Experiences in Reflective Engineering Practice: Co-development of Product Prototypes

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Abstract

The experiences of a commercial engineering project team in a participatory product development project are described. The project differs from other Participatory Design projects in several ways. First, customers and engineers are brought together actually to develop and evaluate a product prototype. Second, this collaborative effort is aimed at satisfying the customer's need and exploring a market. Third, the engineering team is deliberately engaged in improving their own engineering process.

Two themes are explored in this paper. One is that participatory development changes engineering work process and organization in significant ways. In particular, the scope of engineering work is extended to encompass observation and understanding of social effects of technology. The second is that these changes in engineering work ways require reflection on process and method. The paper itself is an exercise in reflective engineering practice.

Keywords

Participatory design, customer centered design, codevelopment, commercial product engineering, work practice, socio-technical systems, customer responsibility, feelings, relationships.

Introduction

Participatory Design is well established as an evolutionary way of developing computer based systems (Floyd, Mehl, Reisin, Schmidt, & Wolf, 1989). This paper tells the story of a participatory co-development project involving a commercial engineering team and an external customer. Co-development differs from Participatory Design because the users are not engaged in system design. The engineers develop the technology – but the users and engineers co-develop the change and extension of the users' work practice necessary to properly apply the system. Furthermore, in contrast to the published discussions of Participatory Design efforts, this project brings engineers employed in a large commercial technology company together with users and customers specifically to (a) evaluate this new technology and work practice, and (b) explore market and product requirements. This collaboration is a new work experience for both parties.

This paper has several goals. The first is to tell the story about experimenting with participatory development of a commercial systems product. The second is to relate some reflections about working in a participative and collaborative way. The third is to enumerate some organizational learning arising from this experience.

Initially, the project engineers had two different kinds of expectations. First, co-developing systems with customers was expected to shorten the time required to discover customer needs and produce products that satisfy them. Working directly with users is a way to learn about an application domain quickly. It also provides a real-life testing ground that is impossible to simulate. Although it is possible to become narrowly focussed on a specialized application, reflection and analysis of the work practices of a given customer can reveal more general market requirements. Furthermore, co-developed products and systems are expected to be

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more reliable[1], to satisfy customer need, and to anticipate the needs that grow from extensions resulting from the customer's evolving work practice and business goals.

Second, working collaboratively with customers is expected to improve the work life of engineers. Working directly with users, and supporting their day-to-day work, requires engineers to be committed to helping users in a personal way. Hierarchical dependency relationships between engineers and managers don't work in a co-development effort that bridges two different enterprises. In addition to independence, team members are encouraged to develop a diverse set of technical, interpersonal, and often interdisciplinary skills. Finally, individuals develop their own direct and informal contacts within their own and the user's organizations. To do this engineers and customers need to enlarge their notions of work. The challenges that co-development present provide the opportunities for exciting and stimulating work lives.

Co-development of product prototypes results in change to the work practices of both the customer and the engineers. Due to it's emphasis on process and method, this project has encouraged reflection on work practices and organizational behavior (Anderson, Barley & Crocca, 1991, Anderson, 1991). A second theme of this paper is that reflection on work process is essential for the successful implementation of participative development projects. It is only through reflection that experience can be articulated and reviewed, and project learning made available for others. Changing the nature of engineering work requires developing and nourishing an organizational memory that captures both objective knowledge and tacit know-how (Graham, 1991).

For us, reflective engineering practice is an outgrowth of Donald Schön's exploration on the reflective work practices of professionals (Schön, 1983). However, co-development demands group reflection in addition to the reflection-in-action described by Schön. This paper is itself one of our attempts to reflect on the impact of co-development on engineering work process and culture.

In addition, we hope to stimulate interest in the Participatory Design research community in our work. We think the project described here represents a different kind of Participatory Design work, and that this work has great potential to improve application system development for commercial enterprises.

The Story

The Class[2] Project

The Class project is an experiment in technology innovation and engineering work practice that began in November 1989. The project is a joint undertaking of Xerox Corporation and Cornell University, and is sponsored in part by the Commission on Preservation and Access[3]. The Commission was interested in sponsoring an experiment on document preservation, since embrittlement of acid paper in books is a problem of growing national proportions. Cornell University wished to tackle this same problem on its own campus. Xerox wanted to learn how to build and deliver document application systems.

