

# Activity Theory and System Design: A View from the Trenches

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## **Abstract**

An activity theory model and a mediating artifacts hierarchy were employed to help identify the needs for tools for customer support engineers who documented solutions to customer problems, a *knowledge authoring* activity. This activity also involves customer support engineers who assist Hewlett-Packard software product users. The particular tools to be designed were knowledge-authoring tools embedded in the customer support tracking application suite, SupportTracker.<sup>1</sup> The research analyzed the role of tensions between the elements of Engeström's activity theory model. The research also explored the benefits of specific interpretations of Engeström's refinement of Wartofsky's mediating artifacts hierarchy. The hierarchy contributed to the identification of desired characteristics of mediating artifacts, particularly tools. The findings included an interpretation of the "where-to" artifact concept as supporting an understanding of the entire activity system as an evolving entity. Specific interventions were used to achieve a positive impact on the evolution of the activity system.

## **1. Introduction**

This paper focuses on a few aspects of an activity theory-based research project. The focus was chosen to aid computer-supported cooperative work practitioners who seek to complement their theoretic understanding of activity theory and gain insight into previously published practical applications of activity theory concepts and models. The data analysis and the presentation of the findings provided practical value to two organizations within Hewlett-Packard: the Hewlett-Packard Customer Support organization and Hewlett-Packard Laboratories. The latter was responsible for providing new technologies to the Customer Support organization.

Knowledge authoring—documenting solutions to customer problems—is one activity in an overall knowledge-management operation [Tournaire 1996], [Hansen 1999]. Within Hewlett-Packard, one organization was studied to understand its knowledge-authoring activity in the context of its customer support operations. Within this group, knowledge management was emerging as an explicit practice; however, direct support for the customer was the primary responsibility [Cornwell et al. 1999]. The Customer Support organization is geographically distributed around the world, providing around-the-clock support to Hewlett-Packard customers who use the Systems Manager Suite (SMS) family of Hewlett-Packard software products. Knowledge authoring often takes place as a side effect of documenting the support cases in keeping with support-management processes.

Support knowledge about application software has become more difficult to capture in a reusable way because most software now has complex dependencies on other

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<sup>1</sup> Pseudonyms for the Hewlett-Packard software tools are used throughout the paper to support readability and clarity of reference while retaining confidentiality.

contextual and environmental variables unique to each customer, such as versions of other software, shared libraries, hardware configuration, and network configuration. One subject noted another significant complicating factor in software: the customer!

The problems that we deal with in software are more complex in my experience in comparison to hardware because there is end-user interaction, which you don't have through the hardware. Most of the [hardware] systems that I maintained in the field, the customer never touched. There is such a variety of things that end users can do with the software. There are so many features and when they go in there and start to use them... it all gets real complex trying to figure out what they've done and how they got to the point that they are at right now. And of course in fixing hardware you isolate it [the problem] to a failing component and you swap...what we call the "Field Replaceable Unit." ...And typically that fixes it. So there wasn't a kind of thing as in software where you just had to plug away and try this and try that in more detail.

In the customer support process, the captured knowledge must go beyond isolated knowledge of the product. Often, the problem the customer experiences can occur only with a particular configuration of hardware, systems software, application software, or the sequence of actions the customer took prior to having the problem. This context must be part of the support case documentation.

The research results were to be used in two ways: (1) to provide input for tool requirements for knowledge authoring and maintenance, and (2) to provide value to the Customer Support organization through findings that might improve their ability to align their knowledge-authoring process with their overall customer support and knowledge-management strategies. These benefits are described after the presentation of our analysis.

The conclusion to this paper comments on some strengths and weaknesses of some aspects of the activity theory concepts applied in this kind of industrial application. The following sections focus on the way that we applied two activity theory models to help identify design requirements for knowledge-authoring tools.

## ***2. Application of Activity Theory***

A small project team in Hewlett-Packard Laboratories was responsible for providing innovative, knowledge-authoring technologies and tools for the Hewlett-Packard Customer Support organization. This team chose to apply aspects of activity theory in order to identify user needs. This research afforded the group the opportunity to explore the ease-of-use of an activity theory model and a mediating artifacts hierarchy and to experiment with their application.

### ***2.1. Activity System Identification***

Thousands of employees at Hewlett-Packard contribute directly to customer support for Hewlett-Packard products. This study focused on one small group, responsible for support of a particular software application family of products used by commercial and enterprise-scale businesses—SMS. The group is part of a larger Customer Support organization that focuses exclusively on commercial and enterprise-scale businesses and provides telephone-based support for Hewlett-Packard hardware platforms and peripherals, as well as for system software and applications software. Our work focused primarily on a single activity system, the documenting of solutions to customers' problems with SMS. In Hewlett-Packard's culture, this documentation activity is called "knowledge authoring." The term *Knowledge Authoring Activity System* will be used to refer to this activity. Closely linked but not discussed in detail in this analysis, was an

explicit *Knowledge Maintenance Activity System*. Finally, both knowledge authoring and maintenance are part of a larger activity of supporting Hewlett-Packard customers, the *Customer Support Activity System*.

## 2.2. Ethnographic Data Gathering

Interviews were conducted with thirty-two subjects who were employees of the Hewlett-Packard Customer Support organization. Table 1 summarizes the area of expertise for the subjects interviewed.

<i>Expertise</i>	<i>Number of Interviewees</i>
Microsoft Exchange	2
HP-UX/Unix	5
Unix Hardware	1
Systems Manager Suite	20
General (Help Desk)	1
Knowledge Management	3

Table 1. Expertise Distribution for Interviewees

Three experts in knowledge management were interviewed together in a single session. One SMS manager was interviewed in four separate sessions. One Unix expert was interviewed over the telephone. Two interviewees did not want to be audio taped; those interviews were documented with interviewer notes and artifacts produced by the interviewees during the conversation. All other interviews were recorded and then transcribed for analysis. Interview sessions lasted sixty to ninety minutes, with the average being slightly over one hour.

