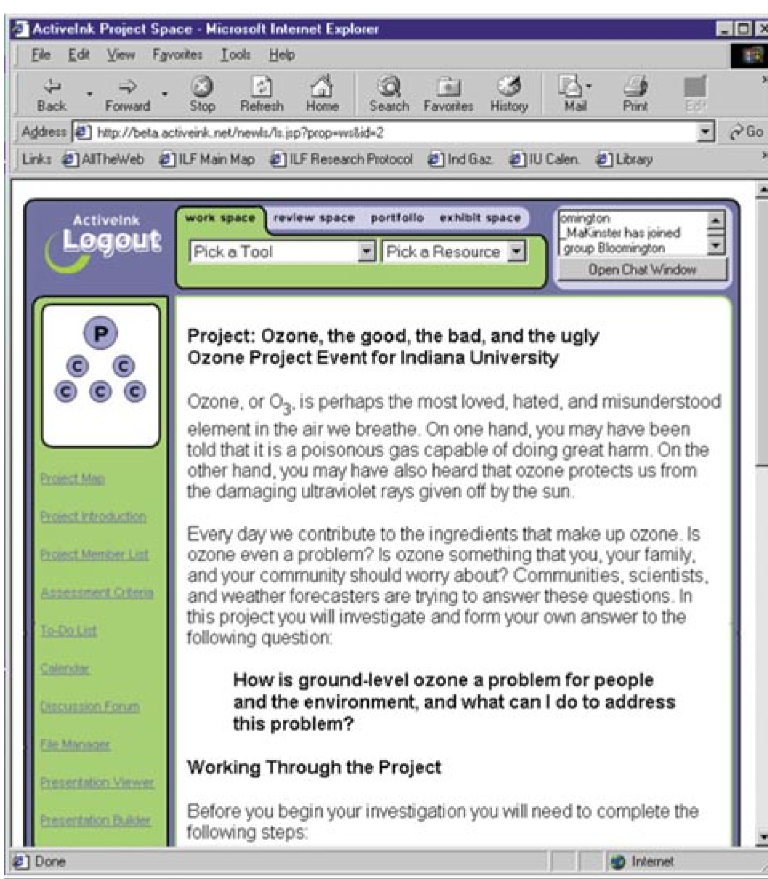

Figure 1. Screen shot of the Air Quality project-level home.

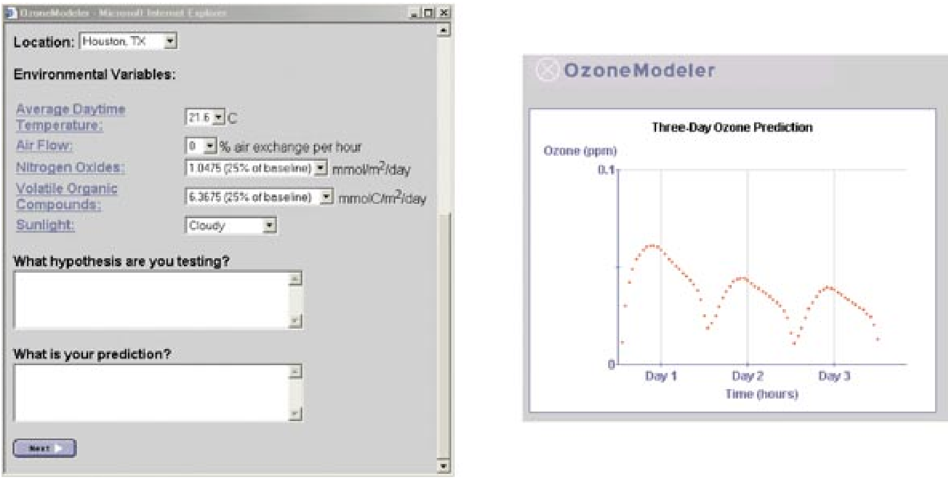

Figure 2. Screenshot of the ozone modeler tool.

the chemical processes underlying ozone formation. The curriculum is driven by students' use of tools in order to answer questions related to a broader environmental science issue. Abbreviated descriptions of the design commitments that underlie the ActiveInk curricula are presented in Table 1. As part of a larger university and K-12 design team, the authors of this study recently developed learning modules for several environmental education domains that include air quality, wildflower diversity, water reuse, waste management, and earth systems.