The project aims at preserving 1000 brittle books from the Cornell University libraries using Xerox proprietary digital image technology. These preserved books are reprinted on acid-free paper and returned to circulation. This phase of the project is concerned with determining the cost effectiveness of digital technology for brittle book preservation. A second phase of the project supports experiments in online access for scholars to collections of digital documents.

The prototype system and its innovative uses for preservation and access to library materials may potentially affect many areas of library use[4] (Kenney & Personius, 1991). In many ways this project is on the cutting edge of change for libraries and for more

1. Improved reliability results from the system design and testing being derived directly from the user experience rather than by exhaustively testing all conceivable combinations of use, regardless of their relationship to the application.

2. "Class" was originally an acronym. We now prefer to use the name alone and have discarded the acronym.

3. The Commission on Preservation and Access is a private, nonprofit organization which serves on behalf of the nation's libraries, archives, and universities to develop and encourage collaborative strategies for preserving and providing access to the accumulated human record.

4. Libraries are facing three serious problems. One is the acid induced decay and imminent loss of volumes printed since the middle of the nineteenth century. Another is the inability to create additional shelving space at a rate sufficient to accommodate the dramatically increasing rate of new publication. And finally, it is becoming increasingly difficult to provide navigation and access to their collective corpus.

established electronic document management practices. Using a prototype system for production library work is providing a wealth of data about product requirements and development methods. Empowering an engineering team to work directly with users is providing data about the motivation and management of semi-autonomous teams and customer driven design.

Co-development versus Traditional Engineering Practice

Although the project team members had built prototype systems previously, no one had ever built and refined a prototype while a customer was using it. And, in contrast to standalone copier products, the engineering team had no a priori idea of how the system would actually be used and the customer also didn't know what working with digital scanning and printing technology would be like.

These uncertainties, coupled with the need to deliver a working system quickly, prompted the engineers also to treat the project as an experiment in engineering process and method. The engineering task was different from others because it created new kinds of work for users. There was no existing engineering process model that provided methods for working on tasks like this. Furthermore, the engineering team had no understanding or knowledge of book preservation, or of library operations generally.

Through contacts with the Xerox Palo Alto Research Center, some members of the engineering team had become familiar with Participatory Design work. The project team used elements of Participatory Design to develop a work process for the project. The team recognized the need to involve the users from the beginning in all planning and development activities. This was seen as a way to explore and discover requirements while building working relationships among users and engineering team members. Open and continuous feedback between users and engineers was necessary to support an iterative, evolutionary development, delivery, and evaluation process.

It was clear from the beginning that introducing the Class system into the library would cause significant changes in the library's work practices. Many separate departments were involved with the selection, preservation, cataloging, and distribution of reformatted volumes. The availability of digital images of books precipitated changes in the cataloging formats used for electronic materials, and this discussion has been carried into the larger library science community (Brugger, 1991). Placement of the printer in the Computer and Communications Center, for example, linked the people in the computer center with the scanning technicians in the library, thus enlarging the scope of library practice.

The engineering team was aware that the Class system was very different from a standalone copier, and it would have social and organizational impacts for the library. In order to help with understanding and managing these effects, the project team contracted with a sociologist at Cornell to conduct an ethnographic study of the co-development work activities.[5] What the team did not understand was the extent to which co-development of a system prototype would change it's own social process and organizational behavior. These impacts are discussed below.

Co-development Work Practices

Several activities were undertaken in a collaborative way, and these laid the groundwork for building the working relationships needed. Three activities are described in this section illustrating how these relationships were developed. One of the key observations from this project is that without personal relationships no co-development is possible, and that time must be spent in nurturing working relationships.

Planning and Requirements Gathering.

The initial phase of the project was gathering requirements and determining a plan of work and a schedule of deliveries. The first collaborative efforts focussed on determining these requirements and plans. Joint meetings were held at the Xerox engineering lab and at Cornell University (the sites are separated by nearly 90 miles). At first all members of the Class team, and representatives of several different organizations at Cornell attended, but the work plan team was soon reduced to about six people, including two from Cornell.

