Knowledge, Identity, and Teachers' Multiple Communities of Practice

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Introduction

This paper examines the effects of teachers' memberships in communities of practice (COP) on their management of their own classroom communities. Drawing from both the main body of sociology of science and the Social Construction of Technology (SCOT) subfield, we argue that teachers' use of curriculum can be equated with the use of any technological artifact in an innovative manner (Bijker et al., 1987). We view curricula as technologies (Shapin & Schaffer, 1985; Mulcahy, 1998) and teachers as "users" of those technologies (Bardini & Hovarth, 1995; Kline & Pinch, 1996; Lindsay, 1999). We distinguish between two categories of users: the curriculum "maker" and the curriculum "user." A maker is a teacher who has been involved in multiple phases of the curriculum construction process: design, development, implementation, and evaluation. A user is a teacher who has only been involved in the implementation phase.

By focusing on teachers' memberships in COP and their curricular innovations, we examine the role that identity plays in the teaching of science as a social activity. We are particularly interested in investigating the ways in which teachers' identities in external COP and as users or makers translate into their classroom practices. Adopting the practice of following technology users from SCOT—viewing teachers as users—provides an interesting way to investigate the ways teachers adopt, integrate, and reconfigure technologies in their portrayal of science. Focusing on users (and their interactions with technologies) throughout the technology's life cycle offers provocative insights into teachers' identities as practitioners of science and as members of the science education community. The level of curricular adoption, integration, and reconfiguration is used as a measure of teachers' assimilation (buying-in) into COP. Teachers' interaction with technologies—in the process of making or using—is explored and analyzed by the ways in which teachers represent themselves when teaching science in a sociological useful way. We are interested in understanding how teachers formulate their identities as users and makers; how teachers associate themselves with various COP; and ultimately, how teachers' social processes and interactions factor into their classroom practice. Specifically, we ask: What are the effects of science teachers' identities as curriculum makers on classroom practices? Does ownership of curricular methods influence teachers' capacities to foster a classroom COP?

For our work, we utilize the work of Etienne Wenger (1998) and Lave and Wenger (1992) to frame our construct of teacher identity and to inform our discussion and portrayal of

COP. We employ the work of Lindsey (1999) and Kline and Pinch (1996) to conceptualize our model: Curriculum as technology—teacher as user.

Objectives

This study is part of a larger research project that examines the effects of teachers' identity and their participation in communities on their capacity teach science in its social context. One overarching question has guided this overall research endeavor: How and why does a teacher choose to teach science as it is practiced in the real world? This is a salient question to ask given the current "national arms race" of high stakes testing which almost exclusively focuses on individual students' mastery of knowledge and skills. In New York State, for example—which has decades of experience in routine testing—a progressive set of integrated State mathematics, science and technology standards is now being reduced to separate subject-specific Regents Exams; the most interesting inquiry-oriented standards have been dropped from the testing plan; group work is largely absent from the assessment plan; and a well-utilized loophole has been closed that had permitted tens of thousands of students to graduate without ever taking the exams. The net result is that science education programs in New York today are more oriented than ever to getting students through standardized tests, and the sociological dimension of scientific inquiry risks being relegated to what Eisner (1985) calls the "null curriculum."

Teachers who choose this route—to teach science as it's practiced in the real world—need to have pedagogical tools, a unique perspective on the purpose of high school science, a view of learning as participation, and an understanding of science in its social context (Cunningham, 1995). Infusing lessons from the sociology of science such as questioning the status of science, working with messy data, examining the details and processes used by scientists in the generation of facts, opening the black box of artifacts and machines, and incorporating the public, economic, and social influences on science, extends the realm of classroom science to new and more demanding levels.

Researchers in science education have examined ways of infusing these types of lessons through the dissemination and implementation of innovative curricula and through various teacher development programs (Costa, 1998; Helms, 1998; Kelly, Carlsen, & Cunningham, 1993; Millar, 1989; Roth, 1997). What has not been examined in the course of these discussions is a focus on the interactions that occur between teachers outside of their classrooms—in professional communities, teacher development programs, or coursework —which influence the ways in which teachers represent science in their classrooms. We know teachers bring experiences, beliefs, and philosophies about teaching science to their classroom environments (Cunningham, 1995; Helms, 1998); what we do not know, however, is how these constructs and teachers' social experiences in these types of communities effect their classroom practice.

Teachers' work goes beyond the classroom and often includes their participation in settings (such as professional development, curriculum development, conferences, and inservice workshops) that foster teacher-teacher interaction. These types of experiences provide teachers with opportunities to exchange ideas as well as develop materials and activities they in turn bring to their classrooms. It also provides an environment where teachers can network and draw on each other for support and creativity.

A worthwhile question to ask is how and to what extent do these social settings and experiences and the camaraderie that develops among teachers within these communities, enhance teachers' professionalism and ability to cultivate a social learning environment in science classrooms? This is an interesting question for several reasons. First, teachers who choose to teach science as it is practiced in the real world are called on to use approaches that support their students doing original research and open-ended investigations, to put in place practices that encourage student-centered classrooms that provide an environment for public discussion and peer review. Taking this approach requires teachers to take on a more professional and non-traditional method of teaching school science. It requires them to have a strong subject matter knowledge (Carlsen, 1988), comfort with laboratory science, and an understanding of science as it is practiced in the real world (Cunningham, 1995).

Second, to cultivate social learning environments, teachers must provide unique and diverse opportunities that take them out of the center role in the classroom and put the focus on students. Third, not only are these teachers choosing to teach science in a sociologically informed way—they are choosing to do so in a time of increased pressure towards conformity. Recently in New York State (NYS), a newly adopted graduation policy puts even more emphasis on high stakes tests[1] and this current reform brings new levels of accountability to teachers. Specifically, this new educational policy of high stakes assessments and tougher graduation requirements link student outcomes to teacher performance. This research looks at the role of COP in classroom practices and it pays specific attention to the social learning environment created by teachers. It investigates teachers' classrooms where science is taught as inquiry and not as content for test results.

In this study, we focus on one COP—"Environmental Inquiry (EI): Learning Science as Science is Practiced"—an interdisciplinary, multi-departmental environmental science curriculum development project that brings together educators, scientists, and secondary science teachers in a partnership to create a curriculum dedicated to teaching science in a sociologically informed way. We follow teacher makers and users through this technology evolution process and examine the ways in which teachers, as a result of participating in this project, create science communities in their own classrooms. In addition, we explore the workability of both Wenger's COP framework and the SCOT technology-user model as a means of examining teacher practice.