The Air Quality module that was used in all four of these classrooms supports student inquiry into the impact of ground-level ozone on humans and the environment. In this module, students are challenged to determine the chemical and environmental variables (e.g., volatile organic compounds, temperature, air flow) that influence the formation of ground-level ozone, develop their understanding of how these variables effect ground-level

TABLE 1
Design Commitments

Epistemological and Pedagogical Commitments
Learning as doing (Dewey, 1963)
Learning as social participation (Brown, Collins, & Diguid, 1989; Lave & Wenger, 1991)
Learning as environmentally and culturally situated (Vgotsky, 1978)
Curricular Commitments
Project-based and problem-based learning (Barron et al., 1998; Blumenfeld et al., 1991)
Inquiry-based teaching and learning (Dewey, 1963; Krajick et al., 1998)
Personalized and performance assessments (Mabry, 1999)
Technological Commitments
Technology for communication (Scardamalia & Bereier, 1991)
Technology for creative construction (Papert, 1981)
Technology as tools (Pea, 1993)
Social Commitments
Supporting knowledge building communities (Scardamalia & Bereiter, 1991)
Empowering individuals and honoring diversity (Savery & Duffy, 1996)
Commitment to excellence

ozone levels, and explore and discuss the human health effects of ozone (Figure 1). The driving (project-level question) question for this module is “How is ground-level ozone a problem for people and the environment, and what can I do to address this problem?” The associated challenge questions in this module are focused questions that feed into the larger, overarching project-level question. The challenge questions are not meant to be explored in a linear fashion. Both the web-interface and the intended curriculum afford considerable flexibility with regards to the manner in which the students approach the challenges. The challenge questions for the Air Quality module are

- What are the factors that affect ground-level ozone?
- Does ground-level ozone have health effects?
- Is ground-level ozone a widespread problem?
- What can be done to reduce ground-level ozone?
- What can my community and I do to reduce ground-level ozone?

Each challenge question has a specific set of associated tools and resources. Tools, such as the ozone modeling tool, enable students to manipulate, graph, analyze, or interpret data as they attempt to answer the challenge questions (Table 2). Resources, such as animations of how ozone forms, case studies of cities with ozone problems, case studies of patients suffering from ozone-related health problems, and diagrams of how ozone can affect humans are provided as background information for student inquiry (see Table 3).

Our Role

The researchers acted as participant observers in each classroom; that is, rather than being removed observers of how each teacher implemented the ActiveInk curriculum, we offered suggestions, guidance, and support in a manner similar to how a customer representative might support a beta testing teacher. As such, we offered on-site support to the teacher in

TABLE 2
Ozone Curriculum Tools

Level	Name	Description
Project	What do I know? Ozone use pre/post survey	Surveys students’ understandings and beliefs about ozone before and after completing the project. Includes reflection questions so that students can compare their own responses to those from experts or peers.
Project	Ozone policy planner tool	Guides students through the process of creating a policy plan.
Project, 1, 2, 3, 4	Thinking about ozone	Prompts reflections on and strutures documentation of students’ activities.
1, 3, 4	Ozone modeler tool (with saved graphs)	Students examine the variables that contribute to ozone formation.
2	Symptom analysis tool	Scaffolds students in collecting information on ozone’s affects on health and promotes reflection and syntheses of their experiences using resources.
5	Survey builder	Allows students to build surveys for printed distribution and analyze the data they collect.

TABLE 3
Ozone Curriculum Resources

Level	Name	Description
Project	Ozone policy planner tips	Models/explains what a good scientific report looks like.
Project	Ozone media introduction	Introduces topic and engages students in project space.
1	What is NO_x?	Gives an overview of NO_x and describes chemical reactions related to ozone.
1	What are VOCs?	Introduces VOCs and their role in the ozone formation process.
1	The chemistry of ozone	Explains the chemistry of ozone.
1	What is a model?	Explains what a model is and their role in this project and science more generally.
2	Stories about health problems	Describes several people's health problems which may be related to ozone.
2	What is an ozone action day?	Explains what an ozone action day is.
2	Dr. Johnson	Doctor gives an overview of ozone's health effects.
3	What is an ozone action day?	Explains what an ozone action day is.
3	Case studies	Examples of three cities struggling with ozone problems
3	Ozone in the news	A mock newsreport from Houston Texas that exemplifies how ozone is in the news.
3	What is a model?	Explains what a model is and their role in this project and science more generally.
4	Houston ozone problems	Discusses Houston's ozone problems
4	Houston case study	Introduces Houston and its ozone problem.
5	Survey design tips	Gives tips for designing and effective survey.