Collaborative planning tasks included building engineering data flow diagrams for book preservation, observing current photocopy preservation activities, evaluating an existing electronic database of chemistry research journals,

5. The ethnographic observation has ended, but the study has not been completed. A report is forthcoming.

and critiquing user interface storyboards. Many Cornell University librarians participated in these activities. These interactions revealed the cultural differences between the library and engineering work. At one meeting the engineering team was attempting to elicit evaluation criteria for system usability from the library staff. The engineer's insistence that the librarians could articulate the criteria if they thought about it was met with a statement like "we just don't know how we'll know how usable the system will be; we'll find out when we use it!"

It wasn't until later, when we had a chance to talk to the participant/observant sociologist, that we discovered how differently librarians and engineers approach their work. In this case the difference involved social values surrounding evaluation. It is common for engineers to work hard at discovering measurable attributes for evaluating components, systems, and procedures. These metrics are used to guide the development of systems. The work of librarians, on the other hand, is organized around preservation of, and access to, books, manuscripts, and art works. The practices of evaluation in a university library differ from those of an engineering team. It is not surprising, then, that librarians might find engineering requests for *a priori* usability criteria to be nonsensical. Furthermore, the engineers' insistence on eliciting these criteria could stimulate negative reactions.

With experiences like this the engineering team began to recognize the impact that cultural differences could make on what appeared, on the face of it, to be simple communication tasks. Communication was also hampered by the idiosyncratic language and acronyms common to the two professions and organizations. Realizations of these difficulties by both parties helped ease the initial tension between the engineers and librarians and also led to some good natured humor about organizational languages.

Technical Progress Evaluation.

A second collaborative activity was including the customers (users and managers) in the monthly engineering project review meetings. This decision made the users privy to the internal workings of the engineering organization, and this led to several awkward incidents. For example, at one point the digital scanning technology (which was also in a prototype form) was suffering from serious implementation problems. During the project review meeting the seriousness of the problem was perceived by the customers as a threat to the delivery of the system, and they communicated their anxiety to their management. This resulted in several phone calls between the Xerox marketing representative and the Cornell project leadership, during which the customers began to learn more about engineering work practice. Engineering reviews are usually honest discussions of project problems and difficulties, and often today's problem has no immediate solution. This is a common situation for engineers, and most proceed on the assumption that sooner or later an acceptable solution will be found. Furthermore, a project review that did not uncover problems would be a failure for an engineering team. It took some time for the librarians to grow accustomed to attending meetings filled with what seemed like only bad news. At one point they asked that the meeting agenda include some good news.

The customers were included in the engineering project meetings. Including them demonstrated the engineers' willingness for open and frank dialogue. This openness helped develop and mature between the two enterprises the trust that is necessary for successful collaboration.

System Support as an Engagement Practice.

Support for a prototype system 90 miles from the engineering lab was a significant challenge. It was resolved by providing a digital telephone pager that rotated through the engineering group; each member has pager duty for one week. Pager calls are usually returned within five minutes. The pager provided more than a simple technique for communicating problems and getting help. It opened up a channel for customer engagement that provided data about the design of the system and the way the users worked with it. Furthermore, the pager allowed all the team members to build individual social relations with the users. Since the 90 mile distance discouraged casual visits, the pager helped bring the two organizations together.

Reflections on Co-development Work: How It Feels

When the group embarked on this project it was expected that the cultural differences between the two enterprises would affect the progress of the project, although it wasn't clear how. In addition, some impact was expected from the choice of using co-development as the team work practice which was a new approach for both the project participants and the corporation. The project group had both to adjust to dealing with the customer, and to dealing with each other in new ways. Part of reflecting on this experiment is to articulate some of the feelings we experienced.

Anxiety and Resistance Towards Planning

Planning and replanning are an integral part of traditional engineering work practices. All of the members of this co-development team had traditional backgrounds. It was therefore a surprise when the team resisted engaging in planning activities. We can still only speculate why the team members initially reacted and continue to react in this way.

First, the range of tasks of a co-development project team is larger than those of a functionally organized group specializing in one aspect of product delivery. Thus no team member had the experience to really understand this scope. Furthermore, planning responsibility had been reserved to the managers of functionally organized groups, hence most members were not experienced planners.

Second, in the traditional product organization, the process model is sequential and linear, and it assumes that the result can be specified up front. In that model, a plan is accepted as a commitment against which the performance of team members is measured. The Class project, on the other hand, has an iterative and uncertain nature. Accepting a plan as a commitment against which one could be measured appears to be problematic and inappropriate.