## 2.3. Data Analysis

During the course of our study, we employed a variety of analysis models and methods ([Wartofsky 1979], [Vygotsky 1978], [Engeström 1990], [Kuutti 1996]). We were especially curious to explore the application of Engeström's activity system model [Engeström 1999, p. 29-32] and mediating artifacts hierarchy [Engeström 1999, p. 398-399]. This paper, then, reports on our findings from that exploration.

### 2.3.1. Engeström Activity System Model

Engeström's activity theory model (Figure 1) was used in the analysis and communication of findings. Each transcribed interview was reviewed in detail. Annotations were made on the transcriptions to classify discussions of each activity system element and relationships among those elements. Often, interviewees focused on tensions<sup>2</sup> within or between elements. This paper focuses on the analysis of tensions that were identified by the interviewees and observed in system analysis. We found that activity system tensions provide rich insights into system dynamics and opportunities for the evolution of the system.

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<sup>2</sup> Engeström calls these "contradictions," but that seems too strong a term for the subtle misalignments and stresses in this activity system.

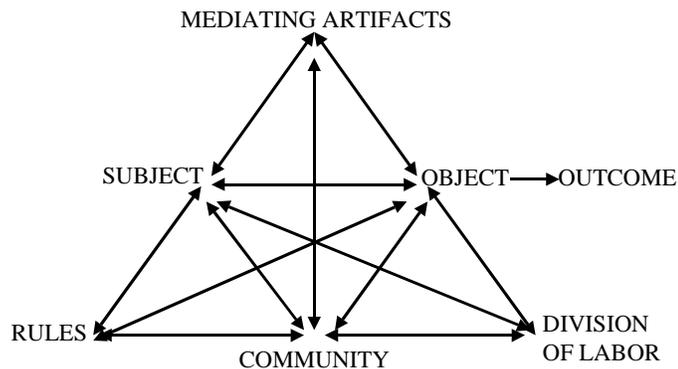


Figure 1: Engeström's Activity System Model [Engeström 1999]

To aid the reader in understanding the analysis, we first describe briefly the general characteristics of each element in the activity system under study, according to Engeström's model.

**Object:** The primary object of this activity system is reusable knowledge for resolution of customer problems with the use of SMS.

**Subject:** Anyone involved in knowledge authoring for this activity system was considered a subject. Predominantly, the subjects were customer support engineers experienced in supporting SMS, although some subjects did not have customer support responsibility, only knowledge authoring and maintenance responsibility.

**Community:** The Knowledge Authoring, Knowledge Maintenance, and Customer Support activity systems involve numerous communities, which can be classified by their stake in the knowledge. These stakeholder groups include document users, creators, maintainers, SMS experts, customer support team managers, and customer support infrastructure developers and maintainers.

**Division of Labor:** The primary means of labor classification is based on the customer support role because that task has the highest priority activity system in the Hewlett-Packard Customer Support organization. Like many commercial customer support organizations, this group is structured to solve customers' problems efficiently and cost-effectively. The primary roles in the Customer Support organization are shown in Figure 2.

The customer initially communicates with "help desk" personnel who can capture basic information about the customer's problem and perhaps answer the simplest of questions. If needed, the customer will then work with a "frontline" engineer who relies heavily on product manuals, previous personal experience, and on-line documentation about similar situations. The frontline engineer must be able to find a relevant resolution for the customer's problem within a short time, often working with the customer by telephone to troubleshoot the problem. If the frontline engineer cannot resolve the customer's problem quickly, the customer's case will be "escalated" and handled by a backline engineer. The backline engineer is a specialist in a particular product or small group of products (in this study, the SMS family of software products). Because these people have a deeper level of knowledge, they are scarcer resources and must be used only when the frontline engineers cannot solve the problem. Finally, if the backline engineer cannot resolve the customer's problem, the case is escalated further to get the support of product "experts." This may occur when a new problem arises that has not been observed by other customers, or when the customer has a unique and nonstandard configuration of the product. These experts include people who designed

and developed the product software, as well as those who are authorized to develop software changes for the product. An “expert” may focus on only one or two software packages within the SMS.

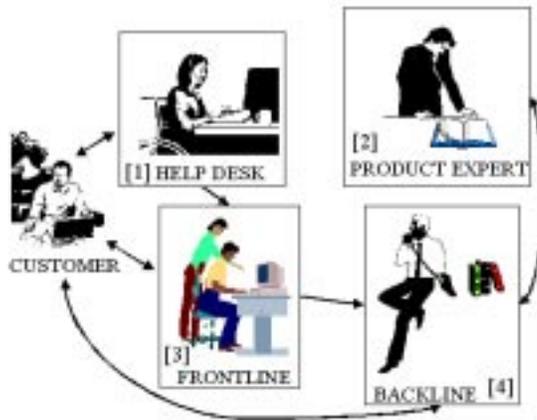


Figure 2: Customer Support Problem-Resolution Roles

**Outcomes:** For the Knowledge Authoring Activity System, there were many outcomes related to the underlying object. In the interviews, subjects focused primarily on the case logs, which track the actions taken to solve a customer’s problem. When the case is resolved, the documented knowledge used by the backline customer support engineer can be submitted for reuse in a knowledge database. The case logs include many kinds of information, much of which was covered in detail by the interviewees. Almost always, the discussion of outcomes was interwoven with discussion of the mediating artifacts that support the delivery of the outcome.

Other classes of outcomes that were not always recognized as such by the subjects included informal electronic notes and messages exchanged among peers, which were forms of knowledge. The mediating artifacts and organization processes did not support reuse of these outcomes in their documented form, but the knowledge captured in the notes and messages could be reused by all who read the correspondence and chose to save the information for personal reference (or just remembered the content).

**Rules:** The most prominent knowledge-authoring “rule” was an informal guideline for when to delete, keep, or certify a support case document. The tools used in developing the document, with information on how the problem was resolved, placed implicit rules on knowledge authoring. The Customer Support Activity System has extensive protocols and rules for issues such as problem escalation, time-to-resolution, customer experience, and where to go for answers to technical questions. Each of these rules influences the Knowledge Authoring Activity System.

Customer problem prioritization formed another class of rules. The interviews revealed a high degree of consistency in interpretation of the protocols for prioritization. Customer support engineers are responsible for explicit classification (and reclassification) of the priority of a customer’s case. The priority ratings correspond to how quickly someone must get back to the customer.

