# Designing Performance Interventions for the Information Age

## *DOPSS Functions and the USE Method*

*Steven Schatz and Thomas M. Schwen*

Dynamic Online Performance Support Systems (DOPSS) are a new class of intervention that can meet the needs of a quickly changing work force in an information age environment. These systems are customized for the target population, with unique meta tags, unique function sets, and dynamic growth for and by users in use. These unique tag sets allow users to quickly and easily add resources to the system, so it is an intervention that grows and evolves based on continued use and input by users. This paper reports on a case study examining the design of a unique function set for military aircraft maintenance technicians. A new method to guide data collection and analysis is used. The USE method (User-centric + Sensemaking + Evolving) is applied, with Schwen's (2001) knowledge model supporting the user-centric collection and analysis of data. The result of this new perspective allows the input and analysis of needs on micro, meso, and macro levels, identifying needs that may cross boundaries of traditional interventions.

## Introduction

In information-rich work environments, particularly those with a changing workforce that is geographically or temporally separated, the boundaries between tools for knowledge management, learning, and performance support are becoming less distinct. Support systems targeted to meet the needs of individuals and organizations in information-rich environments offer design challenges, not the least of which is discerning the needs and goals of the primary actors. Developing a system that meets a large number of goals in these crossover fields, that does not seriously contradict the expectations of those funding development, and that is useful and engaging enough to encourage use by the target population, requires a richer set of analytic tools than those currently available to practitioners in the field.

In this paper, the researchers examine an application of the USE (User-Centric Analysis+Sensemaking+Evolution) design method as it is used to develop a unique set of functions for an online performance support system, which is to be used by workers involved in the maintenance of a Naval aircraft. In particular, the researchers explore how Schwen's knowledge model (Schwen, 2001) may be used to aid analysis of needs as well as to recognize and negotiate conflicting goals of various actors within the target populations.

In this study, the researchers examine a logistics group who dealt, in part, with the maintenance of electronic components of a Naval aircraft. This group had been developing a "knowledge portal," revising extant designs in an attempt to satisfy mandates from Naval commanders to "Web enable" the Navy wherever possible. Those involved in the process of developing one of these portals were concerned by the lack of use of existing portals by end-users. "We are engineers. We understand how to make things work, not how to make people use it and this is not being used," was how one participant expressed the problem. Most of the effort that had been expended prior to our involvement centered on capturing knowledge objects, including digitizing thousands of pages of technical manuals used in the repair of these components. The question expressed by the team from the Navy was, "How do we change the interface to increase usage?"

Upon reflection, one can see a number of implicit design decisions that might point to reasons for this limited use. These include treating knowledge as a static object, conceptualizing knowledge systems as separate from job performance, ignoring the types of information needed or wanted by the target population, and failing to recognize the inappropriateness of the medium for delivery of certain types of knowledge.

Our previous work has involved the design of systems that cross traditional boundaries of knowledge management, learning, communication, and performance support. Too often, it seems, knowledge or learning systems are designed with an *object-centric* focus. The question traditionally asked by designers is, "How do we store, label, and retrieve objects (whether they are considered information, knowledge objects, or learning objects)?" The result of this fundamental design perception/decision is a data warehouse that contains a large amount of data, but most users cannot easily find that data. Our design work opts instead for a *user-centric* focus. Our research has focused on exploring methods to identify user needs and identifying functions that may meet those needs. The result has been systems that are unique to the user population, with unique function sets, unique search/retrieval meta tags, and unique models of implementation. During development of these systems, the researchers have found that the typical approach (certainly being followed by the client in this study) of warehousing information, then trying to find ways to encourage use of the data by the target population does not lead to effective design. This traditional model, wherein the system is built and populated before being launched does not encourage growth of the system. The work of our design team has centered on supplying an initial minimal set of knowledge/learning objects and then supporting the growth of the set through requests by users based on needs and use. We have come to call these systems DOPSS (Dynamic Online Performance Support Systems). This report is a case study of the implementation of a model for analysis and design of the function set of a DOPSS. Before discussing the specific case study, I describe DOPSS systems in order to provide a more clear understanding of our proclivities and preferences.

**Our design work opts instead for a *user-centric* focus. Our research has focused on exploring methods to identify user needs and identifying functions that may meet those needs.**

### What is a DOPSS?

Dynamic online performance support systems (DOPSS) are online, computer based-systems that are custom designed for specific populations facing specific problems. There are three basic functions that most DOPSS will have. The specific implementation of the tools to achieve those functions and the relative importance of the functions will differ depending on the needs of the target population. The three standard functions are (1) meta tags for fast addition of objects and their search and retrieval, (2) communications tools, and (3) matchmaking/connectors.

The objects (learning/knowledge objects) in DOPSS system are tagged with a unique tagging schema developed by investigating user needs. This schema allows very finely targeted, tag-based search and retrieval. The *tag set*, because it is unique to the target population, is small. This makes it fast and easy for users to tag and add objects to the system, thus allowing the contents of the system to grow based, in part, upon user activity. The objects may have different intents—teaching, sharing facts, or providing information. Because these objects are used in the service of performance, there is a pressure to keep the size of learning objects small. If one wants to know how to clear a paper jam, then the user does not want to download a manual or maintenance tutorial. This is a clear distinction from the knowledge portal that was under development. With a move toward viewing the system as a support to performance, the analysis became situated in users and use, rather than in capturing objects.

All DOPSS will have communications tools, be they synchronous (instant message or Web cast) or asynchronous (bulletin board, file sharing). Again, these tools will differ depending on the needs of the target population. The final type of tool that will often occur in a DOPSS is a "matchmaking" tool that helps people in the target organization find one another based on interests, knowledge, or some other criteria.

Within this overall framework, the *function set* of each system is customized based on extensive interviews, observations, and analysis of the target population. Rather than trying to be all things to all people, these systems are designed for groups with homogenous information needs. This may be a small group, such as a marketing team working on the international rollout of a phone, or a large group, such as the one described in the current case. The number of group members does not matter as long as the information need is homogeneous. This homogeneity allows targeted functions and simple tag sets.

The goal of a DOPSS is to provide a framework for sharing information, in order to support performance for jobs in rapidly changing environments. While the initial function set and structure of the system is built by the designer, much of the content in the system will come either directly from users (tagged and uploaded) or be generated as a result of a request from users. Rather than viewing the development as a ship—built and then launched to sail off into the sunset—we view the development of a DOPSS as a garden. We do a lot of work getting the garden in shape, planting what the population wants and needs, and taking into account the environment. However, once the garden is planted, there is continuous work to do, intense at the beginning, with replanting, weeding, and more, and continuing as long as the garden produces.