Third, a plan, when properly done, reveals the extent of the project being attempted. Considering that this team is very small for a project of this size, it was easy to anticipate being overwhelmed by its demands.

Reluctance to Deliver Systems with Perceived Technical Shortcomings

Engineers tend to be craftspersons. This ethic is reinforced by the culture of the traditional organization which emphasizes functional and diagnostic testing of the engineers' output. This attitude is easy to appreciate when the project goal is to get apparatus manufactured in quantity and delivered as finished goods. However, when the goal of an activity is to get a prototype to a customer for co-development purposes, for many reasons it actually becomes undesirable to put the craftsperson's finishing touches on the work. It is very difficult for engineers to give up unfinished work, particularly when, as in the Class project, individuals are identified with their work[6]. With time and experience, this reluctance has diminished but is still apparent.

Enrichment of Engineering Work Practices

The primary engineering work of the Xerox Corporation is design, development, and delivery of office and document products and systems. The engineering division is traditionally organized hierarchically and functionally (although this is currently changing). In this organization, market and customer requirements are transmitted through marketing groups to engineering project teams. Products are tested separately from engineering and then delivered to customers from manufacturing by sales and service divisions. Although cross-functional[7] teams are formed, the traditional work culture separates engineering from other divisions and from users. While this may seem cumbersome, when products provide standalone applications and function, a functional organization can be effective and efficient. Nevertheless, in spite of its apparent inflexibility, the engineering culture commonly supports and encourages continuous learning about both technology and engineering process.

By contrast, the co-development customer simply cannot describe needs in engineering terms. The engineer has to understand what the customer is trying to do and interpret that understanding into specifications suited to describe the required apparatus. This compels the engineer to engage with the user in a dialogue designed to teach the engineer the customer's application and the social context in which that application is pursued.

Moreover, customers are not asking for apparatus but rather asking for help enhancing their business. Whatever new system is designed and installed will change the customers' work practices. That change will modify the social environment. This sort of intervention is new to Xerox engineers and outside the scope of their training. Operating this way requires new skills, new connections both within the

6. In traditional groups, it is rare for work leaving the group to be identified with specific individuals.

7. A "cross-functional" team is Xerox jargon for a team composed of individuals from different organizations and disciplines.

engineers' parent organization and the customer's organization, and a much broader appreciation of the context of their work.

The installation of a prototype system in a customer site by itself creates a support obligation also new to the engineers in an environment like Xerox. The classical purpose of an engineering prototype is to test ideas. While the testing of ideas is the engineers' business, it is not the customer's business. The customer, although willing to endure experimentation in exchange for future potential, is not willing to forego the immediate needs of the business. As a result, the customer's business depends on engineering to support the prototype. Support of prototypes being used by customers extends the work of development engineers. Furthermore, support of a prototype is qualitatively different from standard product support, and it would be new work for service engineers as well. The benefit to the co-development engineers is increasingly intimate understanding of the customer's application and business environment.

Outsiders in Our Own Company

The reactions to the Class project by other organizations within our larger engineering community were often discouraging. We were outlaws, renegades who were ignoring the standardized methods and work practices of the community. Even worse, we were perceived to be building a system with economic value only for the specific customer with whom we were collaborating. We kept ourselves separate from the mainstream engineering community, and as a result we had to deal with conflicting feelings. The separation gave us the license and the support we needed to carry out the work. But in return for this freedom we felt like outsiders, ignored and rejected by the larger community.

The engineering community management often made proposals to terminate the project and put the resources to other work. It is a characteristic of our company culture to begin more projects than it intends to complete. Too many of us have worked on projects that were canceled — decisions in which we took no part. Here was a promising experiment that might be capriciously terminated. Worse, the cancellation decisions could easily fall to those with no understanding of the project or its opportunities. We were expecting what Gifford Pinchot describes as the corporate immune reaction (Pinchot, 1985).

These anxieties prompted us to actions we might not otherwise have taken. One example was the early delivery of a fragile prototype. In a company where time to market is a vexing issue and complex products require long development cycles, our delivery of a (partial) system to the customer had several important consequences. It invoked an unwritten law regarding loyalty and commitment to a customer. Since at that time we had not yet signed a contract with the customer, delivering a system was tacit declaration of an intent to do so, which put us in the position of assuming significant corporate authority. With that single act, we won a measure of both immunity from cancellation of the project and anxiety about corporate reaction.