There was also a rating system for the quality of the knowledge documents. Some customer support engineers used the document rating information, whereas others ignored it.

Interviewer: Do you use the rating system...?

Subject: If I see one that looks really bad, I will-- ...rating bad documentation. Sometimes you may see multiple calls with the same information. Some of the other people... spend quite a bit of time doing those [ratings].

... So you can change if you only want to look for highly rated documents and [you can] change their rating... um... it has to be quality one, two, three, or four. You can say... "include" or "exclude" [in searching for documents of the quality you are willing to accept].

An interesting form of rules was this community's shared terminology or domain-specific jargon. Newcomers had to learn the jargon through reading e-mail and notes, conversing with peers, and inductively reasoning over examples of the terms found in informal communications and problem-resolution documents.

As in most organizations, behavior was strongly influenced by management's metrics. These metrics become an implicit set of rules for the prioritizations of efforts for our subjects. "Time to problem resolution" is one metric. All support engineers know what their responsibility is in meeting management's expectations for problem-resolution elapsed time.

Mediating Artifacts: Artifacts, signs, or means that mediate between the subject and the object are discussed in some detail throughout the rest of this paper. After briefly introducing primary artifacts based on Engeström's Activity System Model, additional discussion is provided using Engeström's refinement of the mediating artifacts hierarchy.

*Tools*: Many kinds of tools were already available and in use among customer support engineers. The most ubiquitous tool in this job was the telephone. Even this recently had become more automated, in the form of a simple computer-based tool for auto-dialing the phone number of customers based on information in the call log. Other critical tools for both knowledge authors and customer support engineers are product manuals. These were predominantly paper-based documents that were kept within physical reach of engineers trying to find answers to customers' questions. Electronic tools that served as mediating artifacts included chat rooms and variations on instant messaging capabilities. On-line knowledge bases were another form of mediating artifact. Documents in these knowledge bases generally complemented the kind of product usage information found in the manuals. Subjects identified the tools they turned to most frequently.

Another tool that I use a lot is Dave. ...He is our team mentor.... I mean he is really, really intelligent. I also use Netscape and we have [HP-proprietary] Web tools.

To many, a tool is anything necessary to do their job, or anything they can use to accomplish a task. In the Hewlett-Packard Customer Support organization, people relied on each other as they would a favorite software application or dog-eared reference manual.

*Training/Learning*: The activity system analysis identified primary mediating artifacts for the Customer Support Activity System. These included manuals, classes, the use of mentors, and organizational learning practices [Senge 1990]. These artifacts contribute to the spread of knowledge about how to support customers in resolving their problems. The analysis identified existing forms of training and learning about knowledge

authoring and identified opportunities for training and tool support for improved practices in knowledge authoring and maintenance. Nevertheless, as one subject observed, “there is nothing like experience.” Nonaka and others’ models for knowledge management acknowledge that much of what makes an organization valuable is exactly that implicit knowledge that individuals acquire through experience but which is very difficult to codify [Nonaka 1995].

Quite commonly, the subjects first expressed their needs in terms of changes to tools (not needs but proposed solutions). Some expressed needs, although related to tool design, would not be entirely solved by improvements in those software tools. For example, a new “expert system” tool (the subjects’ common term for the Knowledge Database) that was in early use was seen as having value to the Customer Support Activity System. However, subjects complained that the *tool* was “too slow.” Further investigation showed that the perceived speed of the application was due at least in part to the choice of database server, not the tool itself.

### 2.3.2. Mediating Artifacts Hierarchy

Engeström’s refinement of Wartofsky’s mediating artifacts hierarchy was used to identify the essential mediating artifacts. We believe that the interpretation of this classification scheme is still open for discussion. We offer some elements of our interpretation with examples of how those interpretations were used in our research.

<i>Artifact Class</i>	<i>Primary Characteristic</i>
What	Contributes a <i>means</i> of achieving the object
How	Contributes to <i>understanding how</i> to achieve the object
Why	<i>Motivates</i> achievement of the object
Where-To	Motivates <i>evolution</i> of all elements in the activity system

Table 2: Mediating Artifacts Hierarchy

#### “What” Artifacts

Most subjects focused their comments on tools used directly to accomplish the activity system object or to produce activity system outcomes. In addition, we observed the use of tools that directly supported the subjects in the Customer Support Activity System as well as in the Knowledge Authoring Activity System. Most of the mediating artifacts for the Knowledge Authoring Activity System were tools used directly in the creation and refinement of the documentation, training, and learning resources, e.g., manuals, and classes. Also, hallway conversations and computer-mediated conversations were central mediating artifacts, especially in transforming implicit knowledge to explicit and documented knowledge. Activity theory practitioners encourage the consideration of shared concepts as a kind of mediating artifact, as well as the presence of analogies. We identified many shared concepts through the shared terminology used by the subjects.

#### “How” Artifacts

The “how” mediating artifacts include informal coaching and consulting on how to create reusable knowledge. However, at the time of this study, the knowledge authors had very little guidance on the creation of reusable knowledge. The SupportTracker tools provided some guidance for capturing the chronology of events related to resolving the customer’s problem. The tracking tool time-stamped notes about the case that were input by customer support engineers working on the case. A few fields of basic

information were required. This became the default template for instructing authors in how to author the knowledge.

### “Why” Artifacts

Training classes and mentors provide the primary “why” mediating artifacts in the Customer Support Activity System. However, some subjects explicitly requested that some “what” mediating artifacts (such as the Knowledge Database) be enhanced to provide decision-rationale documentation. The addition of decision-rationale information in the knowledge documents would introduce a new role or responsibilities into the Knowledge Authoring Activity System. That new role could be one of knowledge engineering in which the knowledge engineer elicits from the expert the rationale for the problem-resolution approach and why that contributes to the object. Alternatively, the domain experts could take on an additional responsibility in their knowledge-authoring role, one that would probably require that they have reflective time away from the telephones to capture the rationale.