For jobs with changing information needs, there is often no time to develop a support system and stock it with information. Solutions, discoveries, and decisions must be shared as they are developed. The challenge for companies that support such jobs is how to keep several people on the same page at the same time, instead of having each person or group constantly "reinventing the wheel." The solution we have pursued is to provide systems that support the sharing of information, allowing users to constantly train each other and support each other's performance. The three keys that support this process are (1) fast and easy tagging in order to allow users to easily add objects to the system, (2) fast and effective search and retrieval so that users may quickly find a few (rather than several million) answers to their questions, and (3) a gardener/librarian/*DOPSS keeper*—a person "minding the shop." This person's duties include user support, finding and adding information, and supporting the evolution of the system (new functions and new tags), much as a librarian does. To be effective, it is essential that the system be dynamic and evolving. While there is extensive formative evaluation of the population, a significant part of the effort and costs of the system come after the system is brought online. For it is then that, through use, the users can drive the development of the system, allowing it to evolve into a truly useful tool. The system will change over time, as users discover new needs and new ways to use the system. In order to support this evolution, designers must be available to support the system. The DOPSS keeper is there to provide help, to gather requested information, to engage users, and to suggest and direct changes. Designers of a DOPSS must take their guidance from librarians, who do not just gather and maintain a collection, but are a resource for help and support, encouraging use and developing programs, gathering new materials and helping the library evolve to meet the needs of the users. Dynamic online performance support systems similarly require constant support and growth.

So, our work with DOPSS systems seemed to hold us in good stead as we examined the needs of this project. As mentioned above, each DOPSS is unique, with a tool set unique to the needs of the target population. In this study, the researchers applied a method called the USE (again, User Centric + Sensemaking + Evolution) method to analyze the needs of the potential users.

### Discussion of the USE Method

**User-centric analysis.** Much of the design of systems that employ knowledge or learning objects has had either a system or an object focus. As discussed previously, in our design work, the design team attempts to discover and meet the needs of the user during use. To do this, we first gather information about the user, the tasks, and the environment in which the users attempt to complete the tasks. We have found Human Performance Technology (HPT) to be a field of endeavor that looks beyond task completion for causes of performance gaps, so is a rich source of tools. Rossett (1996) classifies causes of performance problems into four areas: lack of skill and/or knowledge, lack of motivation, flawed incentives, and flawed environment. Gilbert (1996) highlights the importance of the supporting environment in seeking ways to improve performance, specifically looking at information, instrumentation, and motivation in the environment and in a person's repertory of behavior.

In order to study the person, his performance, and his environment, the field of HPT makes use of a rich set of methods and tools. These include observation, interviews, focus groups, questionnaires, brainstorming, and more (Hackos & Redish, 1998; Jonassen, Tessmer, & Hannum, 1999).

The use of HPT techniques within this model grounds the data in users, their tasks, and their environment. This shifts the focus from trying to describe the specifics of an object to gathering information about user needs.

However, the HPT tools are still focused on the micro (personal level) and share an underlying (and unproven) assumption that micro interventions can be applied to meso and macro level problems. This is not an inherent problem with these data collection tools. It is a problem of orientation while collecting and analyzing data.

Schwen's (2001) knowledge model provides guidance in scaling of analysis from the individual to the group. Schwen first explores the nature of interventions, looking at the target (individual or collective) and then at the nature of the implementation (micro, meso or middle, macro). The vast majority of instructional interventions are driven by analysis of the individual and are intended to impact on a micro level. The designer analyzes the job that a single worker in a shop does and tries to implement a support to help that person do the job better. One person or several individuals are studied both before and after intervention. However, it is rare to look at the work within the shop as a collective activity, even though it clearly is. In this case, the shops and the chief of each shop are the only stable elements. Groups from ships rotate in and out of the shops, with both individuals and groups interacting in the social/work setting. Developing an interaction within this situation, it is essential that the unit of analysis is the shop, not the individual. Then, looking at the use of the proposed tool, the next level of analysis are the groups that make up the potential user groups—in this case, the administration at depot level, the engineers at depot level, the administration at shop level and the shops themselves. Schwen's model provides essential guidance for developing a tool by looking not at the individual, but the group.

**In order to develop a tool that addresses so many levels, the analysis must explicitly examine collective activity on the meso and macro level. The activity of doing the analysis may be bridge between these levels, as the researchers attempted to view and understand the collective workings and understandings in a variety of situations.**

The next, important step is Schwen's mapping of theories of knowing to the micro, meso, macro divisions. As DOPSS systems are, at their core, tools for sharing understandings and information, the nature of knowing is essential to their development. The DOPSS provides a means for capturing understandings at the moment of knowing, a snapshot of the generative dance (Cook & Brown, 1999). While intended for use on the micro and meso level, these are interventions that span these levels and have the potential for impacting the understanding, both tacit and explicit of individuals and groups at all levels. In order to develop a tool that addresses so many levels, the analysis must explicitly examine collective activity on the meso and macro level. The activity of doing the analysis may be bridge between these levels, as the researchers attempted to view and understand the collective workings and understandings in a variety of situations.

Finally, Schwen's model proves invaluable in focusing attention on the needs of the individual, the group, and the organization and to encourage the researchers to look, particularly, for areas where those needs and goals may be different and in conflict.

**Sensemaking to tie data to design.** *Sensemaking* is a theoretical perspective that examines the cognitive processes undertaken by individuals and groups when faced with a situation or information that does not fit into expectations—a "jolt." Sensemaking has been used to explore how organizations interpret their environment and how this interpretation process influences strategic behavior (Schneider, 1997), the behavior of airplane pilots during events preceding a crash (Weick, 2001), and the process of creativity, both individually and organizationally (Drazin, Glynn, & Kazanijian, 1999). "The sensemaking process both draws upon cognitive schemas as a guide for action and updates these cognitive schemas in making sense of experience" (Morrison, 2002, p. F1). The emphasis in sensemaking is on "understanding the processes through which individuals and organizations develop systems of meaning about creative action (Drazin et al., 1999). Weick (1995, p. 2) identifies seven attributes of the sensemaking process: (1) grounded in identity construction; (2) retrospective; (3) enactive of sensible environments; (4) social; (5) ongoing; (6) focused on, and by, extracted cues; and (7) driven by plausibility rather than accuracy.