Theoretical Framework

This research draws upon two primary bodies of literature. The first body of literature, Science and Technology Studies (S&TS), provides the methodological approach for investigating teacher practice. Because it stems from a sociological perspective, it allows for rich and detailed descriptions of actors and practices without bestowing judgement on the actor or the practice. Focusing on social actions reduces the subjectivity and ambiguity in the research data. Thus, the ways in which teachers present themselves as they "do science," and how they portray science, can be viewed in the explicit social acts they make. Researchers are not dependent on subjects' reporting of their own beliefs. Assumptions can be investigated and actions based on those assumptions can be explained. By looking at actions, and requiring explanations for all actions, the privilege of authority is reduced and observation of all entities—human and nonhuman—can be treated equally (Bijker, Pinch, & Hughes, 1987).

The second body of literature focuses on Communities of Practice (COP) (Wenger, 1998). This provides a mechanism for examining how the learning and *practice* of science occurs in high school classrooms. It takes on the challenge of rethinking learning in schools by viewing learning *as* participation (Lave & Wenger, 1992). It centers on teachers' abilities and willingness to create social learning environments in their classrooms where science is taught as it is practiced in the real world. In this scenario, teachers are facilitators and students are the practitioners in the local production of science (MacBeth & Lynch, 1998).

The Lens of Science and Technology Studies (S&TS)

S&TS views science as a social process and scientific knowledge as a social construction. It's roots are in the Sociology of Knowledge (Berger & Luckmann, 1966) where reality is seen as being formed through dialectical processes between individuals and society. In this process, individuals' ideas and conceptions evolve and are objectified in public discourse and social knowledge is in turn, internalized by individual actors. Practitioners in S&TS focus on the role of social interaction in the formation of science. They argue that scientific facts are cannot be based on empirical evidence alone. Facts are actually claims that have been moved to the status of facts as a result of social negotiations between actors and artifacts (Latour & Woolgar, 1986).

These understandings have been extended to the area of technology. Distinctly opposite from the commonly accepted view that technology affects society, SCOT (The Social Construction of Technology) looks at the evolution of technology and highlights the role relevant social groups play in the negotiation of technology's structure and function. This genealogy often reveals alternative possibilities to what had become the standard design of a technology. Determination of the prevailing design is a product of the interaction of different relevant social groups. Both in the technology design phase and after assumed closure (stabilization of an artifact), users' interactions with technological artifacts can effectively result in their reconfiguring the technology (Kline & Pinch, 1996; Pinch & Bijker, 1987). Thus, we view curricula as technologies (Bijker et al., 1987; Shapin & Schaffer, 1985) (Mulcahy, 1998):

> By using *technology* to refer to literary and social practices, as well as to machines, we wish to stress that all three are *knowledge-producing tools* (Shapin & Schaffer, 1985, P. 24).
>
> That 'technology' comprises more than machines… 'Technology' can include social arrangements as diverse as the postal system, transportation, refuse collection, voting mechanisms, education, and so on (Woolgar, 1991, p. 94)."

And teachers are viewed as "users" of those technologies (Bardini & Hovarth, 1995; Kline & Pinch, 1996; Lindsay, 1999; Mulcahy, 1998). As technological users teachers act as agents of technological change (Kline & Pinch, 1996; Pinch & Bijker, 1987).

Over a decade ago, using understandings from the Sociology of Scientific Knowledge (SSK), Pinch and Bijker (1987) developed a model (SCOT) for analyzing the social construction of technology. They now use SCOT to analyze a socially significant group, the users of various technological artifacts, as agents of technological change (Pinch & Bijker, 1987).

In SCOT, technology as a developmental process, is described as an alternation of variation and selection, which results in a multidirectional model of analysis. A major tenet of this model claims that the design, technical content, and use of technological artifacts are all open to sociological analysis. It incorporates three components for examination in user analyses: the role of relevant social groups and interpretive flexibility of an artifact, closure or artifact stabilization, and a detailed description of the case studies of users and their technologies for communication to the larger context.

Relevant social groups are defined as groups of individuals who share an artifact's meaning (Kline & Pinch, 1996). Different groups can have different meanings for the same artifact. This variation in meaning surrounding a given artifact is called "interpretive flexibility". Interpretive flexibility in science or technology can described as the ways in which different conclusions can be reached from the same data, or different technical designs offered in the same constraints. Because technology is considered culturally constructed and interpreted, not only is there flexibility in how people think of or interpret artifacts, but there is also flexibility in how artifacts are defined or stabilized. This opportunity for interpretation lends itself to many different paths of artifact construction by the various relevant social groups. These paths are examined to gain insight into the multiple ways that a technology can be shaped and reshaped during its life cycle. This process usually continues until closure or the stabilization of the artifact occurs meaning one form of the artifact has become more dominant over other forms. Alternatively, closure is said to occur when the relevant social group no longer perceives problems surrounding the artifact or a solution to problems has been determined. Closure can also occur if the problem has been redefined as such, that the artifact now becomes the solution. Closure may not necessarily result in the disappearance of all forms of the technology, however—several forms can exist simultaneously. Additionally, closure can be temporary—new problems can emerge which once again result in a resurgence of interpretative flexibility leading to the re-stabilization of the artifact. In an attempt to examine the larger context, SCOT offers rich case descriptions of the social groups' interactions with the technology. This, is a means of examining the ways in which groups shape, interpret, and change the design of artifacts once considered to be fairly stable.

Previous research in SCOT examined the influence of innovators (designers, manufacturers) on the form and design of technological artifacts (Callon, 1987; Law, 1987;

Pinch & Bijker, 1987; Woolgar, 1991). A number of studies conducted, centered on these technological innovators as the major controllers of technological systems and artifacts (Bardini & Hovarth, 1995; Callon, 1987; Law, 1987; Woolgar, 1991). These investigations focused on the innovators' influence on the design phase of technology. Investigators found that innovators tended to construct the artifacts in their own image. Consequently, the technology they created limited, in fact, the end-user (Bardini & Hovarth, 1995; Woolgar, 1991). Thus, according to Woolgar (1991), both the form of the artifact and the intention of the innovator (direct or indirect) have limited users' access to and knowledge of the "machine (technology)." As a result of this co-construction, the technology creates a boundary between the innovator (insider) and the user (outsider). On the other hand, in her studies on users and technologies, Lindsey (1999) (Lindsey, 2000) disagrees with Woolgar's boundary separation. She argues that users may fall into many different categories and that Woolgar's distinction between only the two categories of insiders and outsiders is insufficient.

Increasingly there has been a shift in focus in SCOT studies from the innovators to the users. Following the technology into the hands of the user has provided a ripe area of investigation. As one researcher has found, once the technology gets into the hands of the actual users, the boundary between insider (innovator) and outsider (user) becomes less clear and in some instances, actually dissolves or is reworked (Lindsay, 1999). In her research, Lindsey followed a specific technology throughout it's life cycle and observed (2000):

> [Users and technology are presented] as a combined element. People only become users when they come into contact, in some way, with a particular technology. A social constructivist perspective introduces interpretive flexibility, the idea that the use and meaning of a technology may be interpreted in different ways by different groups of people. This leads to recognition that the relationships between users and technology are fluid and continually negotiated. 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).