### “Where-To” Artifacts

This activity system did not have an abundance of “where-to” mediating artifacts. In Engeström’s description, this class of artifacts is used to envision the future state and potential evolution of the activity system’s object(s) [Engeström 1999, p. 399]. Within this activity system it was often difficult to find those who were thinking in terms of the evolution or revolution of the object(s). During the time of this research, we were aware of another group, within the business management part of the Customer Support organization, that was considering radical changes in the mediating artifacts, outcomes, and objects of the Customer Support Activity System. However, that group did not have an appreciation of an activity system as fundamentally being a self-evolving organism. We believe that those leading change for the organization did not appreciate the potential role for explicit “where-to” mediating artifacts, although they were not explicitly asked to comment. Therefore, they did not design and implement such artifacts as a vital part of maintaining the health of the activity system. In one public presentation that covered the application of Engeström’s Mediating Artifacts Classification Scheme, the “where-to” mediating artifacts initially puzzled members of the audience [Collins 1999]. However, when examples were provided of the power of deliberately creating and using such artifacts as part of work-related activity systems, the audience responded with comments and further questions about the ways in which this concept might be applied in their activity systems.

One useful “where-to” mediating artifact was the use of analogies to the domain of software reuse. Software reuse engineering and management processes are concerned with the codification of reusable knowledge about software [CFRP 1993a, CFRP 1993b]. Therefore, many learnings and models from this discipline are useful in envisioning the analogous models for other domain knowledge acquisition and management activity systems. Analogies with software reuse were employed in intervention discussions with the Customer Support organization.

We found that our activity theory research became part of the Customer Support and Knowledge Authoring Activity Systems, and served as a “where-to” artifact through the open-ended questioning and interventions (described below).

## **3. Tensions in Activity Systems**

This summary focuses on tensions related to the activity systems we studied, especially the Knowledge Authoring Activity System. This analysis is not exhaustive but rather

provides examples of the kinds of tensions, including tensions within activity system elements, between elements, and between activity systems.

### ***3.1. Tension within Activity System Elements***

**Division of Labor:** Knowledge-authoring responsibilities in this system are primarily the responsibility of customer support engineers. The backline engineers author the majority of the new knowledge because they handle the majority of the customer problems that do not already have documented solutions.

Well, we've got a few products that we support. Well maybe about ten or so now. And about three or four of those are larger than the others. And different people specialize in different products, who are generally covering a few products each. So there is a lot of overlap. So when we get a call in and might review it among people in the same office or if there's a lot of overlap... or at the end of the day might have a conference call and we might talk about a new product.

This description of how the team supports its set of software products may be the best way to support the customer. However, the backline engineer raised this situation as an example of a division of labor that lacked the kind of workload balance and work focus that he wanted.

Subjects expressed conflicting interpretations about the priority of knowledge authoring and their responsibility for capturing problem-resolution knowledge for reuse across the customer support workforce. The "expert" teams that back up the backline customer support engineers voiced even less certainty about their responsibilities for knowledge authoring.

I don't know very many people in [the Expert Center] that are actually producing any kind of proactive documentation of known problems or things to watch out for.

Some subjects believed that knowledge authoring was to be done at their discretion. Division of labor did not include explicit responsibility for authoring a particular quantity or quality of new knowledge.

Interviewer: When you're talking to a customer, do you do documentation in real time?

Subject: I try to. That is the best way, but it's real hard to get all that down. A lot of times I summarize it or if I get another call while I am finishing up this call...if another one is coming in, I'll answer the phone and start working on it. I'll then have to go back and work from memory to update this other call. It's not a good habit to get into. If the phone is ringing, it's ringing, you know [laughs].

**Rules:** The major components of explicit and implicit conventions and relationships in the community of the Knowledge Authoring Activity System appear to be quite harmonious. Interviews were conducted with members of different stakeholder groups within the community (managers and engineers; frontline, backline, and "expert" engineers; producers, maintainers, and consumers of knowledge). All had generally consistent and compatible interpretations of the conventions for interaction. However, the conventions for *communications* across stakeholder groups included gaps.

So, what happens is the customer opens a case with the Response Center [frontline support engineers]. And then the Response Center, if they need help, opens the case with us [product experts]. So it's a separate case and it doesn't have any customer information on it.

The limited communication across stakeholder groups in the community contributes to a lack of appreciation among authors of the needs of other user groups (e.g., backline

authors may not understand the needs of frontline customer support engineers). In fact, the geographic distribution of those in customer support means that a customer's problem may be worked on by many people who know absolutely nothing about each other.

Subject: They basically handle the night issues and those types of calls that come in after hours from customers that have seven-by-twenty-four contracts.

Interviewer: Is it located here?

Subject: It's probably located in several different places. I haven't seen all the different organizations and how they work.

Business process metrics, such as those that measure the time from a customer's initial call to the close of the case, may create an unnecessary imbalance in the activity system. Subjects, in general, were much more aware of metrics in use for managing call completion speed than they were aware of metrics for knowledge-authoring quality, knowledge reusability, or even customer satisfaction. Yet, the Customer Support business actually does track and manage customer satisfaction.

Until recently, measures of knowledge quality, usability, and maintainability had been difficult to articulate due to the form of knowledge captured. The implications of these findings suggest that gauges linked with tools need to focus more explicitly on supporting desired behaviors [Basili 1980, Grady 1998].

Mediating Artifacts: There were many examples of tensions within and between mediating artifacts in this activity system. This is a normal state of affairs in information infrastructures, if not in other types of tools. One of the many conflicts within the set of mediating artifacts identified by the activity theory research was a combination of a new knowledge repository tool and the physical computing machinery from which it ran.

So the whole reliability has suffered. The speed has suffered. However, the tool itself is much, much better. It has so many more features.

The tool includes support for both knowledge authors and users and employs sophisticated data mining technologies that are computationally intensive. The assumption was that this new tool would support authors and users in finding existing problem-resolution knowledge more easily. However, the hardware and network on which the tool ran were not adequate for ensuring timely access to the desired knowledge. Users found the new expert system tool far slower than a previous-generation knowledge base tool—so much slower that it inhibited their ability to find relevant knowledge in a timely way.

All of the tools in the Response Centers should be easy to use, reliable, and fast. And [there should be] less tools! Less tools mean more time to concentrate on problems.