**Using Sensemaking as a theoretical lens to both gather and analyze data roots the activity in examining the purpose the user has for seeking information as well as the type of information the user wants and expects.**

Using Sensemaking as a theoretical lens to both gather and analyze data roots the activity in examining the purpose the user has for seeking information as well as the type of information the user wants and expects. This is useful when designing performance support systems—systems that provide answers to problems—as opposed to generalized searches for information. While one occasionally has time to "cast a wide net" to find tangential information about a topic, one more often searches for objects because of a specific need or a problem. This type of searching may be viewed as a Sensemaking activity: finding information and using it to develop the user's frame of reference to be able to solve the problem or fill the need that initially stopped the smooth flow of performance. For example, a teacher, tasked with teaching a lesson on the phases of the moon, may not have a ready explanation or may need supporting illustrations. The teacher has a need, or a perception, of what she wants, and begins to search to find those objects that can provide information to "make sense" of the task, filling in the gaps in her understanding. The teacher is engaged in a process that includes "placement of items into frameworks, comprehending, redressing surprise, (and) constructing meaning…" (Weick, 1995, p. 6).

So, we need to explore what problems lead the target population to search for information, what types of information they believe they need, and to what use they will put that information. If one develops tags that support this process, the search may be more direct and more effective.

**Designing systems intended to evolve.** Whether it be the economic model, the tradition of the field, or the desire to ride in, fix a problem, and ride off in search of other fires to fight, most knowledge/performance/learning interventions are conceptually a discrete, complete, closed system. Schwen's (2001) knowledge model highlights some of the problems inherent in scaling a system design based on micro analysis to fit macro-level problems. This problem of scaling is one of the oldest in engineering. Petroski (1994) writes of beams that break under their own weight when they get too long and mechanical designs that work as models, but are impossible to build full scale. To build systems to the scale of the intended intervention, and that can evolve based on the changing needs of the target population, the design team has turned to writings in design theory.

Christopher Alexander, an architect, has attempted to identify patterns in structures that have "life" (Alexander, 1979; Alexander et al., 1977). A pattern, in the Alexander lexicon, is the expression of a relationship between problem and solution. "Each pattern describes a problem that occurs over and over again in our environment and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without doing it the same way twice." (Alexander et al., 1977, p. x) Patterns are brought together to create a living space. The relationships between the patterns form a "pattern language." It is most important for those who will be living in the buildings to participate in the development of the pattern language for that building. Design must not be done by "experts" who will not use what they design, but must be centered on the use and the needs of users.

> If I build a fireplace for myself, it is natural for me to make a place to put the wood, a corner to sit in, a mantel wide enough to put things on, an opening which lets the fire draw.
>
> But, if I design fireplaces for other people—not for myself—then I never have to build a fire in the fireplaces I design. Gradually my ideas become more and more influenced by style, and shape, and crazy notions—my feeling for the simple business of making fire leaves the fireplace altogether.
>
> So, it is inevitable that as the work of building passes into the hands of specialists, the patterns which they use become more and more banal, more willful, and less anchored in reality. (Alexander, 1979, p. 236)

Richard Gabriel has used Alexander's work to help guide the design of object-oriented software. As the ideas that drove the development of object-oriented software provide much of the impetus for the development of learning objects, Gabriel's thoughts are particularly relevant. Gabriel (1996) makes a distinction between "habitable" software that allows piecemeal growth and the creation of a "grand design."

> Software needs to be habitable because it always has to change. Software is subject to unpredictable events: Requirements change because the marketplace changes, competitors change, parts of the design are shown wrong by experience, people learn to use the software in ways not anticipated. We notice that frequently the unpredictable event is about people and society rather than about technical issues. Such unpredictable events lead to the needs of the parts which must be comfortably understood so they can be comfortably changed. (p. 13)

The writings of Alexander and Gabriel provide guidance for user-centric systems that grow based on use. Alexander and Gabriel caution against building a "master plan," but instead advise designers to start small and allow piecemeal growth of the system based on continued user input. The danger of relying upon a master plan is that it takes the power to impact their future away from the users. Alexander believes it is impossible to know how a space will be used. The work of the architect is, at best, a guess.

> …but our predictions are invariably wrong. People use buildings differently from the way they thought they would. And the larger the pieces become, the more serious this is.
>
> The process of design, in the mind's eye, or on the site, is an attempt to simulate in advance, the feeling and events which will emerge in the real building, and to create a configuration which is in repose with respect to these events.
>
> But the prediction is all guesswork; the real events which happen there are always at least slightly different; and the larger the building is, the more likely the guesses are to be inaccurate.
>
> It is therefore necessary to keep changing the buildings, according to the real events which actually happen there. (Alexander, 1979, pp. 479-480)

In summary, HPT gives us insight into the needs of end users. Schwen (2001) guides the collection and analysis, identifying levels of needs and potential conflict. Sensemaking creates a bridge from knowledge of user (including what problems they may be seeking to solve and what kinds of solutions they expect) to identification of functions and interventions to initially meet needs. Evolutionary design makes us think of the design of systems not as a ship that is launched to sail into the sunset, but as a garden, where the designers will continue to help the system grow and evolve based on continuing input from users.

## Methods

This article is the report of case study research (Yin, 2002) based in an objectivist epistemology and a postpositivist methodology (Crotty, 1998; Phillips & Burbules, 2000) in a naturalistic setting (Denzin & Lincoln, 2000). The research was conducted to gain a richer understanding of application of the USE method in designing the initial function set for a support/knowledge system for a complex organization.

The researchers explicitly assumed the dual role of designer/researchers throughout the process. This allowed greater latitude in seeking information. Data was collected through group meetings, one-on-one in-person interviews, site visits, observation, and analysis of existing systems. In addition, inside "informants" were available for extensive debriefing sessions; they provided fast responses to question and were invaluable in developing the researchers' understanding of both the jargon and the norms of conduct in the organization.