"Users" are described as mythical or virtual figures for whom a technology is designed (Lindsay, 1999); they are often thought of as being configured or scripted by the inventors of the technology (Akrich, 1992; Woolgar, 1991). Past practice indicates that innovators design technologies under the assumption that the technology's final form is—and will be—uncontested by the end-user. However, studies that unearth the developmental stages of a technology *and* *follow it through its implementation* phase show that users are not passive. They are capable of interacting with technologies in ways the designers may not have predicted. In fact, users often reconfigure the "finished product". By opening and examining an artifact or technology, unforeseen or unintended consequences surrounding the artifacts' uses can be explored. This approach entails viewing a technology as a "black box"(Latour and Woolgar 1986). A black box is an entity (such as a law, relationship, text, procedure, protocol, technology, device, instrument, etc.) whose validity is generally not questioned. Much of scientists' (and arguably—engineers, teachers, lawyers, physicians, etc.) work involves utilizing black boxes in one way or another.

By viewing technologies as black boxes, we are able to reveal the history, the various forms the technology took in the design process, and the negotiations that were part of its creation and the designation of its final form. Taking this approach enables us to uncover the ways in which users act as agents of technological change.

Thus, transferring templates from several SCOT studies on engineering to the realm of education, we examine teachers as technology users throughout the life cycle of the EI curriculum technology. We look at the similarities and differences between computer designers and teacher makers, and computer configured users and teacher users. Similarly, as exhibited by various user groups (Bardini & Hovarth, 1995; Kline & Pinch, 1996; Lindsay, 1999), we explore the ways in which (teacher) user identities become tied to technologies and how these identities are related to their membership in COP like EI. Because our framework involves a social perspective, we rely on Wenger's construct of identity:

> I will use the concept of identity to focus on the person without assuming the individual self as a point of departure. Building an identity consists of negotiating the meanings of our experience of membership in social communities. The concept of identity serves as a pivot between the social and the individual, so that each can be talked about in terms of the other. It avoids a simplistic individual - social dichotomy without doing away with the distinction. The resulting perspective is neither individualistic nor abstractly institutional or societal. It does justice to the lived experience of identity while recognizing its social character—it is the social, the cultural, the historical with a human face (p. 145).
>
> Identity is the vehicle that carries our experiences from context to context (p. 268).
>
> Identity in practice is defined socially not merely because it is reified in a social discourse of the self and of social categories, but also because it is produced as lived experience of participation in specific communities (p. 151).

COP

We illustrate the utility of a COP view in describing classroom practices and in shaping sociologically authentic school science programs. This view of learning—as shared participation (Lave & Wenger, 1992) in a COP (Wenger, 1998)—is a beneficial way of characterizing what takes place in scientific communities. This perspective is transferable to the science classroom where learning by participation can also occur and enhances learning science as it is practiced in scientific communities. Lave and Wenger describe participation—legitimate peripheral participation (LPP)—as the beginning of the community membership process:

> It crucially involves *participation* as a way of learning—of both absorbing and being absorbed in—the "culture of practice." An extended period of legitimate peripherality provides learners with opportunities to make the culture of practice theirs (p. 95).

Wenger describes a COP as being a composite of a shared repertoire, a joint enterprise, and mutual engagement,

> The repertoire of a community of practice includes routines, works, tools, ways of doing things, stories, gestures, symbols, genres, actions, or concepts that the community has produced or adopted in the course of its existence, and which have become part of its practice. The repertoire combines both reificative and participative aspects. It includes the discourse by which members create meaningful statements about the world, as well as the styles by which they express their forms of membership and their identities as members (p. 83).
>
> These practices are the property of a kind of community created over time by the sustained pursuit of a shared enterprise (p. 45).
>
> The first characteristic of practice as the source of coherence of a community is the mutual engagement of participants. Practice does not exist in the abstract. It exists because people are engaged in actions whose meanings they negotiate with one another…Practice resides in a community of people and the relations of mutual engagement by which they can do whatever they do. Membership and community of practice is therefore a matter of mutual engagement. That is what defines a community (p. 73).

We fuse together understandings from SCOT and COP to investigate the ways in teachers' portray a sociological view of science in their classrooms. Viewing teachers as makers or "old-timers" and users or "newcomers" (with regard to their involvement in the EI COP), provides a unique way of investigating the impact of teachers' social learning experiences on their classroom practice.

The EI COP

Lave and Wenger offer a helpful "sketch of a COP" which they describe as follows:

> From broadly peripheral perspective, apprentices [new members to a COP] gradually assemble a general idea of what constitutes the practice of the community. This uneven sketch of the enterprise (available if there is legitimate access) might include who is involved; what they do; what everyday life is like; how masters talk, walk, work, and generally conduct their lives; how people who are not part of the community of practice interact with it; what other learners are doing; and what learners need to learn to become full practitioners. It includes an increasing understanding of how, when, and about what old-timers collaborate, collude, and collide, and wheat they enjoy, dislike, respect, and admire. In particular, it offers exemplars (which are grounds and motivation for learning activity), including masters, finished products, and more advanced apprentices in the process of becoming full practitioners (p. 95).

This sketch provides a particularly efficacious backdrop for studying teachers' social actions and involvement in the EI COP. Specifically, it can be utilized to understand how both users (or apprentices or newcomers described by Lave and Wenger) and makers (who can be viewed as masters or old-timers described by Lave and Wenger) translate their COP experiences into their classroom environments. The technology (curriculum) involved in this study is built on the premise that classroom science be taught as it is practiced in the real world. At it's core are understandings from the sociology of science. Lave and Wengers' constructs provide a meaningful way for examining the social learning environment created by teachers in their local production of science. It also allows for examining how student become practitioners in their own local production of science. It focuses on the social engagements that are made available for learning to occur.

In order to build social learning environments in classrooms, teachers need to be provided with opportunities for social interaction, collaboration, and experiences that enable them to identify themselves as members of a group or community (Sullivan, Magnusson, Marano, Ford, & Brown, 1998). In viewing learning as a social process, as participation, "it makes enormous sense to provide occasions for interaction, joint collaboration, and the collective pursuit of shared goals—that is, to nurture communities of practice" (Sullivan et al., 1998). Whereas some teacher development programs have focused on building a COP in the fashion of mirroring the scientific community (Sullivan et al., 1998), the EI program goes several steps further. First and foremost, the EI project brings together scientists, educators, staff and secondary school teachers in a collaborative effort to create an environmental science curriculum that is sociologically authentic. It involves multiple levels of collaboration with a variety of actors in different settings working with individual and small groups teachers; teachers working with teachers (maker-maker, maker-user, user-user) within and among schools; inservice teachers (maker/user) with preservice teachers; and individual teachers (maker/user/inservice/preservice) with research science undergraduate and graduate fellows. Second, teachers spend three weeks in residency on the Cornell campus engaged in research, collaboration with other teachers, and interacting with educators and staff to build the curriculum (EI technology). In addition to the summer residency, teachers are involved in ongoing workshops throughout the academic year and research symposia (for students to come to Cornell and present their research and to peer review other students' research). This level of participation during the year requires teachers to do the following: Engage their students in original research; to communicate and collaborate with other teachers (inservice and preservice), schools, and students both in person and on the web; and to participate in piloting and reworking the EI curricular materials in their classrooms. Thus, EI is the vehicle for teachers' networking, collaborating, and creating COP in their classrooms.