implementing the curriculum while at the same time critically examining how the ActiveInk curriculum was modified and adapted by each teacher. Specifically, we discussed the underlying pedagogical framework of the ActiveInk curriculum with each teacher prior to its implementation in his or her classroom. In addition, we shared experiences of how other teachers implemented the curriculum in their classrooms. To this end, we responded to the teachers' questions concerning the use of the ActiveInk curriculum. We offered suggestions to each teacher regarding class structure, student group work, and student assessment. Each researcher documented his or her suggestions to the teacher and paid particular attention to how the researchers' suggestions were integrated as part of the teachers' curriculum implementation.

Research Methods

For this study, both naturalistic and quantitative data were used to gain a holistic vision of curricular implementation (Guba & Lincoln, 1983; Scriven, 1983; Stake, 1983). At least one researcher attended each class during use of the curriculum and conducted observations. We focused our data collection efforts on issues of student ownership, feelings of authenticity, collaboration, content learning, the role of teacher, the role of technology, and the role of context more generally. In addition, pre- and postinterviews with the teachers were conducted in order to better understand the thoughts, intentions, curricular decisions, and impressions of each teacher. Students were also interviewed to confirm and probe observations made during class. The researchers used observations, interviews, and document analysis to triangulate emergent understandings (Lincoln & Guba, 1985). In regularly scheduled research meetings, the researchers discussed field notes, student interviews, and teacher observations to direct data collection efforts, generate assertions, and look for confirming or disconfirming evidence regarding our emerging assertions.

These meetings illuminated pertinent issues with respect to the successes and challenges of unit implementation. Consistent with earlier studies of such project-based learning environments (e.g. Barron et al., 1995; Schwartz et al., 1999) we focused observations on (a) what practices emerged (b) what types of collaboration occurred (c) what role the technology served (d) students' ownership over the various projects (e) students' perceptions of the projects (particularly their authenticity) (f) the quality of students' final projects (g) students' learning (h) the role of the teacher, and (i) the role of contextual factors in influencing curricular adoption. Following data collection, the researchers gathered, organized, and generated detailed descriptions of each case (approximately 10 pages in length). Each case study synthesized observations, interview notes, and analysis of documents generated in the cases using Stake's case study methodology (Stake, 1983). The researchers then organized the case studies and examined them for emergent themes and issues that are presented below. The cases themselves have been omitted from this paper for space considerations.

CROSS-CASE COMPARISONS

In the following section, we analyze and discuss each of the four cases across two themes by examining (a) the ways the project-level question was contextualized to meet local needs and (b) characteristics of the cultural context that surrounded the implementation of the curriculum.

Contextualization of the Project-Level Question

Consistent with project-based pedagogy (Barab et al., 2001; Blumenfeld et al., 1991; Savery & Duffy, 1996), situated learning theory (Barab & Duffy, 2000; Kirshner & Whitson, 1997), and self-organizing theory (Barab et al., 1999), this curriculum was designed to foster engagement by anchoring the curriculum around a central driving question, issue, or debate. The driving question for this curriculum was chosen among several possibilities for its appeal to students, centrality to the learning goals supported by each unit, feasibility, and sustainability (Krajcik, Czerniak, & Berger, 1999). When we look across these cases, the project-level question appeared to serve as a relatively poor organizer of the students' experience. In all four cases, students had difficulty understanding and conceptualizing the project-level question. We found that students failed to see ozone proliferation as locally relevant, failed to detect the project goals, and tended to focus on challenge questions that they found personally meaningful or familiar.

Failure to Make Local Connections. In Luke's case (high school case), which was the most successful of the four cases in engaging students in addressing the project-level question, the instructor spent over 30 min introducing the topic and the structure of the curriculum. However, in debriefing the experience, his students expressed frustration with still not understanding the project goals of the unit. Primarily, these students failed to see any connection between the unit, their local or daily lives, and how the findings of this investigation might have an impact on ozone levels. As one student, Jason explained, "We don't really have a big ozone problem, living here in a rural county. Talking to kids in areas where it really is a problem would have been interesting." Jill echoed this idea, "I kept expecting to interact with people outside of this class or something."