From the beginning of the project, the researchers attempted to understand the targeted level of intervention and the actual level of activity. What level (micro, meso, macro) was an intervention intending to impact? The impetus for creating the intervention was coming from which level? The design team attempted to identify potential user groups for interventions, what their potential needs and patterns of use might be, and management expectations for the outcome of implementing a system. To collect this initial information the design team relied on management perceptions. We attended three on-site meetings (at a naval base in Indiana). Each meeting lasted about three hours. Before and after each meeting, the researchers had extensive e-mail and telephone conversations with the management point of contact. Extensive notes were taken during these meetings and reviewed afterwards. By the end of this initial phase, four target groups for the intervention were identified: management, engineers at the depot level, technicians at the I level (who worked on electronic components in a repair shop setting), and technicians at the O level (who worked on components installed on the aircraft).

**From the beginning of the project, the researchers attempted to understand the targeted level of intervention and the actual level of activity. What level (micro, meso, macro) was an intervention intending to impact?**

Data was collected from individuals representing each of these populations. Interviews were carried out in person and on site, so the researchers were also able to observe the environment. Most questions were open-ended, focusing on perceived problems, problems that occurred during times of high stress on systems, and possible solutions.

Three interviews with management level personnel were conducted, each lasting about two hours. To interview technician level personnel, one of the researchers twice traveled to a base in Washington State, spending two days on site each time. During these visits, the researcher was assigned a point of contact who was invaluable in "translating" jargon, answering organizational and operational questions, and encouraging interviewees to be forthcoming in their responses. As a former Chief in both the I and O groups, this point of contact made a significant impact on the quality of data acquired. The I and O groups were very different in job and temperament, requiring different data gathering methods for each. For both groups, an initial group meeting included explanation of the task at hand and broad research questions (descriptions of problems and possible solutions). These meetings lasted about an hour each. For the I group, this was followed by extensive visits to each of the repair shops. The researcher spent between one and two hours in each shop, observing, talking with the head of the shop, and occasionally with individual sailors working in the shops. Throughout these interviews, the researcher attempted to understand the work flow, common problems, problems that occurred during high-pressure situations, and the differing needs and perceptions between micro, meso, and macro situations. It should be noted that the head of each shop can be viewed as a micro level actor. An intervention can target knowledge flow to him. In this case, the repair facility is a meso level organization. However, the entire repair organization (including management and depot level engineers) may be viewed to be meso level, when considering the Navy as a whole, or even a subset of the Navy such as Logistics. However, viewed with finer granularity, the individual sailor may be on the micro level and the head of the repair shop may be on the meso level.

Throughout these interviews and upon reflection afterwards, the researchers attempted to identify conflicts between the needs of individuals acting on different levels. In all, four I level Chiefs (head of a shop) and their shops were investigated. In addition, two interviews with base management were conducted (about one hour each). Throughout the two days, the researcher asked for information and clarification from the point of contact. The researcher used a set of open-ended questions to start the interview process, but allowed the interview to deviate from those questions. Notes were taken during the interviews. The researcher also used a large pad of paper to draw possible interface designs, to clarify workflows and to ask respondents to illustrate points. Interviews were not taped or digitally recorded, as it was felt that this would inhibit free responses. At the end of the day, the on site researcher made extensive field notes and discussed findings with the other member of the research team.

The O level technicians were not receptive to the idea of a knowledge base type of intervention. As they spent their time working directly on the aircraft, they did not see how they could use such a system. Following the lead of their Chief, they rejected the idea during the first group meeting. Consequently, no further one-on-one interviews were possible. The researcher was able to carry out one brief interview during a tour of the aircraft, having asked to be shown the plane. Some valuable insights about information flow came from that interview and are reported in the results section of this article.

Toward the end of the project, a second trip focused on end-user reaction to proposed design of the intervention, the usefulness of the function set, and other ideas that the prototype stimulated. Interviews with Chiefs, their direct assistants, and some sailors focused on reaction to the prototype and new ideas. Between six and eight hours were spent on this second set of interviews and observations.

To obtain information from the depot level engineers, the same format of a large group interview and a number of one-on-one sessions was repeated. For this group, the large group (eight engineers) provided great detail and was very useful, moving quickly into their perception of problems and possible solutions. This meeting lasted nearly three hours. Three engineers were interviewed individually. One person was very open, talking for over two hours. The other two were much less loquacious, talking for an average of 45 minutes each. Notes were taken, the pad for illustration was used, but the interviews were, again, not taped or digitally recorded.

Finally, after a prototype had been designed, meetings with management were conducted. Two meetings, each two hours long, focused on findings, design, implications, and further directions. In addition, an interview with the head of another knowledge portal design effort was conducted, exploring potential fusion of ideas.

Throughout the interviews and observations, differences in perceptions, motivations, and facts were noted in field notes. The researchers did not attempt independent verification of details, believing that the *perception* of a thing or belief was more important in guiding design than its relative accuracy.

## Results

A large amount of data were collected. In order to impose some order upon them and to aid in analysis, the researchers sought to identify needs and goals, both stated and implied within each group analyzed. Schwen's knowledge model was used to gain a richer understanding of the level (micro, meso, or macro) of knowledge or intervention needed to meet these needs and goals.

### Management

There were two groups within the management team. The first was decision makers funding this development project. Their motivation was not knowledge capture or functionality. While they had some visions of how the final tool might be used, they seemed mostly concerned with orders from above that all things Navy should be "Web-enabled." As one member put it, "We have been looking at everything we do and asking, 'Why is this not online?' and 'How do we put this online?'" Many groups from different parts of the Navy were developing prototypes for such knowledge portals and this group wanted to be the one that provided the model for development. The culminating event for this project was scheduled to be a visit by the Chief of Naval Operations, with the team hopeful that he would find the project worthy and fund further development. Management wanted to use as many new information and communication technologies as possible, expressing interest in video conferencing and Web-based support systems (very bandwidth-intensive interventions) while individuals who served on ships talked of problems getting e-mail and flatly stated that such high-bandwidth interventions were not feasible. A primary motivation of these management members was the protection and expansion of their sphere of influence and activity.

The second group within the management function consisted of former Navy employees who were now employees of a large private consulting firm, essentially a long-term temporary agency. These workers were largely involved in technical matters. They were the primary points of contact with the researchers and were very forthcoming with information. They also, as employees of this firm, were clearly motivated to expand any projects for which their company provided personnel. Some technical decisions seemed to make interventions more complicated than necessary, requiring knowledge specific to other employees of this firm.