Teachers' Evolution in the EI COP: Newcomers & Old-timers

The EI program has evolved into a well-established COP. It's repertoire includes: Extensive fieldwork and laboratory research, use of specific computer technologies (STELLA, GIS, PowerPoint), on-line peer review and communication, daily/monthly/yearly collaboration between teachers with and among schools; and the establishment of teacher identities (the technology gurus, bioassay experts, technology (devices) design experts, leaders, experts and novices).

EI began with teachers coming to a structured program that focused on fieldwork in environmental science where teachers (users, novices, newcomers) worked with formal stabilized curricular materials. As newcomers or users (configured), teachers worked with environmental science experts and Cornell staff to gain experience working with these activities to facilitate classroom implementation of these materials. This program evolved into a curriculum development project in which several initial participants (users) returned and became makers who would create the EI technology in conjunction with scientists, educators, Cornell staff, and other teachers. The following year, the makers continued to finesse old and new curricular activities and became the instructors for the new users (newcomers). The makers' participation in EI evolved from peripherality to full participation and they transformed into masters within the EI community. In the final formal year of the program, the master/makers worked on special assignments and continued to assimilate the EI technology into their classroom syllabi to the point in which the technology became their own (see EI COP Evolution graphic below). In the past year following the end of the formal summer program, teachers have continued to participate in workshops and to bring their students to the research symposia at Cornell.

EI COP Evolution

1990		**2000**
Users (Configured)/Outsiders/ Newcomers	**Users/Apprentices/Newcomers & Makers/Experienced & Old-timers**	**Makers/Old-timers**
Experts work with configured users	**Makers work with scientists, educators, EI staff, and other teachers** **Makers work with Users/Newcomers/Apprentices**	**Masters craft the technology** **Masters *become* the insiders**
Legitimate Peripheral Participation	**Movement towards full participation**	**Full Participation**
Implementation of stabilized technology	**Design, development, and reconfigurationof EI technology**	**Continued implementation & Reconfiguration of EI technology**
	EI assimilation into makers' classroom repertoire **Reference to EI community & other members**	**Full EI assimilation into makers' classroom repertoire** **Reference to EI community & other members**

Methods

The primary subjects of our study are four secondary science teachers who participated in EI. Two of the teachers (who we have identified as "makers") were selected because in the course of the interviews, classroom and workshop observations, and ongoing conversations, they came across as aggressive innovators of curricular projects. However, to situate the teachers in a larger context, we collected background data from all 14 teachers who have participated in EI. The other two teachers were selected because of their involvement with the makers during the most recent summer program and their interest and plan to implement EI materials during the coming school year. They were participants in a concurrent program and worked with EI teachers in the afternoons—because these teachers did not design the curricular materials, we have identified them as "users". All of the summer participants completed a background questionnaire and were interviewed during the summer program and the school year. Curricular materials were developed by the teachers during the summers and were collected and analyzed. In addition, site visits to a subsample of seven teachers' classrooms were conducted last year to gain insights about curricular implementation and innovation.

Our study is a case study of four teachers (Yin, 1994). These teachers have been interviewed regarding their beliefs about teaching science, professional experiences with science, membership to various communities of practices (organizations, committees, extra-curricular activities), and science classroom instructional design regarding implementation and innovation. Their curricular projects and implementation plans have been analyzed. We have closely monitored their implementation of the innovative units through classroom observations, interviews, on-going conversations, and videotaping of their classrooms. This particular piece of a larger study (dissertation research) focused on following teachers through the implementation of a Bioassay unit. This process took place over a 3-8 week period. This unit was selected because teachers were concurrently implementing the unit in a variety of classrooms. The implementations were concurrent because teachers were preparing their students for participation in a student peer –reviewed Research Congress held at Cornell. Teachers and students were not only engaging original research experiments (gathering, analyzing, and interpreting their findings), they were preparing for the project's culmination at the peer review congress. Participating in this activity required teachers and students to engage in the research process and find ways to communicate their findings to a larger context. In doing so, teachers were asked to go far beyond the traditional “cookbook” lab approach to science. This process also involved teachers’ modifying curricula and being open to conducing open-ended investigations in their classrooms.

We followed teachers through this process by visiting their classrooms, conducting interviews, and maintaining on-going conversations throughout the implementation process. (Findings from this research effort are summarized in tables 1-8) and will be discussed in the results section.

Results

Several interesting insights about the relationship between teachers’ membership to external COP and their classroom practice have emerged. Results support others’ findings (Cunningham & Carlsen, 1994) that teachers’ beliefs about the ability of high school students to conduct “real” science research are shaped by teachers’ experiences with science. In this study, all four teachers claimed their research experience in science contributed to their bringing the practice of research and open-ended investigations into the classroom (Table 1).

Table 1: Teacher Background & Experience with Science

	Makers		**Users**	
Teachers	**Andy**	**Nigel**	**Ike**	**Terry**
Educational background	B.S. Chemistry Graduate work in Chemistry	B.S. Biology M.S. Education	B.A. Biology MAT Biology	B.S. Geology MAT Earth Science
Previous Career	Pharmaceutical Chemist	• Veterinary Technician • Marine Biology research	• DEC • Environmental firm	Geologist
Experience with Science	Conducting bioassays in pharmaceutical lab	• Research in Marine Biology • Research in Vet. Sci.	Research in Environmental Science	Research in Oceanography

Additionally, teachers saw their strong content knowledge central to teaching inquiry science. Teachers who have been characterized as “makers” tend to draw support from their associated communities of practice and this appears to enhance implementation, innovation, and the creation of a classroom COP (Table 2).

Table 2: COP

	Makers		**Users**	
Teachers	**Andy**	**Nigel**	**Ike**	**Terry**
COP Membership	EI, ISET, grants (NSF& technology), coaching, curriculum committee, conference presentations	EI, CIBT, NSTA, STANYS, staff development leadership, environmental awareness club w/students, conference presentations	Trout Unlimited, Greenpeace, National Wildlife Federation, ISET Coaching, interest in starting Ecology club	ISET, STANYS, Earth Science Mentor Network, conference presentations, Environthon, research & publication
Attributes Gained from COP	EI & ISET: sharing ideas, interaction with other teachers interested in creating curricula Grants: access to technology & networking/ communication via the web Coaching: teaming and groupwork	EI, CIBT, NSTA, STANYS: curricula for new approaches to science teaching, presentations, keep up to date on current research Prof. Dev.: presentations, leadership	Trout Unlimited, Greenpeace, National Wildlife: Stewardship skills, environmental awareness ISET & CIBT: ideas & innovations, curricular materials	ISET, STANYS, Earth Science Mentor Network, conference presentations: latest research, colleagues' experiences, new teaching methods, NYSED updates

The makers describe networking with other makers and users at the summer program and school year and events to be both a significant opportunity and a support system for sharing ideas and testing new innovations.