Good Feelings About the Work Itself

In contrast to our peer community was the customer community where our work and our participation was highly valued. That esteem was expressed in several ways. First, they were committing important, seriously decayed materials to the system early in the project. Their doing so made us nervous because we were less confident than they in what we had so far built. Second, we were recognized and welcomed. Our work was eagerly awaited and continues to prompt a flow of energy and creative ideas from them. The system is enthusiastically represented by the customer to other institutions. The team continues to be invited to the customer's planning functions where further deployment of the the system is contemplated. Finally, the customer commits time to help us as we spread the word of the available opportunities within our own corporation.

This work also has socially redeeming value. If successful, we will have had some small part in preserving the intellectual heritage of the last one hundred and fifty years. What's more, this technology holds the promise of democratizing access to materials the way the printing press democratized literacy. The consequential restructuring of our educational and commercial institutions will offer many new opportunities to society at large.

Confusing Relationships Between the Two Enterprises

Our good feelings about the customer and our feelings of disenfranchisement from our own community led us to feel closer to the customer than to our parent organization. In the effort to lower our mutual barriers, we unwittingly blurred the boundaries as well. We began to think of those individuals on the customer's staff who used our equipment as part of our engineering group. We even considered rewarding them with performance awards similar to those given within our corporation. Fortunately, we had the foresight to ask whether such an act was appropriate, and we were assured by their manager that it was not. Indeed, the intensity of the response, bordering on umbrage, gave us another strong clue to our collective unawareness of the impact of cultural differences.

We also erred by inadvertently trying to belong to their community. We felt more comfortable responding to their chief administrator than to our own senior management. We found ourselves adjudicating between the cultural imperatives of the two enterprises. For example, the Cornell library systems staff was working to provide campus-wide access to the books being scanned. At the same time we were being asked by Xerox to turn the prototype system into a product. These conflicting demands forced us to put off satisfying requests from the library staff, and this jeapordized our working relations with them. The dilemma was natural enough since their chief administrator was encouraging us while we were still having to prove ourselves internally. The customer, of course, needs us to be a separate, money making venture. Without that, the promise for a system with a long, useful life quickly fades.

Reflections on the Experience: What We've Learned

Co-development provides a unique learning experience for both users and engineers. In addition to learning the social and technical aspects of developing systems that affect organizational work practices, direct collaboration around using technology in actual work settings enlarges and enriches the work experience of both parties. In this section, some of the key areas of learning are described.

Confronting the Real World

One of the most obvious results of co-development is that the engineering team is immediately and continuously presented with the reality of customer needs and desires. This experience is very different from that of a traditional engineering group that very rarely sees its components or products in actual use. The give and take required to support new work practices allows engineers to relax their desire to deliver only what is finished and polished. They learn to make tradeoffs between the ideals of a completed system and what the user can use right now to get their work done.

In addition, working closely with another enterprise provides experience putting technology to its stated, desired use. The difference between what the user says they want to do, and how that actually is put into practice, is enormously instructive. It illustrates how technology and systems interact with particular work environments to constrain and direct their implementation and adoption. For example, early in the project the library insisted that marking the structural data of the scanned books (tables of contents, chapter starts, indices, etc.) would be part of the task of the scan technicians. However, it has turned out that the preservation staff is more interested in scanning the deteriorating books than in labeling the structures. The structural information is of more interest to the cataloging and access librarians. As a result, although the capability was available, scan technicians did not mark structural elements in the books that have been scanned. That work remains unfinished.

All this, in turn, permits reflection on the nature of engineering work and work process. Co-development permits an evolutionary model of system design and deployment to be considered as an expansion and extension of more traditional, serial development models.

Changing the Nature of the Organization

Our engineering community has traditionally been organized by specialization. Each group has a specific role to play in the design of a particular piece or subsystem of the product. Furthermore, there are standard methods and work practices that are used to guarantee quality in the result. These groups have built-in social relationships that are ordained by the formal organization chart. Individuals can be replaced, but the roles and reporting relationships remain unchanged. Decision responsibility and authority is retained in the specific locations designated by management. Communication with such a team is generally restricted to be via a single individual or office, depending upon the size of the unit in question. The individual is subsumed by the organizational unit.