The final student projects reflected this lack of appreciation as many of the students stated that their choices had little to do with the production of ground-level ozone levels. At the end of the experience, the students felt that there was little they could do to change ground-level ozone levels, and that people concerned about ground-level ozone should just move to areas with lower ground-level ozone concentrations. In summary, they saw the project as very removed from their personal experience. In this way, students did come to understand the project-level question, primarily by addressing it directly, but they did not take ownership over the problem (Savery & Duffy, 1996). Luke commented that if he were to do this project again, he would choose a project-level question that would relate more closely to the local needs and concerns of his students. Although Luke had helped design the curriculum, he still found that only through trying the project with his class could he see the ways that he would customize it to meet their specific needs and interests.

Failure to Detect and Understand the Project Goals. In both Susan's (large suburban high school case) and Roger's cases, (preservice case), the students and instructors agreed that the class "never really got a handle on what the curriculum was about." Roger never addressed this concern, choosing instead to "let students figure it out on their own." Susan, on the other hand, addressed this issue throughout the unit by reminding students of their daily goals (verbally and online) and eventually constructing poster-boards that reminded the students about the curriculum structure. Both teachers spent very little class time pushing students to relate information among the challenges and spent most of their time addressing navigational issues or making sure that students were on-task. Consistent with the predominant classroom practices, these instantiations of the curriculum consisted of digging up facts related to ozone rather than doing activities to address the driving question or creating a product. In both Susan's and Roger's classes, the students failed to produce a final artifact that represented their personal answers to the project-level question; instead, they worked through the online activities, challenge-by-challenge, in a manner similar to filling in worksheets. There was no culminating activity where students synthesized what they learned.

Student Interest Driving the Investigation. In John's class (alternative school) students were given a great deal of freedom in choosing what questions they wanted to address. Although he tried to have his students focus on the project-level question, they quickly skipped most of the challenges dealing with chemistry, instead choosing to focus on building a community survey. In this way, the students reappropriated the curriculum so that the project-level question would allow them to focus on the question "What are my community's beliefs about ground-level ozone?" John's lack of familiarity with the chemistry behind ground-level ozone and the process of building valid surveys coupled with a classroom ethos that valued individual freedom over community accountability created a situation in which students created data collection instruments based on insufficient methodology for developing items and problematic sampling techniques. Although the project-level question was appealing to the students, it ultimately did not serve as an effective anchor for guiding student inquiry around the scientific concepts related to the chemistry of ground-level ozone. Instead, students were "anchored" around notions of community opinions and understandings which did not require them to develop richer scientific understandings.

There were similar patterns in other classrooms as well. For example, the students in Luke's class were afforded considerable flexibility as to which challenge questions they investigated and in what order. A majority of the male students chose to focus on using the ozone modeling tool and manipulating environmental variables, and most of the female students focused on the personal cases of people with different medical ailments that are effected by high ozone levels. Luke's only constraint for his students' final projects was that they were to use the ActiveInk curriculum in order to write an ozone policy paper.

Assimilating the Curriculum into Classroom Culture

We observed three distinct types of classroom cultures among these cases: Collaborative Communities of Inquiry, Individualistic Grade-Seeking Cultures, and a single Libertarian, Antiauthoritarian, Political culture. The observance of these cultures appear to be caused by a combination of several factors, including the teacher's prior experience with technology, the teacher's pedagogical style, and, most importantly, the preexisting school and classroom cultures. In each of these cases, the classroom rules, expectations and norms, and division of labor persisted throughout the experience and appeared to drive much of the activity in during these units.

Collaborative Community of Inquiry. In one of the classrooms the culture was one of collaborative inquiry. Luke's students (rural high school) collaborated freely both formally and informally. Even though they worked individually on their assignments, his students consistently asked one another for help, questioned one another's understandings, and collaborated in locating resources. At the same time, Luke engaged in constant assessment, stopping students during their inquiry in order to probe their understandings, challenging their thinking, clarifying concepts, and promoting critical discourse. Occasionally, Luke intervened by challenging the whole class with a question. For example, he stopped the class to ask them, "Could you tell me the relationship between VOCs, NOs, and ozone." Alex responded to him that NO, and NO_2 are produced by cars and trucks. "If there is a lot of ozone, those will break it up." Kathy disagreed, pointing out that UV + NO_x reacting with Oxygen results in the production of ozone, which is the natural production of ozone that she and Luke talked about earlier. Luke continues to probe student understandings. Kathy quickly retracted: "Wait, it is VOCs, not oxygen." Luke pointed out that before they could begin to effectively use these models, they needed to figure out which of these assertions is correct. This type of interaction and discussion was typical within Luke's classroom.