Snapshots of teachers

The teachers in this study were observed over a period of 1-2 months. By spending time in their classrooms and talking to teachers about their practice, we were able to get a sense of their meanings of practice and their experiences as they implemented the Bioassay curriculum. Below we describe a "snapshot" to represent each of their classrooms and acknowledge their practices as they relate to their COP memberships and their identities as makers and users (See tables 3-4).

Table 3: Teacher Identities

	Makers		Users	
Teachers	**Andy**	**Nigel**	**Ike**	**Terry**
Major Influences on Classroom Practice	• Coaching • Workplace skills • MST Standards • Students • Kinesthetic learner • Philosophy about teaching science	• Professors & education programs • Research experience • Mentor teacher (impetus to teach differently than mentor)	• Professors • Personal graduate school experience • Research and career experience • Activity instead of boredom • Desire to take risks and try new activities	• Professors • Research and career experience • Philosophy about science
Beliefs about Teaching Science	• Inquiry science • Open-ended investigations • Students doing original research • Application to students' lives and experiences • Ability to make connections	• Activities – students (and teacher) need to move around • Teach science as science is practiced – bring current research into the classroom • Students doing original research • Open-ended investigations	• Activities • Hands-on • Working in groups • Open-ended labs (85%) • Thinking & reasoning skills • Work with current research • Ability to make connections	• Real research • Teaching science as science is practiced • Relevance to local environment • Science is an activity of discovery, encouraging curiosity, and figuring out patterns
Classroom Practice	• Teaming • Student centered, limited lecturing • Incorporating students' life experience • Job and workplace skills • Practice real world science—application to students' lives • Project-based learning • Technology rich • Less emphasis on grades – multiple	• Groupwork • 30-50% lab • 50-70% lecture • project-based labs • self-designed curricula • Practice real world science—application to students' lives • Less emphasis on grades • Willingness to experiment with new ideas and activities—not concerned with failure	• Behavior modification • Learning skills • Conflict negotiation • Workplace skills • Character education • Less emphasis on grades – multiple assessments • Inquiry based • Willingness to experiment with new ideas and activities—not concerned with failure	• Empower students— • ownership of the data • Hands-on and minds-on • Allow the curriculum to select for students' various strengths • Multiple assessments • Inquiry science but teacher directed

	assessments • Willingness to experiment with new ideas and activities—not concerned with failure • Learn from students	• Learn from students	• Learn from students	
Instructional Design	• Projects • Teaming • Student centered • Multiple assessments—akin to the workplace • Flexibility • Activity-based (kinesthetic) • Student presentations and peer review • Students working concurrently in 4 different classrooms & labs	• Multiple assessments • On-going Projects • Flexibility • Activity-based • Structured • Student presentations	• Multiple assessments • Projects • Flexibility • Activity-based • Achieve understanding and making connections between and within science content • Connect experiences • Two-way between teacher and students • Posters and student presentations	• Groupwork • Labs and hands-on activities • Teacher directed • Open-ended investigations • Student presentations

Table 4: Insights & Emergent Themes

	Makers		**Users**	
Teachers	**Andy**	**Nigel**	**Ike**	**Terry**
Insights	• Teacher enthusiasm = student enthusiasm • Students work together (prepare for careers) • Not afraid to make mistakes and have students correct • Life skills and science skills • Have students teach each other • Students in leadership roles in the classroom • On-going and concurrent long-term projects	• Willingness to experiment and try new ideas • Not afraid to make mistakes and have students correct • Life skills and science skills • Learn from students • On-going and concurrent long-term projects	• Teacher enthusiasm = student enthusiasm • Willingness to experiment and try new ideas – take risks • Not afraid to make mistakes and have students correct • Life skills and science skills • Learn from students • Have students teach each other • Students in leadership roles in the classroom	• Teacher enthusiasm = student • Make it fun • Take risks • Encourage 9^{th} graders—“don’t decapitate them” • Willingness to experiment and try new ideas • Students in leadership roles in the classroom

Andy

Andy is a maker. He has been involved in the design and development of the EI technology from the beginning stages. He has designed and written the curricula for all of his applied science classes. Both his educational and professional background is in chemistry although he does limit himself to this. He often presents at conferences where he shares his knowledge and expertise in technology, the NYS standards, and in designing science technology and various research projects. Andy has funded his entire computer lab via school grants and outside funding.

A COP exists in Andy’s classroom. Andy and his students have developed a repertoire of practice that corresponds to the EI COP and resembles the ways in which science is practiced in the real world. In the course of his students’ high school career (in this particular science program created by Andy), they are likely to have him as a teacher for at least 2 out of their four years of science[2]. This has provided Andy with a mechanism to create a COP over time. Students enter the 9th grade class as newcomers to the community and through time, experience, and participation, evolve into old-timers by their senior year.

He teaches non-college bound students, most of who are classified students (resource needs, learning disabilities, Individualized Education Plan), in a dynamic and non-traditional way. He teaches three levels of this class: 9th grade, 11th grade, and 12th grade. For this study, although we visited all three classes, we focused primarily on the senior level class. During a typical day in science class, his 13 senior level students are spread out in 4 different classrooms—a classroom, a lab, his computer room, or the in the library—each team working on their group projects. Students are given their daily assignments of what they should attempt to accomplish for their portion of the class project during a single class period. Once they get the assignment for the day—off they go. There is a strong sense of respect, comfort, and trust in this classroom. For the bioassay project, students from several of his classes contributed (in the form of research and presentations to other classes) to this overall 12th grade project. This is made possible by Andy's structuring and management of the Applied Science program in his school. Each grade level is organized and specific skills are taught to prepare students for the subsequent year in applied science. Basically, his classroom repertoire resembles a sort of "on the job training" for the next job the following academic year. In the current project, the 9th and 11th grade classes ran many of the preliminary tasks such as preparing solutions and running initial bioassays. The overall project investigated the effects of acid deposition on lettuce seed growth. Students conducted bioassay experiments, created Power Point presentations, and discussed their results and progress electronically with interested scientists and student peers. Their final project involved the construction of an acid rain making device, a poster presentation and a Power Point Presentation of their bioassay results.

Andy's classroom is the exemplar of student- centered inquiry science distinguished through project designs and original research. His enthusiasm and desire to relate the practice of science to the real world shows through in his educational design tactics that center on student life experience and applicability the future workplace or education. This is significant because most of the economy consists of small family farms. His goal of giving students real experiences in the context of science is evident. He asserts "work with their experiences…fit science into their lives." His experience in research and science seem to give him the comfort and confidence to encourage and facilitate open-ended investigations. His approach of students working and being assessed as effective team members appears to be influenced by his many years participating in athletics and coaching where he emphasizes a work centered attitude. As he describes, “in coaching I like to see kids improve and feel good about themselves—and the same applies to the classroom.”