By contrast, the Class team is organized to take complete responsibility for its customers. This kind of team can be characterized as semi-autonomous since it doesn't have fixed dependencies on the parent organization. The team is not limited to the design of a specific subsystem or, for that matter, even to design, but extends from contract negotiation to support of the installed system. Of course, not all individuals in such a team are equally skilled at all aspects of the project. As the project continues, different individuals necessarily assume leadership roles. Moving into or out of a leadership position is seen neither as promotion nor demotion.

Trying to work in this way has been personally challenging for all team members. Communication among team members about who is leading particular activities is often confusing. Deliberate, concentrated effort is required to keep all team members informed.

Increased Efficiency

The semi-autonomous team has some important advantages over traditional structures. The first advantage is that decisions are being made by those actually working on the task or problem affected by the decision. This eliminates the queuing and learning bottlenecks associated with reserved decision making.

The second advantage accrues from the need for all members of a co-development team to know who is working on what and what the user really needs. Because the larger work situation is understood by all, the team members are able to become advocates of the customer. This results in systems and applications that better meet the customer's needs.

Third, the work engages the whole person. Since team members have perspective on the entire project, they are able to operate beyond the bounds normally proscribed by their job disciplines. A multiplicity of perspectives are thereby gained which enriches the quality of the work.

Fourth, everyone is fully employed. In a traditional organization, a great deal of time is spent by individual team members waiting for others to complete their tasks. In the semi-autonomous team, individuals assume a wide variety of tasks which largely avoids the waiting time characterized by serialized activities.

Finally, the work group is organized according to the application rather than according to some specific function. Members collectively represent the range of skills needed to do the entire job. The decision to add members is driven mostly by the need for a missing skill. The members of a traditional group, on the other hand, are largely homogeneous and members are added as the work load increases. The traditional structure was created to facilitate mass production of identical things not flexible production of a wide variety of things.

Increased Fragility

The organization chart of the traditional hierarchical group provides a social skeleton which resists disintegration of the group. The semi-autonomous, or flat, team has no such intrinsic support. Members must form functioning relationships with the other members of the team and with the customers. They must learn to depend on each other. Furthermore, the relationship forming and maintenance activity goes on continuously. Each time the project moves to a new phase or an individual seeks to grow into a new job, the team undergoes implicit reorganization. The success of that process depends heavily upon the openness and completeness of communication within the group. Without proper communication, trust will degrade and team members will be unable to depend on each other.

But good communication is still not enough. The needs of different tasks will occasionally collide. Team members must be willing to deal with more complex and adult relationships than those found in a traditional setting. They must value honest appraisals of the work progress. They must respect each other's skills and need for growth and development. It sometimes will happen that when one person grows out of a current role, others will feel deserted by that action.

Individuals choose many of their tasks but are also encouraged to work in areas new to them. This implies risk taking and, in order to get people to take risks, it is necessary to create an environment in which help can be sought and received, and where failure is treated as a learning opportunity rather than an infraction.

New Work for Managers

The manager role in the semi-autonomous team is substantively different from the role in a traditional structure. Rather than being in control of the team, the manager is part of the team. The manager provides the administrative services each organization needs to function properly. The social aspect of the job is more complex because this team member has the responsibility for personnel actions concerning peers rather than subordinates. The relationships are more complex and adult as opposed to the parent-child relationships of the hierarchical group.

The manager is still the focal point for communication, but the requirement is very different. The group operates with negotiated dependencies based on mutual trust. Trust comes from the respect each team member is accorded for their skills and their commitment to the group task. The manager must enable that by ensuring sufficient information is available to allow everyone to make good decisions. The manager does that in part by cultivating the needed skills throughout the team. Teaching junior engineers how to spend money, for example, is a prerequisite to their having spending authority. The manager must also insure that each team member can continuously know the complete status of the project and have an opportunity to contribute ideas and work.

Barrier and Boundary Issues

As has been noted earlier, one of the most complicated aspects of co-development involves the maintenance of appropriate boundaries. Creation of cross-functional teams within a corporation face the same difficulties as teams that attempt to work across enterprise boundaries. As Hirschhorn and Gilmore (1991) have written, "We don't need barriers, but we do need boundaries. We cannot ignore differences in authority, skill, talent and perspective that help us divide up the work and distribute accountability in effective ways." Vendors and customers need to know for whom they work, and what their roles are in the joint work. The different objectives of commercial corporations and educational institutions make boundary management an important task for the Class project. In fact, the Class team has two boundaries to manage: (a) the inter-enterprise boundary between Xerox Corporation and Cornell University, and (b) the intra-enterprise boundaries within Xerox. Some of the issues relating to these boundaries have been described above.