One challenge in the analysis was recognizing that interviewees often talked about the problem with the "tool" when the problem was actually with the processes, conflicting roles and responsibilities, or other elements in the activity system.

Object: During the course of this research, stakeholders began to speak of possible changes in the object of the activity system. This tension presented itself as some lack of clarity about the object of the Knowledge Authoring Activity System. One shift in focus seemed to be away from merely reusable knowledge to reusable and maintainable knowledge. This seemingly simple maturation in the object will have profound implications for the design of mediating artifacts, competencies needed by knowledge creators (subjects), and specific forms for the knowledge (outcomes).

### 3.2. Tensions between Activity System Elements

Subjects versus Mediating Artifacts: For the parts of the Knowledge Authoring Activity System that operate as a handicraft system [Kuutti in Engeström 1999, p. 367-371], there were few conflicts between the subjects and their handcrafted mediating artifacts. These artifacts include e-mail, voicemail, and shared terminology. However, even informally shared tools have their proponents and opponents. Opponents generally stated their case by simply describing the steps one has to take to use the tool, assuming it would be “obvious” that there were too many or too complex steps.

So, if a person wants to file a note, he/she must open up a Unix window and open up an editor, save the information from the note to the editor window, then transfer that file into the [Knowledge] Database.

In another example, a broadcast request and response tool (“InstaNote”) was used to obtain information on a specific customer problem. Subjects described their use of the tool, ways in which it was well matched to their tasks, and ways in which it was obtrusive or poorly matched to their tasks and the overall activity of knowledge authoring (as well as the overall customer support activity). In their descriptions, they implicitly provided design requirements for future groupware collaboration tools used during customer support.

Interviewer: Do you use InstaNote?

Subject: Um... I have it but um... I rarely use it. Because usually if I were to use it, I use it because, one, I'm sending it to one specific engineer and, two, it's more noticeable than the [chat room tool]. You see, the [chat room tool] is just a little window like this. And a lot of people have it reduced and don't notice it and don't even look at it. If you send a message to the InstaNote, you get this big yellow window right in the middle of your screen and you can't miss it.

Mediating Artifacts versus Object: In this system, few mediating artifacts have as their sole purpose the support of knowledge authoring. This situation is likely to change, now that the organization is maturing in its knowledge management processes. However, at the time of this study, most mediating artifacts primarily supported customer support objects and outcomes while secondarily supporting the reusable knowledge object. As an example, the primary tool used to capture knowledge is SupportTracker. That tool has constraints on information entry and format that are reasonable for case logging, but are quite constraining for the capture of reusable knowledge.<sup>3</sup>

Without Knowledge Database I would struggle a lot harder trying to find resolutions to problems. Because... [a] solution to a problem... gets saved, ...you know that is invaluable. It saves so much time when you consider what you would have to do if you had to walk through all those steps and re-figure that solution out again every time. The first time is always the hardest, but it saves hours and hours of work by the end of the day.

Another problem arises when two different subjects provide information for the case document with different objects in mind.

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<sup>3</sup> There are other mechanisms for codifying reusable problem-resolution knowledge in this system. However, they are not as widely used because they require reflective time that customer support engineers (the knowledge authors) do not feel they have. There are many places in the activity system, however, where knowledge authoring is quite successful.

...when we look in the call review information, all we have is useless information.... It's just [a] "problem summary." But it doesn't have anything in there about what the problem is. All it has is some cryptic information that doesn't tell you anything.

For the problem summary here, it's supposed to be... I'm *assuming* it's supposed to be the summary of the problem. It's not. And a lot of times I don't even look at this window anymore. So from that point, it's almost like a useless window. But there's a lot of [other] information here that is important, so I have to look at [it] periodically.

The person who made the original problem summary entry provided exactly the kind of information that is essential to tracking the call without realizing that someone else in another part of the chain of people who provide the customer support would need very different kinds of information. As the interviewee noted, stakeholders make different assumptions about the purpose of mediating artifacts.

Subject versus Rules: Knowledge users become auxiliary knowledge authors when they annotate the codified knowledge with a rating of the document's value in solving a problem. The activity system has a set of explicit and implicit rules for the community's participation in rating knowledge documents. However, there was considerable conflict among subjects regarding the importance and semantics of the ratings. Many subjects appreciated the value of the rating capability yet failed to use it.

I myself have never used the "Certify" feature because, one, I'm not sure what would be considered [certifiable]. I've been through the training, so to speak, but they never mentioned it. I either "Keep" [the documented knowledge] or "Delete" it.

### 3.3. *Tensions between Activity Systems*

Knowledge Authoring versus Customer Support: In the system as it existed during the study, most of the fundamental conflicts were due to differences between the Knowledge Authoring Activity System and the Customer Support Activity System. The most basic tension existed within the subjects. Those responsible for knowledge authoring had as their first responsibility customer support.

Because, when I'm searching [for a relevant document in the Knowledge Database], like I said, I've got a customer on the phone. And I'm not going to say, "Hold on, Mr. Customer. I need to annotate this document because it's a very bad document."

Also due to the secondary status of knowledge authoring in this small group, mediating artifacts (tools) were used both for knowledge authoring and for other forms of problem-resolution documentation. The documentation supported *short-term* knowledge reuse—for resolving a single customer's problem. Indeed, frontline support engineers viewed the problem-resolution documents as a means for documenting the status of providing customer support, not as a long-lasting corporate knowledge asset.

Knowledge Authoring versus Knowledge Maintenance: An emerging activity system, not discussed in detail in this analysis, was an explicit Knowledge Maintenance Activity System. At the time of this research, knowledge maintenance was very limited. Very few people in the larger Customer Support organization considered it their responsibility to maintain the knowledge (e.g., repair defects, adapt or extend to related problem characterizations).

And that really comes back to the authoring stuff, because I think that's crucial. You know, I've got a fair amount of experience up here [points to his head]. And it's not in the Knowledge Database. So, one of my jobs is that I sit here and be the "knowledge database" for all the engineers in the area. That's part of my job now.