Nigel

Nigel has taught science for 7 years. After leaving veterinary science, he began teaching high school science. Since he began his career in education, he has been actively involved in presenting at various science education conferences and has been attending summer educational programs on a regular basis. He has been an integral part of the development of the EI curriculum and has written the curriculum for his environmental science classes.

At first glance by an inexperienced observer (who is not familiar with the science classroom), one might see chaos in this classroom. Upon further inspection however, one sees a lot of fun and activity being had by the students. Nigel has two classes of basic environmental science where half of the student population are students with special needs (resource needs, learning disabilities, Individualized Education Plan). In Nigel’s classroom, students are free to be themselves. They are busily working concurrently on several ongoing research projects from bioassays to building bio-regulators and composting experiments. Students work in groups under Nigel’s guidance. In the case of the first round of the bioassays, none of the lettuce seeds germinated. When students went to inspect their seeds after planting a week earlier, they discovered they had “no results.” Nigel used this incident to talk about they way research often goes in the real world, using his earlier career experience in the veterinary science research lab. Nigel went on to say to his students, “this is what it is really like in a real lab…I remember when all of our animals died in a hepatitis vaccination experiment…and you have to figure out what went wrong and why…what happened today in class actually happens in research.”

Ike

Ike entered teaching after working in various environmental organizations. Ike has only been teaching for just over a year. You wouldn’t know it when you walked into his ill-equipped science classroom to find students busily working on their bioassay experiments. His students, like the other teachers’, are mainly classified students and, like in the other classrooms, are working in groups and getting ready for the research congress. Ike allows them to explore their interests and choose which toxins that want to use in their lettuce seed and duckweed bioassays.

He moves around constantly offering suggestions and answering questions. One student works on the only computer in the classroom as she prepares her poster presentation. Ike's students are 9th graders who have been tracked all through school. They sadly refer to themselves as the "dumb ones" but Ike discourages this belief telling them they are doing harder and more time consuming projects than his Regents classes. He informs them how much more time he spends preparing for their class than his other classes. His kids come in every day with positive attitudes, happy, and ready to go. "I have learned to teach a whole different way than the way I was taught to teach—by doing projects these kids will remember what storm water is (that there even is such a thing) and what a lethal-dose 50 means—they'll remember they built devices and [conducted experiments]…more than they'll remember a test they took that day…when they see me excited about being here, they are excited."

Terry

Prior to teaching, Terry was an oceanographer. He has experience in research and has published in this field. Eight years ago, Terry began his career in teaching. This past year, he took over the general science class and decided "enough of the cookbook labs and the textbook-generated curriculum [let's bring research science into the classroom] and a fresh way of learning for kids." Terry said as he explained to me why he pilots EI and other innovative curricula. He enjoyed his previous work in research and wants to teach kids how to do research. "If the students see me enthused, they become enthused."

Terry directs his students (which are also classified students) and puts them into two large research groups for the bioassays. Although Terry tends to often direct students more than the other teachers in this study, he draws upon students' expertise and selects different kids to take on leadership roles in the classroom. He selects one student in particular to teach him and the others about using EXCEL in the computer lab. Terry uses this student to help interpret the graphs they have made from the lettuce seed bioassays. Terry sees this as an opportunity for the curriculum to select students and facilitate their strengths and build their self-esteem. Terry adds "kids appreciate when teachers can get off their pulpits and say let's work on this together…you can teach me…I don't have all of the answers."

In addition to the visits, on-going conversations, and written feedback, several common themes or ideas emerged from the interviews that are common to all four teachers, which include:

- The intention of making the connection between the real world and classroom science practice.
- Each teacher indicated that when they came to class enthused it generated student enthusiasm.
- Each teacher approached science from an interdisciplinary perspective and worked on making their classroom practice connected to the real world and local environment. They used project-based activities and inquiry investigations to promote understanding and creative thinking and reasoning.
- They presented science as fun, real, and applicable to their students' lives
- Each teacher emphasized the importance of trying out new ideas, taking risks, and of not being afraid to be wrong or making mistakes in the classroom.
- The makers attribute their experiences in the EI COP paramount to their implementation and reconfiguration of the EI technology.
- The users attribute their experiences in the EI COP paramount to their confidence in implementing the EI technology.

Teachers in this study exhibited different levels of implementation and reconfiguration of the EI technology. Although inquiry science is occurring in all classrooms, several differences stand out. Andy's classroom has the most extensive and well-established COP environment. His classroom COP repertoire is evidenced by his classes' daily routines. Students interact with Andy and each other as co-workers involved in a common research project. Andy provides support, suggestions, and guidance to his students as they pursue their research ideas. They work in different teams on a weekly basis and collaborate and pool their data regarding their findings that become part of their long-term research projects on local stream ecology and bioassays. From 9th grade on, students learn about the history they will become part of as they progress in their applied science career. They learn how to work in teams, negotiate their respective group and classroom roles and tasks, and present their findings to the advanced classes. Responsibility skills, scientific technique, and being part of a research community are talents that are learned and developed along the way.

Although both teachers focus on project-based science and students doing original research, the frequency and intensity of open-ended investigations and time dedicated to collaborative research projects is higher in Andy's classroom than in Nigel's. Nigel's classroom repertoire is characterized by joint collaboration between research groups within and between his environmental science classes. In taking environmental science with Nigel, students know before hand that they will become part of an ongoing local stream study and will be balancing simultaneous research projects throughout the academic year. They become science practitioners and are responsible for pooling their data and presenting their results to their classmates and for peer review at Cornell's research symposia. They learn the art of "multi-tasking" and negotiating work with classmates during the course of the year as well how to deal with experiments that go awry.

Both Andy and Nigel have a longer history and more experience (and roles) in the EI COP than Ike or Terry. They tended to run more student-centered classrooms where they took the role of the facilitator and their students were the main practitioners of their classroom science. Whereas Terry's classroom is a more teacher-centered environment, Ike's classroom appears to closely reflects the beginnings of a classroom COP. On a daily basis in Ike's classroom, students are found working in teams on research projects associated with bioassays and studies on their local forest. They create reports and peer review each other's projects and prepare for the research symposia at Cornell. Ike has adopted and implemented protocols, teaching tools, and portions of Andy's classroom repertoire in his own classroom. For example, he uses Andy's teaming approach to students doing groupwork, he has his students prepare PowerPoint presentations of their findings, and interestingly, he can often be heard using language and "classroom talk" that closely resembles Andy's style and classroom demeanor.