Toward the end of the unit, and consistent with this culture of collaborative inquiry, the class actually voted to abandon the idea of doing individual presentations and decided to cocreate one big class paper. Grades were not an overriding concern for the students or for Luke; the class had already established that students would be graded on their ability to construct a sound argument that drew on scientific evidence and sound scientific reasoning. Thus, collaboration to reach course learning goals, rather than competition for high grades, marked the student–student interactions and ended up driving the final products. This culture would be best characterized as a supportive learning community of inquiry.

Individualistic, Grade Seeking Cultures. In contrast to the Luke's (rural high school) case, the culture of both Susan's (suburban high school) and Roger's (preservice) classrooms might be described as individualistic and grade-seeking. In both cases, the classroom culture was one of completing work for some sort of exchange or compensation. In Susan's class, for example, there was very little collaboration and discussion between students or negotiation of what was being studied and why. In the first few days of the project, students worked productively, but Susan often felt concerned and frustrated that there was no purpose behind students' activities. She felt that they were not internalizing the driving question of the curriculum. Although a significant portion of students appeared to be actively engaged and worked diligently through the unit, most students were usually minimally engaged at best. In an attempt to motivate her students, Susan made regular comments about how much emphasis of her assessment would be based on homework assignments, the class presentation, and the text that the students entered into the ActiveInk tools. As the technology problems persisted, Susan relied even more heavily on extrinsic factors such as grades to motivate students. Susan confided to the researchers that in her next iteration of the curriculum she would like additional support from the curriculum designers prior to the unit in order to identify ways to more readily engage her students in the unit activities.

In Roger's classroom (preservice case), the culture was characterized by his desire to ensure that students' learned the "appropriate" science content. Roger perceived his primarily responsibilities as teacher to include the provision of specific learning opportunities, defining high standards for his students, and assessing whether or not his students reached those standards. As such, Roger seldom interfered with students' work, gave very few just-in-time lectures, and never encouraged students to collaborate across groups. Instead, and somewhat surprisingly, Roger graded papers or simply observed from the middle of the room as his students worked through the curriculum. He conceptualized students' roles as to do "the best they could," and then would assess their work in order to ensure that students were developing an understanding of the content. In previous units within this class, the role of assessment was quite critical. Some of the students had performed poorly on presentations, tests, and quizzes, and received low grades from Roger. As a result, a concern and preoccupation with grades persisted into this project and some students seemed continually concerned with whether or not their responses and actions would meet Roger's expectations.

It became apparent that Roger's expectations in terms of assessment were unclear to many of the students. This tension was exacerbated midway through Roger's class when he informed the students that he would be grading students on a normative basis according to how thoroughly they answered the questions posed within the curriculum. From then on, the focus of many students' activities were on whether or not they were doing "enough" to satisfy Roger's expectations and receive a decent grade for the unit that would raise their course grade. Competition between students for grades and a lack of cross-group facilitation established an environment where collaboration across teams was nonexistent, and instead the student teams seemed to focus on "giving Roger the answers that he wants" in a manner that was quick and efficient. In this way, the classroom culture in Roger's class might be characterized as antagonistic, competitive, and exchange value driven.

Libertarian, Antiauthoritarian, Political Culture. In John's classroom (alternative school), the culture was open, loose, and nonauthoritarian. This culture promoted spontaneous collaboration and political activism that valued individual freedom. John was most interested in providing an atmosphere in which students might pursue their own interests while using the ActiveInk curriculum as a support for their work. During the first few days of the unit, John tried to introduce some chemistry concepts, but students largely ignored or did not comprehend these science-related elements of the curriculum. Instead, his students chose to focus almost exclusively on building surveys about ozone proliferation and spent very little time examining the chemical reactions associated with ground-level ozone, the causes of ground-level ozone, or reasons why it is a health concern. In fact, when the students were interviewed, they provided very ambiguous ideas as to the causes and danger of ground-level ozone.