...it's bad if I have to be the resource. I am a very expensive knowledge database. To maintain me costs a lot more than it does the Knowledge Database. Now I can draw you inferences the Knowledge Database can't. However, there is a lot of stuff that's "if you see this, do this," or "if you see this, perhaps it is this" or "let me tell you how this works." And that information is not captured [in each of the Knowledge Database entries].

However, one organization was emerging with the charter for knowledge maintenance. Their initial interpretation of this responsibility was that they would maintain repositories of knowledge, and perform quality control on the structure, terminology, and clarity of the knowledge. Their further responsibilities would include technologies to support knowledge use: for example, search engines or meta-data for the Knowledge Database.

This activity theory-based research data suggests widespread need for creation of easy-to-use, accurate *content* for the Knowledge Database. Immediate attention to addressing that need may be the highest priority for the new Knowledge Management organization.

There is an inherent conflict between ease of authoring and ease of maintenance. For example, domain experts consider documenting ways to resolve customer problems in free text form to be the easiest to author. However, they are difficult to maintain because the unstructured text must be maintained through manual means. In contrast, knowledge authors resist using structured knowledge representations that support maintainability because they find using them more time consuming and less "natural" as part of their customer support process. This conflict in objects between the two activity systems must be treated holistically. That is, there needs to be an overall plan and set of requirements that optimize across the whole set of knowledge authoring, knowledge maintaining, and customer support activity systems.

#### **4. Software Design Requirements**

It is possible to identify some software design requirements for the SupportTracker directly from the analysis of mediating artifacts and of the tensions within and between elements in the activity systems. Examples of these design requirements based on analysis of the mediating artifacts hierarchy include:

- **"How" Artifacts:** Produce knowledge authoring tools that *guide* knowledge authors in the creation of more easily reusable knowledge.
- **"Why" Artifacts:** Structure knowledge documents such that users can readily find the rationale for resolving the customer's problem in the prescribed way.
- **"Where-To" Artifacts:** Provide project management links between documentation of business decisions for the evolution of the customer support business and SupportTracker design requirements documents.

Examples of SupportTracker design requirements based on the analysis of tensions include:

- **Within Mediating Artifacts:** Delays in retrieval of relevant documents must be reconciled with user expectations for speed.
- **Within Division of Labor:** The overall infrastructure includes functionality for (1) reinforcing the relative priority of customer problem resolution and (2) knowledge creation. Knowledge-authoring tools will support validation of accuracy and usability.

- Between Subjects and Mediating Artifacts: Groupware tools must support individual preferences for software communication media (e.g., e-mail, chat room, instant messaging, shared whiteboard).
- Between the Knowledge Authoring Activity System and the Customer Support Activity System: SupportTracker design will focus on customer support status tracking information. Separate software will be optimized to support knowledge authoring.

The interviews and analysis revealed widespread, shared common terminology that was related to the concepts in the activity system. An ontology of these concepts and their relationships could be further analyzed to provide desirable capabilities in the knowledge-authoring environment. For example, the concept ontology could be directly translated as dimensions of the database schema. This natural match to the dominant, shared concepts in the activity system community could substantially improve ease of use of the Knowledge Database.

It is also possible to “mine” the documents and communications to discover requirements for knowledge authoring and maintenance tools from the semantics associated with these terms as used within the community. A simple example is the use of the term “certified knowledge,” which has a few synonyms within the community (e.g., Response Center Engineering Note—RCEN). This suggests a design requirement for the user interface to recognize certain synonyms and support access to subsets of the Knowledge Database based, for example, on a request to see the certified knowledge when the request is made using any of the synonyms. Through the analysis of these terms, it is also possible to uncover additional capabilities that a knowledge authoring and maintenance environment might try to provide.

SupportTracker most directly serves as a mediating artifact that guides subjects in how to achieve the object for customer support. However, it places constraints on how to author knowledge. Many subjects noted that the tool placed an artificial constraint on how the case was documented, creating a conflict with the object of reusable, documented knowledge. This issue was not news to the customer support providers. However, it was unknown to the customer support software engineers responsible for new features in SupportTracker, because they thought in terms of the Customer Support Activity System object and not the Knowledge Authoring Activity System object. Through activity theory-based analysis, this issue was captured explicitly as a SupportTracker design requirement. Recognizing the intertwined nature of the two activity systems and their mediating artifacts ensured explicit attention to requirements for tools that influence knowledge authoring. Understanding the priorities between activity systems is essential in crafting tools that support efficient and effective knowledge creation and maintenance.

## **5. Activity System Evolution**

Some activity theory practices devote explicit attention to the practitioner’s impact on the activity system through the process of data gathering and analysis. Our project intentionally designed mediating artifacts that could support the evolution of the activity system. These mediating artifacts were forms of intervention in the activity system.

### **5.1. Interventions**

After the activity theory-based analysis of the data, the project used numerous forms of intervention to influence design requirements for knowledge-authoring tools and to

identify systemic issues that were impeding progress toward better, more reusable knowledge. However, the impact began during the interviews and observations.

The Hewlett-Packard knowledge-authoring community has a culture that communicates predominantly through talking and listening. Written materials must be short and to the point if they are to be read. Therefore, most of our interventions were based around conversations, presentations, discussion sessions, and workgroup technical meetings.

### 5.1.1. Interviews

Within each interview setting there was an interesting dynamic and tension between the open-ended interview technique and the desire for reliable data. The influence of observation on the observed is a well-known phenomenon. The mere act of watching subjects can increase their awareness of mediating artifacts, rules, and the activity system object. In this study, individuals often became more aware of misalignments in their work methods or tools. In some cases, subjects reported that the interview and observation caused them to better understand the use of a tool.

Interviewer: Do you use this rating scale feature?

Subject: What rating scale feature? Oh that box there? This is the first I knew about it.

Many of the interviews were conducted with customer support engineers who were also supposed to serve as knowledge authors. Merely identifying the purpose of the Knowledge Authoring Activity System research increased their awareness of their role as authors.

### 5.1.2. Initial Findings Briefing

Soon after the completion of the interviews and observations, four stakeholder groups were brought together in a meeting to discuss initial findings from the data. The stakeholder groups included representatives from (1) a research team investigating knowledge-authoring technologies, (2) a research team investigating knowledge search and presentation technologies, (3) a team of customer support engineers serving as backline support engineers for the SMS products, and (4) the knowledge maintenance team.