The view of knowledge for this group was "possessed knowledge." It was the official line, as set forth in manuals and official communications. The interventions were created on the macro level using group, explicit, macro knowledge (Naval policy) with the intent of impacting the individual, at micro level. This is a pattern more clearly associated with military organizations, but certainly should be looked for in any organization. It may be paraphrased as, "As the leaders say, so shall it be done by every living thing."

**After interviewing one management person for several hours, one researcher noted in his research journal, "This is a very complex organization within a very complex organization." The management was quite aware of the complexity of the organization and the need for change.**

After interviewing one management person for several hours, one researcher noted in his research journal, "This is a very complex organization within a very complex organization." The management was quite aware of the complexity of the organization and the need for change. There were repeated references to the need for a "change in culture" during a four-hour interview with the head of logistics. That such a high-level person would take so much time as well as fund such research indicates a real interest in facilitating change. This person noted the new facilities that the group was going to occupy, moving from a converted warehouse with long labyrinths of hallways to a new building with an open feel similar to a college campus. He hoped that the physical space, along with a new management focus on "culture change," would make a difference.

When, at the end of the design project, the researchers offered a set of functions that set out a very new direction, the Chief Information Officer of the base, upon understanding the implications, excitedly embraced the new direction. This tension between the established, in-place methods, and a recognition and acceptance of change, provided a dynamic tension within the management group.

### Hands-on Repair Personnel

A very different view of knowledge, activity, and needs emerged from on-site observation of the O and I level personnel. The following description from the on site researcher's journal written the evening after the first base visit situates these personnel.

> Whidbey Island is about 100 miles north of Seattle. It is rather remote. It is attached to the mainland by a short bridge. The town of Oak Harbor and the Naval air base are symbiotically linked. The purpose of

the base is to provide a home base for two types of aircraft—the EA-6B Prowler, an anti-radar plane and the P-3, a "spy plane." My focus is the EA-6B. The Prowlers are assigned to aircraft carriers. When those carriers go to port, the planes go to Whidbey. While at Whidbey, more detailed maintenance can be done.

The maintenance groups are divided into two areas; the O level (operations) work on the planes in hangers and on runways. The attitude of O level techs is that they use "duct tape and baling wire to get their planes to fly." Their maintenance is on the aircraft, not the components. If a component is broken, the O level people remove and replace the component. The I level people work on components. There is not valuation between O and I levels. "Some guys like to work on parts in air conditioned shops and others like to work on airplanes out on the runway," explained one. The O level sailors are assigned to a set of planes. The I level sailors are assigned by expertise (microwave, radio, circuit boards, etc). Both O and I levels are assigned to squadrons which are assigned to ships. On ship, the O's stayed with the same planes. The I's are in shops with other I's who are assigned to other squadrons that have different kinds of planes. At Whidbey, I's show up to work at shops divided by functionality. The personnel in these shops turn over completely every few months. The only stability is the Chief, who is in charge of a shop. One of the shops also had an assistant chief who was permanently assigned.

The base is an interesting mixture of home and hotel. The great majority of people on the base are there for six months as they prepare for a six-month sea voyage. This is where the people who deal with aircraft on an aircraft carrier are stationed while the carrier is in port. The ship is their main focus during their enlistment and while at Whidbey, they are separate from their ship. There is a sense of temporariness; there are few adornments either inside or outside the buildings. A few years ago, the P-3 aircrafts began to be stationed at Whidbey and those in charge immediately erected a P-3 memorial park. Only in reaction to that was a similar Prowler memorial erected. Looking at the barracks, which resemble large, multi-storied dormitories, it is hard to tell if they are empty or full. However, there is also a continuous hum of activity. Planes take off all night long. All day the hangers are full and each plane is covered with dozens of people cleaning, scraping, examining. The shops are not full of people, but they have shelves of components to be fixed and in some cases, a line of larger components line the hallways outside the shops. In other parts of the buildings, aircraft engines are pulled apart and serviced. The building where the I level works is large, old, and functional. The ceilings are very tall. The floors are usually painted cement. There are few windows. The feeling one gets is a factory built in the 1960s. The place is well lit. The building is cool (many of the shops are extremely over air conditioned for the components). There is a relaxed, but purposive demeanor with most of the people. The people are mostly young and male, although women are not so rare as to evoke stares or special interest. A great majority are in uniform. One rarely sees people standing around chatting in the halls. Conversations happens in shops and offices. Offices are small, with old, cheap furniture. There are a few old wall dividers. Most desks in offices as well as in the shops have a computer. Most desks belong to someone who is permanently stationed at Whidbey. At desks there were a few personal items (pictures and books). The only adornments in other places were pictures of aircraft and commanding officers. Overall, the impression was of a place built and maintained for function, not comfort.

## Knowledge Problems Expressed at Whidbey

While interviewing and observing I level Chiefs, a disconnect between official procedure and actual activity became obvious.

> My people are supposed to connect the board to the test bench. It gives them a list of possible failures which they must clear in order. Now I know that the first reading is a software error. There is a change request in for that, but I am not allowed to reset the parameter for that component. I have to find the engineer who is in charge of that board who can give me authorization to make that change or ship it back to depot. (Chief D)

Some work-arounds are not allowed, but are passed along orally as technicians come back from ships where they have worked with I level technicians from other areas. Some have been passed on within a shop from the previous Chief.

> We have an old portable test bench. It was supposed to have been retired, but there are occasionally boards that won't pass the new benches, but they will pass on the old bench. If I didn't keep the old one around, I would have to either send the board back to depot or cycle through the process of trying a repair and sending it out to install and test in the aircraft. (Chief E)

When asked what they do when they hit a problem that stumps them, several said, "I pull out my rolodex." Asking whom they called resulted in stories of high-pressure times (such as the first Gulf War), when long hours brought people closer together.

Another problem area mentioned regularly was access to information about inventory.

> We have an inventory system, but we are not allowed access to the particulars. C (the woman with access to the inventory system) knows where everything is, but won't always tell you. I spend a lot of time going up and trying to find out when a part is going to arrive. (Assistant Chief S)

Several people mentioned the time-consuming job of finding out which engineer had the authority to allow changes in parts that no longer exist. One person estimated 25% of his job was involved with this problem.