Terry, on the other hand, tends to utilize a more structured classroom management approach. However, his students do get the opportunity to work in groups, pool and present data results, and collaboratively put together the findings of their research efforts. Because Terry draws upon the expertise of various students, they have the opportunity to take leadership and teaching roles in the classroom. Additionally, his environmental science class is given the opportunity to have their work analyzed by a local environmental firm which contributes to their ownership and "realness" of their data collection and science practice.

The details of each teacher's classroom COP observations and findings are displayed in Tables 5-8.

Table 5: Repertoire of Classroom COP	
Teacher	**Repertoire**
	Routines, works, tools, ways of doing things, stories, gestures, symbols, genres, actions, or concepts produced & adopted by the community.
Andy	Daily team assignments (groupwork); PowerPoint presentations; weekly class presentations/updates; simultaneous use of different classrooms spaces; concurrent interclass & inter-group collaboration on class research projects; student roles & establishment of identities within the classroom community—as tool makers, lab specialists, and technology experts; inter-and individual class research project updates posted on the class's web page and the EI web site; common & consistent reference to EI community & Cornell; electronic communication within outside scientists.
Nigel	Interclass & inter-group collaboration—pooling data; posting research results on the EI web site; reference to the EI community; culminating class presentations.
Ike	Team assignments (groupwork); reference to EI community; Cornell; and specific EI makers; PowerPoint presentations.
Terry	Reference to EI community; Cornell, and specific EI makers; student roles & establishment of identity—drawing upon students' expertise.

Table 6: Shared Enterprise of Classroom COP	
Teacher	**Shared Enterprise**
	Practices that become the property of a community created over time.
Andy	Structuring of the applied science program so that each grade level prepares for the next grade level via "sub-contracting" of lower grade levels working for Senior level classes in collaborative research projects. Thus, students anticipate their roles as they progress in their high school career; teaming; on-the-job teacher and peer expectation; local stream studies; student original research and presentations at Cornell's student research symposia.
Nigel	Local stream studies; community action; student original research and poster presentations at Cornell's student research symposia.
Ike	Local forest study, working with local environmental agencies, teacher-guided (moderate) student original research and poster presentations at Cornell's student research symposia.
Terry	Local stream study, working with local environmental agencies, teacher-guided (strong) student original research and presentations at Cornell's student research symposia.

Table 7: Mutual Engagement in Classroom COP	
Teacher	**Mutual Engagement**
	People are engaged in actions whose meanings they negotiate with one another.
Andy	Classroom expectations & goals; work-centered classroom structure & management; class projects and group and student roles; peer review; what work and scientific research means in the classroom.
Nigel	Classroom expectations & goals; peer review; responsibility; what work and scientific research means in the classroom.
Ike	Classroom expectations & goals; class projects; peer review; what work and scientific research means in the classroom.
Terry	Classroom expectations & goals; what work and scientific research means in the classroom;

Table 8: Legitimate Peripheral Participation in Classroom COP	
Teacher	**Legitimate Peripheral Participation**
	A process by which newcomers become part of a COP—acquiring a mastery of knowledge and skill—a way to speak about the relations between newcomers & old-timers, activities, identities, artifacts, and COP.
Andy	LPP in 9th grade to full participation by 12th grade. Transformation of students from novices/ newcomers to master/old-timers
Nigel	Student full participation by end of year; experienced practitioners and some masters
Ike	LPP in beginning of school year to moderate LPP by the end of the school year. Novice/newcomer to qualified apprentice.
Terry	LPP, novice

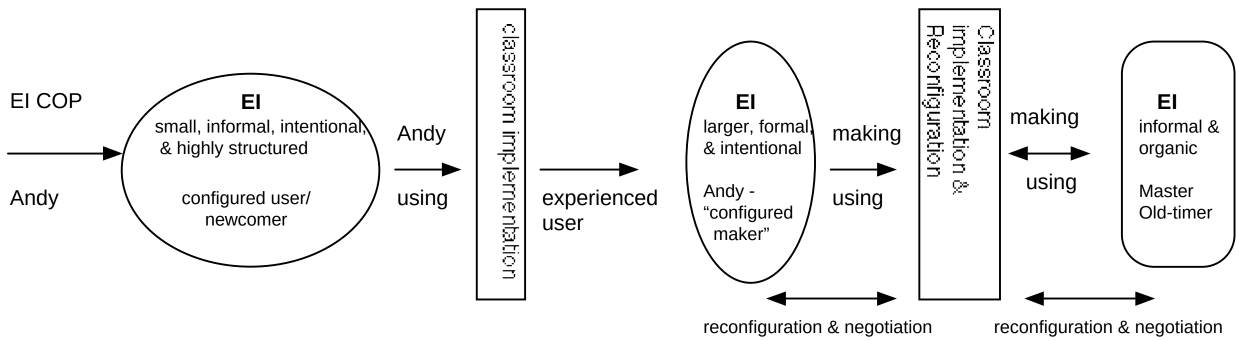
Discussion

Originally we were interested in seeing to what extent users' classroom practice would be different from makers' classroom practice. We were curious to see if being part of a curriculum development program (i.e., Andy and Nigel) would influence the level of technology implementation and reconfiguration in the classroom environment in contrast to users that did not participate in the curriculum development program (i.e., Ike and Terry). Our original hypothesis was that makers would exhibit a higher level of curricular implementation and reconfiguration because of their familiarity with the materials they designed. However, we're not convinced, at this stage in the research, that this is the case (refer to tables 5-8 for details). There are some indications that users may be just as likely to implement and reconfigure with the same rigor as the makers. For example, given enough time and EI COP support, it's reasonable to foresee that Ike will take on the role of a maker in the classroom and mature into a master in the COP community. It conceivable that what we've portrayed here as users are actually future makers. Perhaps a more accurate framework may be to distinguish three groups: makers, early adopters (which would describe Terry and Ike), and users (which would be represented by the traditional teacher). This would recognize that the adoption of the EI curriculum in itself is an innovative act.

Even though we have found this dyadic model (curriculum as technology, teacher as user) to be a valuable tool for articulating teacher practice, it has become rather "messy". As noted earlier, Lindsey (1999) found Woolgar's boundary between insiders and outsiders insufficient and we are also finding the same applies to our findings. When one follows a technology throughout it's life cycle—into the hands of the user—many different iterations of reconfiguration and user identity occur (Lindsay, 1999; Lindsey, 2000). In Lindsay's (2000) research, she found that one group of users reconfigured a technology so much that in time, their knowledge of the technology was so extensive that they came to know the technology better than the original designers. Thus, the boundary between insider and outsider was completely reworked—*the outsiders became the insiders.*

We have seen a similar occurrence in our work. Some of our makers—the masters in the EI COP—through a great deal of crafting and reconfiguration of the EI technology, have come to resemble the users (original outsiders) described above. Arguably, they too have become the new insiders and know the technology better than the original EI staff and others. Through observing and documenting many iterations of teachers making and using technologies, it is becoming increasingly difficult to assign the label user or maker permanently. We have witnessed makers making and using technologies. We have also found that users, on some level (whether it's the addition of white space on an artifact or a total reinvention of an activity), always reconfigure technology. We also see makers reconfigure a presumably stable technology. Although we are not ready to abandon this model, we are rethinking how to conceptualize these aforementioned occurrences. Perhaps it is more insightful to look at teachers' interactions with technologies as "using" and "making"; and to examine their identities though their representations of themselves and their portrayal of science in the process of making and using technologies in their classrooms. This illustrates the importance of considering technological frame[3], identity, and negotiations between artifacts and actors. Focusing on the reconfiguration of seemingly stable artifact offers a potentially more useful way of examining teachers' interaction with various technologies and determining how these interactions function in teachers' identity construction and in the management of their classroom COP. Employing this tactic and retracing makers' histories, and refocusing on the role of reconfiguration, we review one maker's interactions (Andy) with the EI technology and explore how his membership in the EI COP influenced his technological reconfiguration and classroom COP (see figures that follow).