Despite a lack of focus on learning science content, the open, critical, and political culture of the school seemed to promote student collaboration, peer-critique, and activist student politics. Junior School is "designed for the development of the 'whole person,' encouraging the students to achieve academic excellence, feel good about themselves, and see learning as a lifelong activity." Students collaborated throughout the unit and felt free to observe one another's work. In addition, some of the students were even willing to switch groups part way through the unit. The most dynamic cross-group collaborations occurred at the end of the unit when a handful of students critiqued one another's surveys and revised their own surveys based on the feedback that they received. John's students were obviously comfortable critiquing one another. Similarly, his students were eager to engage in activities such as surveying people in the community that would reveal local political beliefs and attitudes as well as allow them to express their own beliefs. Finally, the open nature of this school culture allowed these students to leave campus during the school day in order to interview people in the community about their perceptions of ground-level ozone-related issues.

In some respects, John's class represented a learning community (Scardamalia & Bereiter, 1991). However, it differed from many conceptions of learning communities in the primacy that was placed on individual freedom, rather than learning scientific content or the acquisition of specific skills. Unlike the other cases presented in this study, assessment was of very little concern. John spent relatively little time giving feedback, probing students' understandings, or asking students to articulate their understandings during the unit. He gave no formalized feedback or grades of any kind. John also delivered no just-in-time lectures and spent very little time observing students activities or pointing them to appropriate resources. The power of the experience seemed to arise out of the correspondence between the existing classroom culture and the types of opportunities afforded by the Survey Your Community challenge in the ActiveInk curriculum.

CONCLUSIONS

These cases suggest that contextualizing the curriculum is ultimately a local phenomenon that arises as a result of a number of factors, including students' needs, students' goals, teachers' goals, local constraints, and the teacher's pedagogical values. Our study provides a more detailed picture of how a particular problem-oriented "innovative science learning environment" unfolds in the context of different classroom cultures. We will now briefly discuss how these assertions and factors were manifest in the classrooms we examined.

Across all four cases, we found that teachers assimilated the ActiveInk curriculum into their classroom culture. Each of the teachers picked out tools and resources that were seen as valuable, matched their strengths, were consistent with their pedagogical beliefs, and were perceived as potentially engaging for their students. Each of the teachers reconfigured the curriculum in unique ways, and in general, the more they adapted the curriculum to their local needs, the more students engaged with the curriculum in a manner consistent with how it was designed. We found that for the most part the preordained project challenges did not have local relevance to students and were not likely to anchor learning in productive ways. Rather, the most effective instantiations involved teachers taking the tools, resources, and challenges we provided them, and rearranging them in novel ways that met local needs. In each of these cases, we saw moments where teachers were confronted with a choice of whether to continue with the curriculum as it was designed or whether to redesign the unit on the fly.

One approach to effectively supporting the implementation of curricular innovations is through participatory or user-based design (e.g., Carr, 1997); however, this may also create certain problems. Theoretically, collaborations among researcher-teachers and teacher-designers have a greater chance of successfully implementing innovative curriculum because they understand the underlying pedagogy behind the curriculum as well as the local needs and constraints (Carr, 1997; Randi & Corno, 1997). To a certain extent, this was true in the case of Luke's implementations of the curriculum, as it was the most successful in engaging students in addressing the project-level question and engaging in them in inquiry. However, this case also reveals a danger in having user-designers implement curriculum. Luke was so engrossed in the process of designing this curriculum that when it came time to teach with it, he felt a strong pull to "stick to the book," or implement the curriculum as it had been designed. In reality, it appears that abandoning the original curricular plans and reframing the project to meet local needs and constraints would have been the more productive route. In this way, successful implementation might be conceptualized as supporting teachers in not being simple curriculum users, but comakers of any curriculum (Avery & Carlsen, 2000; Lindsey, 2000).

Consistent with Randi and Corno (1997) we argue that researchers need to respect and leverage teachers' implementation practices, acknowledging their experiences and expertise as strengths rather than liabilities to be circumscribed. Looking across the four cases, the process by which the curriculum was implemented can be described as assimilation into the classroom culture; that is, the curriculum was adapted to fit the teachers' needs, pedagogical beliefs, experiences, and techniques and was adapted in order to meet the culture, needs, constraints, and issues-at-hand in each classroom. There was a good deal of variance across implementations as teachers repurposed the ActiveInk curriculum to meet their particular situations. One can argue that there was more cross-case variance than invariance among pedagogical processes. It appeared that as the ActiveInk curriculum was used, local constraints were better predictors of the implementation experience. These cases suggest that the classroom culture, which is a culture nested within the broader school culture (Banathy, 1991), persisted when the ActiveInk curriculum was introduced and was a major determinant in how the curriculum was implemented. In each case, we saw that the predominant classroom culture remain in place across instantiations.