The briefing, especially the discussion of tensions between the subjects and the mediating artifacts, served as a catalyst for dialogue between the providers and users of the knowledge. This dialogue created a new depth of understanding among the knowledge providers about the needs of the knowledge users. Having a representative of those users available to discuss more deeply the meaning and implications of the research analysis contributed significantly to the knowledge providers' appreciation of the issues and implications for design decisions. Hearing directly from a representative of the engineers who author and use problem-resolution knowledge documents had more impact than if the activity theory researchers had simply presented a synthesized version of the interview data and an analysis of the implications for software design.

### 5.1.3. One-to-One Sessions

One-to-one meetings were held to discuss the implications of the research findings. These interventions focused on meeting with opinion leaders in each of the stakeholder groups. A series of one-to-one working sessions was held with a member of the knowledge maintenance team who had attended the initial findings briefing and who had been interviewed. Her responsibilities included the design of a knowledge management operating model and requirements for reusable and maintainable forms of

knowledge. She also had responsibility for influencing design requirements for an organization developing next-generation knowledge-authoring technology. The working sessions included information exchange, validation of work in progress on the operating model and reusability and maintainability design requirements, and validation of research findings.

Another example of the one-to-one meetings was a session held with the primary designer for next-generation knowledge technologies. This individual had proposed a novel knowledge representation and reasoning framework with the explicit intention of improving ease of use and ease of maintenance. The intervention took the form of a few one-to-one meetings, e-mail exchanges, and feedback on design documents that explicitly pointed to design requirements derived from our activity system model and mediating artifacts hierarchy analysis. The intervention included recommendations to conduct empirical usability and maintainability experiments. Those recommendations were repeated later to sponsors for the knowledge technologies research.

#### 5.1.4. White Paper

Another form of intervention was a company-confidential white paper on strategic considerations for knowledge management technologies. Although this paper had a broader targeted audience than the Knowledge Authoring Activity System, it was also delivered to stakeholders in that activity system. The white paper gave examples of considerations in the selection of knowledge management technologies appropriate to the needs of the Knowledge Authoring Activity System. This paper targeted senior managers and strategic decision makers. Alignment in understanding issues across strategic and tactical stakeholders is a critical factor in the success of major changes. Part of that alignment involves bringing to the attention of senior managers a “big picture” of how their organization currently works and where there are opportunities for improvement that would positively impact business goals.

#### 5.1.5. Participation in Knowledge Management Strategy Initiative

At the time of this study, the Customer Support Business organization identified an organization-wide need to update their knowledge management strategy. They chose to work toward consensus, to find common needs in the diverse subcommunities of the organization, and to identify short-term actions that could be taken toward better reuse of knowledge and knowledge tools. A small task force team was identified to take the lead in the proposal of the knowledge management strategy.

A two-day meeting was held, organized by the chair of the Knowledge Management Strategy task force. Members of groups involved in customer support knowledge acquisition, creation, use, and maintenance were invited to present their current approaches, in order to identify common needs and existing knowledge and tools that might be reusable or leverageable. Our research findings were not presented formally. However, during the course of the two-day meeting, there were many opportunities to share findings from the study with the whole group. Perhaps more important, in one-to-one discussions it was possible to convey study results that were directly applicable to the work of the particular individual involved.

A subsequent subcommittee meeting identified opportunities for a common knowledge-authoring technology. Our research findings provided insights that were used to evaluate strong and weak candidate technologies based on how well they would achieve the object (reusable knowledge) and how well matched they were to the competencies and work styles of the subjects. The study's findings on the tension in roles between the Customer Support and the Knowledge Authoring Activity Systems also helped the

participants to understand the constraints (a form of design requirements) on knowledge-authoring technology selection.

#### 5.1.6. Technology Research Working Sessions

The Hewlett-Packard Laboratory research team met in working sessions to review the findings of the study and to produce proposals for technology research directions. The technology research proposal targeted changes in technology that would reduce the tensions between the mediating artifacts, the subjects, and the objects of the Customer Support Activity System and Knowledge Authoring Activity System. For example, one technology research area was in knowledge representation for customer support knowledge. There is an inherent tension between ease of authoring and ease of use. Most customer support engineers who author new knowledge are most comfortable producing text summaries. However, searching large databases to retrieve appropriate customer support information is much easier if the information is stored in a structured way. Furthermore, ease of use is improved if the system provides some decision support. Decision support systems are usually based on structured knowledge, such as decision trees, rule bases, model bases, or neural nets. By understanding the tensions and the organizational structure, the team was able to identify a research agenda for optimization of the knowledge capture approach and decision support knowledge representation.

### 5.2. *Forms of Impact*

The research included a qualitative assessment of the impact of the research conducted. We did not conduct a comparative study because we were primarily interested in what an activity theory approach could contribute, rather than whether it was the best possible theoretical framework for our application. The primary impacts we observed were in validation, increased sense of urgency, increased awareness, closer collaborations among stakeholders, and identification of design requirements.

#### 5.2.1. Validation

Both the Hewlett-Packard Laboratories research team and their transfer partners in the Customer Support organization already had some ideas about ways to improve the way knowledge was authored. During the validation process, some of their technology proposals were questioned because they were at odds with either the object, subject, or division of labor. In particular, some technology proposals focused on ease of authoring, but had inferior solutions for reusability. Other technology proposals would support automation and reusability, but would be too difficult to author. With the activity system model and mediating artifacts hierarchy analyses available, it was possible to improve the proposed technology approaches.

#### 5.2.2. Increased Sense of Urgency

With technology research poised to begin, the findings of the study increased a sense of urgency among Hewlett-Packard Laboratories researchers to take early steps to ensure that the research would, in fact, consider the whole Knowledge Authoring Activity System, the Knowledge Maintenance Activity System, and the Customer Support Activity System. Priorities and trade-offs would have to be decided, but could now be based on an understanding of the elements in the activity systems and the tensions within and between the activity systems. The research team members held working sessions to identify critical technology needs for the set of customer support-related activity systems and translated those into a proposal for research.