> See this radio? Some of these have been in use since Korea. They are standard walkie-talkies and they work fine. However, some of these have transistors in them that haven't been made for 20 years. Now if I go to this database, it tells me to replace it with one part. If I go to THIS database, it tells me to use another. I am not allowed to make this decision, because when this radio goes into a shop somewhere else, they need to know what is going on. So, there is an engineer, somewhere in the Navy who has the authority to tell me what part I can put into this radio. But that is not that engineer's only job. It is just a line on a list somewhere on a memo. They may not even know they are the person to make that decision. Finding that engineer… THAT is a problem. (Chief M)

**When asked what they do when they hit a problem that stumps them, several said, "I pull out my rolodex." Asking whom they called resulted in stories of high-pressure times (such as the first Gulf War), when long hours brought people closer together.**

The O level group immediately opted out of the project. As most of their work involved working around the aircraft, they saw little use for a computer-based support tool. In addition, they saw no need for the means to look up policies. "All of our regulations are written in blood" was the comment during the initial group meeting. When asked to explain, the Chief related the following story.

> Last week someone put their hand on a tire of a plane after it had landed because it looked like it was bulging and they wanted to see if it was hot. The tire burst and killed him. So, everyone knows not to do that.

When asked how long it took to pass this information around the fleet, the Chief estimated word traveled within a couple of days. Later, the researcher pursued the matter with the informant, asking how the information could have traveled so quickly. It was explained that there were daily reports to which any Chief could add a note. These were semi-official communications, not from authoritative sources, but passed through official communications channels, carrying more weight than an e-mail message. These messages constantly flow between repair facilities.

#### Knowledge and Needs at Hands-on Facilities

The explicit knowledge, largely contained in manuals, that was the focus of the management view of the system was not a high priority for individuals and groups working at the hands-on level. Indeed, some meso-level knowledge from the existing manuals would be lost through digitizing. In a few of these shops, these manuals were mounted for easy access: several feet of manuals next to each other, like one would see in an auto parts store. Notations, pages folded to indicate important parts, physical location within the manuals, and wear patterns all served to transmit some tacit collective knowledge from the meso level to individuals as they sought to solve problems. This knowledge sharing would be lost with the introduction of digital manuals. In addition, sailors pointed out that the schematic diagrams were one of the most-used parts of the manuals and those would not print well with the current state of printing technology available.

Of greater interest was the informal, collective knowledge that impacted the organization on both the micro and meso levels. The informal connections accessed when a Chief picked up his rolodex were used extensively for problem solving. There were no plans in place for methods to encourage or capture this knowledge. As many of the Chiefs were intending to retire, this very important asset was also very vulnerable. Suggestions of an online log or communications tool were greeted with caution, as much of the communication and advice was both informal and not standard procedure, so there was some hesitancy in committing such advice and information to an easily reviewed source. Clearly there was a demonstrated difference between knowledge of practice and knowledge of possession (a distinction made by Schwen in his 2001 article, extending Cook and Brown's 1999 article, between knowledge that may be viewed as inert versus knowledge that is developed and used in the process of activity) and while efforts for the original design of the knowledge portal were aimed at dissemination of explicit possessed knowledge, there were indications that the knowledge of practice was passed surreptitiously and had little means for reification, capture, or reuse.

**The informal connections accessed when a Chief picked up his rolodex were used extensively for problem solving. There were no plans in place for methods to encourage or capture this knowledge. As many of the Chiefs were intending to retire, this very important asset was also very vulnerable.**

The sharing of knowledge between Chiefs and sailors as they rotated through the shops and interacted with other technicians, both from other areas on the ship and from other ships, was also a rich source of shared knowledge. It is important to note that the "realities" for each group (depot management, shop Chiefs, depot engineers) did not correlate with the perceptions of other groups. The disconnect between depot level management and Chiefs and sailors at the shop level was particularly extreme. In several instances an incident was described and motivations were explored by two different actors with the two views of the same incident exhibiting substantively different features.

In considering choice and design of functions, the researchers noted that the greatest impact in practice could be gained by developing functions that improved access to information (of various kinds) and that improved communications among and between groups. By making it easier to find who had authority to authorize changes in test benches or components, hundreds of man-hours could be saved. By establishing systems to allow and encourage sharing of questions and answers, a step toward capture of knowledge practice on the meso level could be taken.

## Levels of Knowledge

One can see in this analysis that the same knowledge may be viewed as different levels, depending upon context. Most of the analysis viewed a shop as the unit of analysis (micro), within the meso group of (for example) the I level shops at the base. One may also view the micro level as being the individual sailor interacting with a piece of equipment, with the knowledge within the shop as being on the meso level. One may view the maintenance organization as being the macro level, or it as being at the meso level with the Navy being the macro level. The power of Schwen's model is that it encourages analysis to consider the implications of intervention on all levels. The power is in the view, rather than in trying to establish which view is the correct one. It is this interplay between levels that knowledge must navigate in practice that must be studied. In order to be useful, systems and other HPT interventions must also reflect the dynamic interplay of role and knowledge.

In this analysis, we largely focused on the shop as the unit of consideration as it was a stable point. Sailors and equipment passed through the shop over time. What knowledge was able to be exchanged, transmitted, and captured in these locations was a point of leverage for a system. We suspect that one of the challenges in developing such systems for complex organizations is identifying such points of leverage.

## Depot Level Engineers

The interviews with depot level engineers were much more difficult to arrange. It was not clear to what this reticence could be ascribed. When the researchers met with the engineers, first in a large group and then in individual sessions, the people were as forthcoming as all other participants had been.

Much of the conversation with engineers focused on the challenges of working within a complex organization.

> We have boards that are listed as either fix, send to depot, or throw away and replace. An expensive board got on the replace list mistakenly. It was just a typo. It took me over a year to get that corrected because of one person who didn't want to admit a mistake had been made. In the end, I got a little short tempered and insisted. Instead of being commended for saving so much money, I was reprimanded.

When the researchers were asking about sources of information, the same person referred back to this story, saying that the reason he first found out about the problem was he got a call from a friend in the field asking him if the new order to throw away those boards was right.

As with the Chiefs in the shops, the engineers relied on informal communication to stay current as well as to find necessary data. One told of the need to find the fuel consumption of an engine under different conditions. He made a call and found out the information quickly. Looking it up or calculating it would have taken days.

The engineers seemed to express a greater sense of isolation from the repair facilities. As the engineers tended to have longer job tenure and budget cutbacks have eliminated programs that brought technicians to the depot level to meet and work with engineers, there are fewer people in the field who these engineers can call. Even when parts were returned to the depot level, these engineers did not do much of the repair work and do not interact with the base level shops. Management had not mentioned the group of depot level technicians during initial meetings. It was not until very late in the project that this additional group of workers was mentioned—another layer within the complex organization.