LIMITATIONS

The results of this study reveal many important issues for educators developing large-scale curricular implementations; however, there are many limitations regarding this study that should be noted. The sampling methods, predominance of technology failures, nature of this project being in its developmental stages of implementation, shifting roles of the researchers, and lack of disciplined inquiry into the classroom cultures prior to the use of ActiveInk demand that the results of this study be taken with some caution. These limitations serve to point toward areas for further study.

The teachers who participated in this study were a convenience sample, chosen due to their willingness to use the ActiveInk curriculum and the potential of these settings to highlight theoretically interesting issues. No systematic attempts were made to sample broadly, or select teachers according to their attitudes about technology, project-based learning, or curriculum adoption. Based on the willingness of these teachers to participate in this study and use a multisession, web-based project-based project, we recognize that they maybe more open to adopting (and possibly adapting) curricular innovations than many of their colleagues. The classrooms were also very different from each other, making cross-case comparisons somewhat problematic. These teachers were also less experienced than a representative sample of science teachers (no teacher had more than 7 years' experience, and most teachers were in their first 3 years in their particular position). Furthermore, we did not study any urban classrooms, which are known to have particular types of implementation issues (Songer, this issue). Thus, although the classroom context played a major role among these cases further study examining how this relationship interacts with teachers' pedagogical beliefs, individual classroom contexts, and attitudes toward curricular innovations would be useful.

The educational research community needs more longitudinal studies of how classrooms evolve over multiple iterations of using such a curriculum. This will help us to better understand the relationship between adoption, adaptation, and successful implementation as well as the relationship between the culture of the classroom and the teaching and learning practices that take place. Each of these cases in this study was the first time that these teachers used this curriculum. Each teacher shared a number of ideas about how he or she would teach the unit differently in the future. While a lack of experience with the curriculum is certainly a confounding factor, the strong desire that teachers showed to modify the curriculum to meet their own needs suggests that added experience might only lead to more adaptation of the curriculum in order to meet local constraints and tailor it to their classroom culture. Examining these same teachers over time will be a focus of our future studies.

If classroom culture plays a critical role in shaping the adaptation of an intervention, then more systematic examination of the cultures within these schools/classrooms prior to implementing the ActiveInk curriculum is necessary. In two of the four cases (rural ozone case, preservice teachers ozone), the researchers had established formal relationships with the participating teachers during which they had observed the teachers at some point during the year prior to the study. In the one case (alternative middle school), the researchers had participated in other projects within the school and we were aware of other research reports on this particular school culture. We feel that these experiences, coupled with pre- and postinterviews and observations, give us a solid basis for making assertions about the role of broader cultural contexts in shaping how this curriculum was implemented in each case. However, in order to make stronger assertions about how the cultural context played out in each implementation, more data is needed. Specifically, it would be useful to have interviews and observations of each classroom before and after implementation, data from other nonparticipating classrooms, interviews and observations of administrators and other faculty, and parents and community members.

In each of the aforementioned cases, technology failures played a critical role in how the unit unfolded. Each school dealt with network reliability issues, desktop computer hardware problems, filtering software that created network bottlenecks, and inadequate technology coordinator support. The researchers supported these teachers by troubleshooting hardware and software, installing browser plug-ins, and/or suggesting alternative lesson activities. By playing a supportive role similar to that of a "customer service representative" we were able to address some, but not all of the technology glitches. These cases impressed upon us the need to provide teachers technical, emotional, and personnel support when using technically innovative curricula that are likely to have glitches. These cases also suggest that the technical constraints of each environment, such as the network reliability, amount of local technical support available, and configuration of desktop machines played a large role in determining how the curriculum was implemented and whether or not the teachers felt it was a success.

Throughout these implementations, the researchers attempted to provide teachers personalized instruction in how to use the curriculum. We offered to lead them through the materials, share stories of other implementations, and provide any additional resources or information they required. Nevertheless, one might argue that such professional development may not be necessary and/or sufficient for introducing teachers to such project-based, technology-rich curricula. Quite different results may have been observed had we provided more formal training, or developed a supportive network of teachers using the curriculum. Further, in each of these cases it was the teacher's first time implementing the ActiveInk curriculum. In all likelihood, these teachers may have much less difficulty with the curriculum or be faced with quite different challenges during future implementations.