One important requirement is the ability to work in two different cultures: that of the customer and one's own. Engineers need to be familiar with the work and social processes of the customer's workplace. However, they really have no place interfering with the social and political dynamics that characterize that workplace. The appropriate balance is only acquired through experience.

An outcome of this cultural difference is that the engineering team needs to learn a great deal more about the customer's work practices than the customer needs to learn about engineering work. This asymmetry results from the differing work tasks of the two groups. The engineers' work is to help users succeed at their work. In order to help a specific customer to adopt technology in support of their work, engineers need to understand that work practice. The user of course needs some appreciation of engineering work in order to successfully collaborate in the development. As the drivers of co-development, the engineers need to learn about the user's work domain. This requires acquiring observation and analysis skills similar to the ethnographic methods of anthropologists. These learning needs enlarge the scope of engineering work. Co-development teams need to understand the technical and social aspects of systems and be able to use this understanding in their work.

Summary and Future Work

The project is now 2 1/2 years old. In addition to supporting the book preservation activity, the system is being used to provide custom publishing of professor's class notes from the Cornell University bookstore. This extension into demand publishing exemplifies the kind of evolution from application support into market exploration that was expected from co-development work. However, the success of using a prototype to determine system and market requirements brings up many questions for an engineering enterprise.

For example, when is it appropriate to enter into a co-development arrangement with a customer? The Cornell library staff has admitted that if they had known at the beginning what was required for co-development of a prototype product, they might have had second thoughts about entering into this kind of a relationship. For them it has been more work than they anticipated.

Xerox is beginning to differentiate co-development relationships from less intense customer engagements. It is not clear that continuous co-development is a profitable way of delivering products to customers. However, co-development does appear to be a suitable process for uncovering and refining system and application requirements. As such it needs to be incorporated into the repertoire of engineering process models that inform and support product development.

How does an enterprise take what is learned from a co-development project and use it to inform more traditional product development procedures? The kind of reflection represented by this paper is one way to package learning, but how does this learning enter into the work process and practices of the larger engineering community? These are questions that we are just beginning to address.

However, there is also a need to deliver multiple installations of a prototype in order to more fully explore a given market. Different customers will have different work ways, and understanding the diversity of applications and uses for a system will provide important data for the incremental and evolutionary development of systems and applications that can satisfy customer needs and desires. Exploration of these ideas represent further experiments in product development and delivery that are just now being undertaken.

References

Anderson, W. L., Barley, S. R., & Crocca, W. T. (1991) . Customer Co-development: The Cornell-Xerox Joint Study Project Interim Report (Tech. Rep. No. SSL-91-139) . Palo Alto: Xerox Palo Alto Research Center.

Anderson, W. L. (1991, June) . User Co-development and Technology Innovation: A Case Study in Work Team Growth and Development. Paper presented at the 10th Scientific Meeting of the A. K. Rice Institute, St. Louis, MO.

Brugger, Judy (1991), (private communication) Catalog Mangement and Authorities Librarian, Olin Library, Cornell University, Ithaca, New York.

Floyd, C., Mehl, W., Reisin, F., Schmidt, G., & Wolf, G. (1989) . Out of Scandanavia: Alternative Approaches to Software Design and System Development. Human-Computer Interaction, 4, 253 - 350.

Graham, M. B. W. (1991) . Notes on Organizational Memory: Practice and Theory. (unpublished manuscript) . Palo Alto: The Institute for Research on Learning.

Hirschhorn, L. & Gilmore, T. (1991) . Boundaries not Barriers: Building the Flexible Organization. (unpublished manuscript). Philadelphia: Wharton Center for Applied Research.

Kenney, A. K. & Personius, L. K. (1992) . Digital Techniques. In B. Buckner-Higgenbotham (Ed.), Advances in Preservation and Access, Vol. 1. Meckler Corp.

Pinchot, Gifford, III (1985) . Intrapreneuring. New York: Harper & Row.

Schön, Donald A., (1983) . The Reflective Practitioner: How Professionals Think in Action. New York: Basic Books.