**Design Recommendations**

Based on the data collected, a set of functions was developed that attempted to answer the needs expressed and solutions expected by the target population. Having looked at the information and knowledge needs of the identified target population, it was clear that the immediate needs were not the reified, macro-level explicit knowledge targeted by the original portal designs. Instead, a much greater need was functions that allowed "matchmaking"—finding those within the organization who were assigned authority to allow changes or supply information. This knowledge was also explicit, macro-level information, but was not as easily available as data originally targeted (training manuals). The implicit information residing within the physical manuals would be better accessed if they remained as physical entities within labs. Indeed, the objects were knowledge sharing tools themselves, offering a place to make notes, offer suggestions via explicit means (notations, corrections on diagrams) and more implicit (used pages, pages in proximity) information.

A second area of need involved tools to support communication that would support the information knowledge sharing that occurred, with the ability to save and retrieve these information objects by others at other times.

Finally, providing those in the field and those at the depot level means for more free communication promised to provide extensive cost savings with both immediate returns and long-term value with capture of useful information. A "Hail a Tech" link to allow Chiefs at the shops to ask a depot level engineer or technician a question when they were stuck was estimated to provide substantial savings in the reduction of units sent back to the depot for unnecessary maintenance.

After developing the function set, a prototype was developed. A return trip to the base allowed the researchers to gain further input from target users and further refine and focus the design of the functions and the interface.

The prototype and the new design directions were presented to management at the end of the project. These recommendations were a significant departure from the course along which the group had been proceeding. Perhaps the largest difference was the idea that the system would start with minimal objects and would grow based on user input and requests. This necessitated establishing a librarian or gardener function (discussed previously) that would be available to find and add information as well as support the evolution of functions within the system.

During the discussion of the functions proposed, the technical director maintained silence. His view had remained, "Tell me what you want me to build and I'll build it." The questions from the CIO and the Chief who had funded the project revolved around what had already been built and what problems might be encountered with the new functions proposed. Rather suddenly, the directors realized the import and impact of the proposed functions. It was an "ah ha!" moment.

"Let me get this right," the CIO said. "You are telling us that what is important are new pieces created. That putting old pieces of information in the portal is not what is important."

"Putting in old pieces is only important if and when they are requested by users. Most important is to build a system that can respond to users as they input new and request old" was the reply.

"Then what you are telling us is that what we have been doing is wrong. We have been looking at existing documents and asking how to put them on the Web. You are saying the connection and communication is more important."

"Exactly!"

The tenor of the meeting and the tenor of the project changed at that moment. Discussions for the rest of the meeting focused on how to proceed not only with the immediate project, but how to operationalize this new approach.

**Performance support systems are specifically designed to provide information at the point of activity—to support practice. Practice must co-exist with all levels, so a system that is useful must be designed based on the needs of all levels.**

## Conclusions

The purpose of this paper was to report on a case study where the USE method was employed to develop a unique function set for a performance support system. These systems cross the boundaries of traditional interventions, gathering and sharing information from and to support performance on both the micro and macro level. Cook and Brown's view of knowledge as a generative dance (Cook & Brown, 1999), with the tension between knowledge in possession in all four "quadrants" brought into action through practice may provide an explanation for this. Performance support systems are specifically designed to provide information at the point of activity—to support practice. Practice must co-exist with all levels, so a system that is useful must be designed based on the needs of all levels. While a static, prebuilt intervention—be it training or support system, it is possible to apply a micro level solution to the meso or macro (although with substandard results). Conversely, a dynamic, growing system, such as a DOPSS must be designed from and for all levels. In order to effectively design these systems that are increasingly important within fast-changing jobs (especially in the information economy) we must have new tools for analysis. Schwen's (2001) knowledge model provides an essential new tool for ascertaining the needs of the target populations and allowing this new class of interventions to meet their needs in the initial design of function sets.

The design team, based on this analysis, postulated that the function sets will almost certainly be different for every group. The movement of Web services that are all things to all people is not useful here. These systems need to be personalized to the target population. The number within the population is not important. It may be dispersed physically and/or temporally. However, there must be a shared, homogenous information need; otherwise, focused function sets that will encourage adoption and use will be impossible. Our current work with labeling (meta tagging) for search and retrieval further supports this conclusion. Systems must be designed to encourage use, for what is the point of a technically wonderful system if is not useful for the target audience?

Schwen's (2001) knowledge model proved useful in guiding data collection and analysis. In addition, the researchers used the model to explain the project, process and findings to the clients. This was a significant advantage, as a great challenge in the implementation of DOPSS systems is justification of funds for design, development, and evolution. With organizations steeped in a static conception of knowledge, funds are assigned to build static warehouse-type systems. In a DOPSS system, where more analysis of end users is required during development and, more significantly, a new function of DOPSS keeper (librarian/gardener) is an ongoing expense, a new model to explain costs is necessary. Instead of valuing a system by how many objects are contained within, these new views of knowledge provide guidance to valuation based on use. If knowledge is created through the generative dance between practice and the knowledge held, then every time a DOPSS system is used, it is either supporting creation, storage, or sharing of knowledge. So, a use-based funding model provides a more accurate ROI.

## Implications

This study is a small case study conducted over a short period of time. It is but a first step in testing the USE model in the design of DOPSS systems. This particular study was further limited in that the system was not taken beyond the prototype phase. Internal priorities in the post 9/11 Navy precluded a continuation of the project. It is hoped that at some point in the future, this work can be continued to the implementation of the DOPSS so that the researchers and design team may study the efficacy of the initial function set and the evolution of the set with use.

As the USE model is tested with other organizations and by other designers, a richer understanding of its usefulness will be possible. As Schwen's (2001) knowledge model and others are employed, new applications will certainly suggest themselves.

These are but small initial steps, but viewing systems as dynamic, evolving based on use by users, viewing knowledge as an active process, and attempting to understand organizations and interventions with an awareness of the intended and actual level of impact certainly sets us on a path toward the design of implementations that answer the needs of a new age of work and workers.

## Acknowledgment

The first author wished to thank Joyce Beaver, Bob Miller and Mike Wise for their generous efforts during this project.

## References

Alexander, C. (1979). *The timeless way of building*. New York: Oxford University Press.