IMPLICATIONS

Consistent with Randi and Corno's suggestions (Randi & Corno, 1997), these cases suggest that the most powerful opportunities for designing meaningful learning experiences occur when teachers adapted curricula to meet the needs of their local contexts. Designing learning experiences in response to students' goals and consistent with teachers' strengths seemed to produce the most productive learning. It is entirely possible that as teachers use the ActiveInk curriculum over several instantiations, they might refine an approach (or approaches) that they find effective. However, the results of this study point equally to the possibility that locating and exploiting opportunities for driving questions and challenges is a dynamic process that will always be rooted in the particularities of a given learning context. Therefore, regardless of how well designed a curriculum is, good teachers will always transform the curriculum into one that is consistent with their personal pedagogical beliefs, classroom culture, and students' interests and past experiences; that is, every classroom environment is unique and it is the primary role of the teacher to locally contextualize curricular materials to support their students' learning (Barnett & Hodson, 2001; Clark & Peterson, 1986).

These cases certainly highlight the importance of examining the learning environment as a system that includes subjects, tools, objects, rules, norms, division of labor, etc. (Barab, in press), rather than looking only at the curriculum or the interactions between teachers and the curriculum without acknowledging the context. Indeed, the way that these activity systems responded to new environmental inputs and adapted to environmental constraints suggest that learning environments might be fruitfully understood as open, self-organizing systems. Healthy learning systems were observed identifying end paths and reorganizing spontaneously to meet desired end states (Barab et al., 1999). In this way, a major task for designers becomes how to encourage teachers and learners to own and reconfigure the goals and tasks dynamically in a learning environment. Learning environments that give teachers the tools and data they need to reconfigure curriculum on the fly may better support this type of reorganizing the curriculum that was the hallmark of the more successful cases. Specifically, teachers (and students) in this study might have benefited from having a sense of students' goals and expectations early in the curriculum, and so that they might configure learning experiences responsive to students' needs. Based on our findings, we argue that the role of designers becomes more indirect as curricular decisions are made locally. At the very least, these cases called into question for us to what extent the experiences we observed should be described as "the ActiveInk curriculum being implemented in several classes," or "several classroom cultures manifesting themselves through instantiations of the ActiveInk curriculum." This subtle distinction has important implications for designers of educational interventions that are used across broad contexts.

Across all of these cases, the inertia of existing classroom cultures and practices was quite forceful, shaping many of the activities that occurred. Indeed, the potential of an instructional design to affect a particular classroom experience seemed miniscule in comparison. As such, the entire notion of building "scalable" educational interventions becomes somewhat problematic. Rather, more appropriate goals seem to be building educational interventions that are flexibly adaptive to local needs and constraints and supporting teachers in making dynamic decisions about redesigning learning environments (Schwartz et al., 1999). As designers, conceptualizing our role as producing tools and resources which are assimilated by activity systems is a bit humbling, but may ultimately result in a better and more useful curriculum for teachers and more meaningful, relevant, and locally grounded learning experiences for students.

Another approach is for designers to more actively facilitate the process by which teachers move from users to makers (Lindsey, 2000). One way to accomplish this process is by making the design of a curriculum transparent, where the pedagogical rationale and curricular goals are readily and actively communicated to teachers. Unfortunately, historically, this approach has not worked especially well. Another approach might be to conduct design experiments (Brown, 1992), where researcher-designers serve as a support team for teachers, examining how curriculum is used and providing resources for teachers to improve classroom practice. In three out of these four cases, the teachers were excited and eager to continue working with researchers to improve their practice, and we intend to do follow-up studies in order to track future use of this curriculum. These kinds of collaborative relationships have been successful on small scales (Corno & Randi, 1999), but how to scale up such resource-intensive processes remains a challenge.

By designing supportive learning communities around innovative curriculum, developers may be able to design more scalable collaborations. By bringing designers, teachers, and researchers together, perhaps collaborative communities can form whereby adaptation stories are shared and encouraged (Avery & Carlsen, 2001). However, pursuing this type of community means shifting the historical role of researchers from one of experts to ones of collaborators, where researchers serve, support, and collaborate with teachers who are the local experts at conceptualizing curriculum to meet local demands. Finally, these cases remind us of the importance of school and classroom cultures in the learning process. Ultimately, curriculum designers need to acknowledge that their designs are not self-sufficient entities; instead, during implementation they become assimilated as part of the cultural systems in which they are being realized.

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