### 5.2.3. Increased Awareness

During the course of the interviews, many subjects became somewhat more aware of their roles as knowledge authors. However, the awareness did not translate into any dramatic increase in reusable knowledge authoring. Based on our analysis, we hypothesize that this was because the subjects so strongly identify first as customer support engineers, second as users of the knowledge, and third as authors. However, among those who participated in these interventions, awareness increased immediately as a direct result of the presentation of information and models that helped them to understand the issues in knowledge authoring from a more holistic and multi-viewed perspective.

### 5.2.4. Closer Collaboration among Stakeholders

The initial presentation-of-findings briefing brought together stakeholders who seldom had taken the time to meet directly. The Engeström activity system model served as a focus for discussions. However, the most direct collaboration came when the presentation turned to very specific findings. This moved the conversation from the philosophic and abstract to specific requirements for knowledge creation, use, and management tools and environments. Presenting only the design requirements mentioned in the following subsection, the stakeholders were able to latch onto the implications for their organizations. Those hoping to influence design provided additional anecdotes and metaphors for the consideration of those responsible for research and development of new technologies. The researchers and developers could try out ideas for technologies with collaboration from the customer support engineers.

### 5.2.5. Identified Design Requirements

The design requirements identified in the study were still qualitative and in need of refinement and integration with other design considerations. However, they included requirements for ease of authoring, based on the skills and workstyles of the targeted authors; requirements for “seamlessness”<sup>4</sup> between authoring and customer support tools; and specific attention to having the user interface do more intelligent tailoring of what knowledge was presented and how it was presented, based on user (customer support engineer) preferences.

## **6. Conclusion: Practical Value of Activity Theory**

The activity system model and mediating artifacts hierarchy produced numerous insights into the Knowledge Authoring Activity System as well as the Knowledge Maintenance and Customer Support Activity Systems. Findings from the analysis, using these two tools, included specific requirements for next-generation SMS tools, as discussed earlier. We conclude with some general observations on using Engeström’s models.

### **6.1. Challenges**

Although activity theory provided invaluable insights, we needed complementary models and concepts for communicating with others. Even technology researchers and managers were daunted by the activity theory models and terminology. For example, the distinction between an “object” and the everyday use of the term “objective” was too subtle to communicate effectively without giving a mini-tutorial. Most subjects in our study found the discussion of the activity system’s “object” uncomfortable.

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<sup>4</sup> A seamless implementation allows tools to be integrated in such a way that the flow of control and data between tools requires no work by the user.

Many also found Engeström's activity system model, especially its relationship arrows between the elements of primary relationship, to be confusing. As simplified as that single model is, compared with, for example, a software state diagram or object-oriented use case model, the software research engineers struggled to decompose the model into a simpler topology that would support focusing on one point at a time. Of course, part of the message in Engeström's model is that activity systems are complex and have many first-order relationships between elements.

The mediating artifacts hierarchy is directly related to the activity system model, specifically identifying forms of mediation between the subjects and the object. The classification scheme enabled us to identify forms that are inadequate or missing but are needed by the subjects to better achieve the object. However, stakeholders needed many direct examples of the benefits of understanding the distinction among these forms of mediating artifacts.

In general, Hewlett-Packard managers were most comfortable and able to read through models that were in the form of operating models—either process models, simple information flow, or materials flow models. In presenting the findings of the study to various stakeholder groups, we found that the model that drew the most recognition and comprehension was one drawn by one of the interviewees. It depicted the flow of a customer's problem and its resolution through the customer support organizations. In fact, this problem-flow paralleled the knowledge-authoring flow. Figure 2 was a stylized and simplified version of that model.

We avoided any mention of activity theory's philosophy and psychological concepts. Even though those concepts enhanced the researchers' understanding, the Customer Support community's culture typically communicates from an engineering perspective. In fact, some researchers and customer support engineers were quite vocal about their disdain for "fuzzy studies" (i.e., social sciences). Others were polite, but struggled to understand the basic abstractions in Engeström's models.

To some subjects, "activity" is fundamentally a verb and not a noun. The Engeström activity system model is expressed totally in terms of nouns. It is difficult to sense the *activity* in this model. Process models and process views of activity are a natural way to express the activity. They seem to complement the strengths of the activity theory models and focuses. Together, they can provide a more complete base for analysis and communication of findings.

## 6.2. Value

Engeström's activity system model contributed to the efficiency and quality of the analysis. We were able to map the data from the interviews and observations directly to the elements and relationships between elements in the model. The seven elements of the model (subject, mediating artifacts, object, rules, community, division of labor, outcome) were an efficient means of identifying fundamental parts of the activity system. The activity system under study was focused on productive work (i.e., producing reusable problem-resolution knowledge for customer support engineers). The activity was essentially collaborative and evolving, with tools and other means mediating between the knowledge authors and the system's object. This is well-matched to Engeström's activity system model and the activity theory behind it. It was quite efficient to analyze the data against the elements and relationships between elements in the model. Identifying tensions and conflicts related to the mediating artifacts was particularly helpful in identifying design requirements for knowledge-authoring tools.

The mediating artifacts hierarchy enabled us to look more closely at the mediating artifacts and to understand the role of each within in the activity system. The hierarchy also served as a checklist against which we could determine missing or inadequate classes of artifacts. Interviewees often volunteered their needs in terms of a kind of information, capability, or tool that they needed to accomplish their primary responsibility (customer problem-resolution) and to a lesser extent those needed to author reusable problem-resolution knowledge. They consistently identified needs for what we would call “what” and “why” mediating artifacts. Observations of the way knowledge was authored revealed needs for improved “how” mediating artifacts. Finally, we observed subtle and indirect indications within the community of “where-to” mediating artifacts that were contributing to an evolution in the activity system’s object. We also identified an opportunity to introduce more “where-to” mediating artifacts to support changes in the Customer Support knowledge management strategy. Taken together, these four classes of mediating artifacts and the tensions between them and the rest of the activity system enabled us to identify desirable features and functionality for the next generation of Knowledge Authoring Activity Systems and to identify systemic issues in the Customer Support environment that needed attention.

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