Alexander, C., Ishikawa, S., Silverstein, M., Jacobson, M., Fiksdahl-King, I., & Angel, S. (1977). *A pattern language*. New York: Oxford University Press.

Cook, S. D. N., & Brown, J. S. (1999). Bridging epistemologies: The Generative dance between organizational knowledge and organizational knowing. *Organization Science, 10*(4), 381- 400.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. London: Sage Publications.

Denzin, N. K., & Lincoln, Y. S. (2000). Introduction: The Discipline and practice of qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The handbook of qualitative research* (2nd ed., pp. 1-29). Thousand Oaks, CA: Sage Publications.

Drazin, R., Glynn, M. A., & Kazanijian, R. K. (1999). Multilevel theorizing about creativity in organizations: A Sensemaking perspective. *The Academy of Management Review, 24*(2), 286-307.

Gabriel, R. (1996). *Patterns of software: Tales from the software community*. Oxford: Oxford University Press.

Gilbert, T. F. (1996). *Human competence: Engineering worthy performance*. Silver Spring, MD: ISPI.

Hackos, J. T., & Redish, J. C. (1998). *User and task analysis for interface design*. New York: Wiley Computer Publishing.

Jonassen, D. H., Tessmer, M., & Hannum, W. H. (1999). *Task analysis methods for instructional design*. Mahwah, NJ: Lawrence Erlbaum Associates.

Morrison, J. B. (2002). *The right shock to initiate change: A Sensemaking perspective*. Paper presented at the Academy of Management, Denver, CO.

Petroski, H. (1994). *Design paradigms: Case histories of error and judgment in engineering*. Cambridge: Cambridge University Press.

Phillips, C. C., & Burbules, N. C. (2000). *Postpositivism and education research*. Lanham: Rowman & Lettlefield.

Rossett, A. (1996). Job aids and electronic performance support systems. In R. L. Craig (Ed.), *The ASTD training and development handbook* (4th ed., pp. 554-580). New York: McGraw-Hill.

Schneider, S. C. (1997). Interpretation in organizations: Sensemaking and strategy. *European Jouranal of Work and Organizational Psychology, 6*(1), 93-102.

Schwen, T. M. (2001). *The digital age: A Need for additional theory in instructional technology?* Guangzhou, China: South China Normal University.

Weick, K. E. (1995). *Sensemaking in organizations*. Thousand Oaks, CA: Sage.

Weick, K. E. (2001). *Making sense of the organization*. Oxford: Blackwell Publishers.

Yin, R. K. (2002). *Case study research: Design and methods* (3rd ed., Vol. 5). Newbury Park, CA: Sage Publications.

## STEVEN SCHATZ

Steve Schatz is an Assistant Professor of Educational Technology at the University of Hartford, coordinator of the Learning, Innovation, and

Performance Certificate program, and an independent consultant in instructional design, knowledge systems, and organizational learning. He is president elect of the Northern Connecticut Chapter of ISPI. His clients include Acer, AMD, Visa, Versity, and Coca-Cola. His writing has appeared in *Performance Improvement Quarterly*, *Performance Improvement*, and other academic journals. Chapters of his latest book are available at www.dopss.com and www.canteenconsulting.com. *Telephone*: (860) 768-4277. *E-mail*: schatz@hartford.edu

## THOMAS M. SCHWEN

Tom Schwen is Professor of Education and a member of the Graduate School faculty at Indiana University. He has consulted with several Fortune 500 Companies on matters of strategy, including training and performance improvement. *Mailing address*: W. W. Wright Education Building, Room 4064, Bloomington, IN 47405. *Telephone*: (812) 856-8469. *E-mail*: schwen@indiana.edu

PERFORMANCE IMPROVEMENT QUARTERLY, 19(2) PP. 211-230

# Chasing a Fault across Ship and Shore
## *Explaining the Context of Troubleshooting in the U.S. Navy*

*Michael A. Evans and Thomas M. Schwen*

Knowledge management (KM) in the U.S. Navy is championed as a strategic initiative to improve shipboard maintenance and troubleshooting at a distance. The approach requires capturing, coordinating, and distributing domain expertise in electronics and computer engineering via advanced information and communication technologies. Coordination must be achieved to ensure ship readiness. A potential challenge for human performance technologists is to develop robust theoretical frameworks to analyze and explain existing practice within this context. To illustrate, we present the case of U.S. naval sailors and civilian subject-matter experts (SMEs) collaboratively troubleshooting complex shipboard radar systems across ship and shore. Adapting perspectives from organizational theory, information science, and educational psychology, we conduct a multi-level analysis of the context of distributed knowledge and work. Findings suggest that regulative and normative restrictions, boundary spanners and objects, and disruption of coordination across system components influence practice substantively. Implications for research and practice, including a readdressing of the existing cannon of analytical frameworks are offered.

## Introduction

The U.S. Navy currently champions knowledge management (KM) as a strategic initiative to coordinate domain expertise and exploit advanced information technologies to improve the maintenance and troubleshooting performance of sailors and subject-matter experts (United States Department of the Navy, 2003; Venkatraman & Henderson, 1998). The approach entails capturing, coordinating, and distributing knowledge and work across technical communities, engaging individual, group, and organizational levels of the naval enterprise. At risk is the successful adoption and diffusion of radical socio-technical innovations in light of competing strategic initiatives (Abrahamson, 1991, 1996). One such initiative is *Optimal Manning*, referring to the process of reducing ships' forces to as much as one-fourth current numbers (personal communication, 2002). An identified conflict between KM and Optimal Manning is that a general reduction in forces inevitably results in the removal of experienced sailors and technicians from the field. Thus, a KM initiative may be deployed on a structure depleted of sought after expertise. Consequently, a challenge for human performance technologists is to develop robust theoretical frameworks to analyze work, and design new support systems within this overly complex scenario. Our approach entails examining the distribution of knowledge and work across functional units from multiple perspectives, focusing on expertise sharing that goes beyond traditional KM (Ackerman, Pipek, & Wolf, 2003; Naval Sea Systems Command, 2003). The approach is to draw theoretical concepts from organizational theory, information science, and educational psychology to investigate organizational, group, and individual issues of KM. The paper is organized as follows. First, we provide an overview of methodology and current organization for context. Second, we propose selected theoretical frameworks to analyze knowledge and work from multiple levels. Third, we analyze excerpts drawn from a larger case study of distributed troubleshooting (Evans, 2004) using these frameworks.