Reconfiguring the EI Technology



<u>**EI Timeline**</u>	<u>**Andy's participation in EI COP**</u>
Summer 96	Participated in structured professional development activities that focused on watershed dynamics.
School year 96-97	Implementation of watershed dynamics curricular activities.
Summer 97	Participated in the EI curriculum development inservice program. At the request of the project co-director, designed and developed a design challenge (water sampler) packet for the Watershed Dynamics chapter of EI. This was used as the featured activity and protocol for the Student Design Challenge competition hosted at Cornell the following Fall.
School year 97-98	Implemented and reconfigured the design challenge activity by making it more open-ended for his students. He added changes to the original packet. Piloted other EI members' work on Bioassays.
Summer 98	Participated in the EI curriculum development inservice program. At the request of the project co-director, designed and developed another design challenge (storm water retention model) packet for the Watershed Dynamics chapter of EI and this was also used in the Fall for the 2nd Student Design Challenge competition hosted at Cornell. Piloted and reconfigured the Bioassay unit by making the activities more open-ended and project centered (tied in local stream ecology, water chemistry).
School Year 98-99	Implemented and reconfigured the design challenge activities by making them more open-ended for his students and enlarging the project to include stream chemistry and water pollution. He added changes to the original packets and they were assimilated into the EI Technology. Continual piloting and reconfiguring of the Bioassay unit by making the activities more open-ended and project centered (tied in local stream ecology, chemistry, acid precipitation, soil chemistry). Had students fully engaged in the on-line peer review component of the bioassay unit in preparation for the research congress at Cornell. The bioassay unit and the design challenges have been assimilated into the Applied Science program.
Summer 99	Worked as a consultant (master) to finesse the Bioassay peer review web-site at Cornell making it more user friendly to teachers.
Current - ongoing	Continued reconfiguration of EI technology and participation in workshops in the EI COP.

Andy's case presents some fascinating findings. He has served in many different roles and capacities in the EI COP: As a newcomer and configured user ; as an actual user who became an experienced user; as an experienced user who became a configured maker (configured by the program engineers of EI); a configured maker who became a maker/master; and an expert/master and an insider who now knows aspects of the technology better than the original EI engineers. Also interesting to think about is Andy's multiple interactions with the EI technology and how he represents himself, the technology, and science in the process of using and making the technology. As a maker, he created several key chapters of EI and while engaging in this design process, explicitly articulated that his crafting of the technology occurred with his image in mind as well as the image of the would-be user in mind whom he describes as the "typical teacher". As Lindsey discovered, it's possible for the original outsiders to become the insiders. This is also the case with Andy. However, an added twist to this case, is that Andy has functioned as an insider, a user, and an insider again—through his multiple iterations and reconfigurations of the technology. Hence, the dilemma in permanently labeling a teacher as a user or a teacher as a maker. Perhaps, at this point, its valuable to view teachers as *making* and *using* in the technological design and negotiation process. And consequently, to see makers, users, and the closure or stability of an artifact as *temporary*.

Conclusion

We have found that teachers who choose to teach science in a sociologically useful way have strong subject matter knowledge, experience with science, and tend to draw upon their memberships in COP for support, ideas, and curricular innovations. Specifically, we have found that teachers who are involved in, and have ownership in, a curriculum development project—over time—tend to implement and reconfigure the curricula when given a medium (such as the EI COP) for collegial support, interaction, and resources to practice authentic science in their classrooms. Employing tools from S&TS and SCOT allows for rich studies of teachers' social interactions with multiple actors (colleagues, staff, scientists, policy) that aid in understanding teachers' actions in their classroom practice. This methodology adds another perspective on viewing the social—in addition to teachers self-reporting of their beliefs, practices, and experiences.

A viable next step in the research process would be to follow the EI technology to completion. Once it is in its final form—as a stabilized artifact, a bound curriculum—following it into the hands of the users may prove to be a fruitful and enlightening study. Utilizing the lens of S&TS and the concept of reconfiguration will enhance our understandings of why and how teachers represent themselves as they portray science in their classrooms.

Implications

This study articulates a different view on learning where social participation and community membership provide the vehicle for learning science as it's practice in the real world. It asks policy makers to rethink the current trend in education and reexamine the ways in which learning *can* occur in schools—no differently than they ways in which we learn in everyday life—by participation and social engagement with others. When teachers are given the opportunity to collaborate and have ownership in curricula and assessment, teaching and learning becomes a participatory event for all actors involved. Learning is viewed as participation, and science as practice:

> [*Situated Learning*] takes as its focus the relationship between learning and the social situations in which it occurs. Rather than defining it as the acquisition of propositional knowledge, Lave and Wenger situate learning in certain forms of social coparticipation. Rather than asking what kinds of cognitive processes and conceptual structures are involved, they ask what kinds of social engagements provide the proper context for learning to take place (Lave and Wenger, 1992, p. 14).

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Notes

[1] Recently, New York State has instituted new graduation requirements mandating that all students pass Regents exit exams to graduate high school (New York State Board of Regents, 1994) This new policy puts new pressures on students (those who, for the first time, must pass exit exams to obtain a high school diploma), teachers (teaching "all-Regents" heterogeneously grouped classes with high stakes assessments), and administrators (who are faced with community and state responses/pressures concerning high-stakes exam outcomes). Both the guidelines and new state/national polices call for teachers to change their educational design and potentially, their pedagogical style.

[2] It's worthy to note that another EI teacher at Andy's school teaches the 10th grade applied section. Consequently, students in the applied program are exposed to both Andy's curriculum and the EI technology

[3] [T]he meanings attributed to an artifact by members of a social group play a crucial role in my description of technological development. The technological frame of that social group structures this attribution of meaning by providing, as it were, a grammar for it. This grammar is used in the interactions of members of that social group, thus resulting in a *shared* meaning attribution…The interactional nature of this concept is needed to account for the emergence and disappearance of technological frames (Bijker, 1098, p. 172-173).