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Scenario-Based Usability Engineering

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Chapter 3

Analyzing Requirements

Making work visible. The end goal of requirements analysis can be elusive when work is not understood in the same way by all participants. Blomberg, Suchman, and Trigg describe this problem in their exploration of image-processing services for a law firm. Initial studies of attorneys produced a rich analysis of their document processing needs—for any legal proceeding, documents often numbering in the thousands are identified as "responsive" (relevant to the case) by junior attorneys, in order to be submitted for review by the opposing side. Each page of these documents is given a unique number for subsequent retrieval. An online retrieval index is created by litigation support workers; the index encodes document attributes such as date, sender, recipient, and type. The attorneys assumed that their job (making the subjective relevance decisions) would be facilitated by image processing that encodes a documents's objective attributes (e.g., date, sender). However, studies of actual document processing revealed activities that were not objective at all, but rather relied on the informed judgment of the support staff. Something as simple as a document date was often ambiguous, because it might display the date it was written, signed, and/or delivered; the date encoded required understanding the document's content and role in a case. Even determining what constituted a document required judgment, as papers came with attachments and no indication of beginning or end. Taking the perspective of the support staff revealed knowledge-based activities that were invisible to the attorneys, but that had critical limiting implications for the role of image-processing technologies (see Blomberg, 1995).

What is Requirements Analysis?

The purpose of *requirements analysis* is to expose the needs of the current situation with respect to a proposed system or technology. The analysis begins with a mission statement or orienting goals, and produces a rich description of current activities that will motivate and guide subsequent development. In the legal office case described above, the orienting mission was possible applications of image processing technology; the rich description included a view of case processing from both the lawyers' and the support staffs' perspectives. Usability engineers contribute to this process by analyzing what and how features of workers' tasks and their work situation are contributing to problems or successes[1]. This analysis of the difficulties or opportunities forms a central piece of the requirements for the system under development: at the minimum, a project team expects to enhance existing work practices. Other requirements may arise from issues unrelated to use, for example hardware cost, development schedule, or marketing strategies. However these pragmatic issues are beyond the scope of this textbook. Our focus is on analyzing the requirements of an existing work setting and of the workers who populate it.

Understanding Work

What is work? If you were to query a banker about her work, you would probably get a list of things she does on a typical day, perhaps a description of relevant information or tools, and maybe a summary of other individuals she answers to or makes requests of. At the least, describing work means describing the *activities, artifacts* (data, documents, tools), and *social context* (organization, roles, dependencies) of a workplace. No single observation or interview technique will be sufficient to develop a complete analysis; different methods will be useful for different purposes.

Tradeoff 3.1: Analyzing tasks into hierarchies of sub-tasks and decision rules brings order to a problem domain, BUT tasks are meaningful only in light of organizational goals and activities.

A popular approach to analyzing the complex activities that comprise work is to enumerate and organize tasks and subtasks within a hierarchy (Johnson, 1995). A banker might indicate that the task of "reviewing my accounts" consists of the subtasks "looking over the account list", "noting accounts with recent activity", and "opening and reviewing active accounts". Each of these sub-tasks in turn can decomposed more finely, perhaps to the level of individual actions such as picking up or filing a particular document. Some of the tasks will include decision-making, such

[1] In this discussion we use "work" to refer broadly to the goal-directed activities that take place in the problem domain. In some cases, this may involve leisure or educational activities, but in general the same methods can be applied to any situation with established practices.

as when the banker decides whether or not to open up a specific account based on its level of activity.

A strength of task analysis is its step-by-step transformation of a complex space of activities into an organized set of choices and actions. This allows a requirements analyst to examine the task's structure for completeness, complexity, inconsistencies, and so on. However the goal of systematic decomposition can also be problematic, if analysts become consumed by representing task elements, step sequences, and decision rules. Individual tasks must be understood within the larger context of work; over-emphasizing the steps of a task can cause analysts to miss the forest for the trees. To truly understand the task of reviewing accounts a usability engineer must learn who is responsible for ensuring that accounts are up to date, how account access is authorized and managed, and so on.

The context of work includes the *physical, organizational, social,* and *cultural* relationships that make up the work environment. Actions in a workplace do not take place in a vacuum; individual tasks are motivated by goals, which in turn are part of larger activities motivated by the organizations and cultures in which the work takes place (see *Activities of a Health Care Center,* below). A banker may report that she is reviewing accounts, but from the perspective of the banking organization she is "providing customer service" or perhaps "increasing return on investment". Many individuals — secretaries, data-entry personnel, database programmers, executives — work with the banker to achieve these high-level objectives. They collaborate though interactions with shared tools and information; this collaboration is shaped not only by the tools that they use, but also by the participants' shared understanding of the bank's *business practice* — its goals, policies, and procedures.

Tradeoff 3.2: Task information and procedures are externalized in artifacts, BUT the impact of these artifacts on work is apparent only in studying their use.

A valuable source of information about work practices is the *artifacts* used to support task goals (Carroll & Campbell, 1989). An artifact is simply a designed object — in an office setting, it might be a paper form, a pencil, an in-basket, or a piece of computer software. It is simple and fun to collect artifacts and analyze their characteristics (Norman, 1990). Consider the shape of a pencil: it conveys a great deal about the size and grasping features of the humans who use it; pencil designers will succeed to a great extent by giving their new designs the physical characteristics of pencils that have been used for years. But artifacts are just part of the picture. Even an object as simple as a pencil must be analyzed as part of a real world activity, an activity that may introduce concerns such as erasability (elementary school use), sharpness (architecture firm drawings), name-brands (pre-teen status brokering), cost (office supplies accounting), and so on.

Usability engineers have adapted ethnographic techniques to analyze the diverse factors influencing work. *Ethnography* refers to methods developed within anthropology for gaining insights into the life experiences of individuals whose everyday reality is vastly different from the analyst's (Blomberg, 1990). Ethnographers typically become intensely involved in their study of a group's culture and activities, often to the point of becoming members themselves. As used by HCI and system design communities, ethnography involves observations and interviews of work groups in their natural setting, as well as collection and analysis of work artifacts (see *Team Work in Air Traffic Control*, below). These studies are often carried out in an iterative fashion, where the interpretation of one set of data raises questions or possibilities that may be pursued more directly in follow-up observations and interviews.

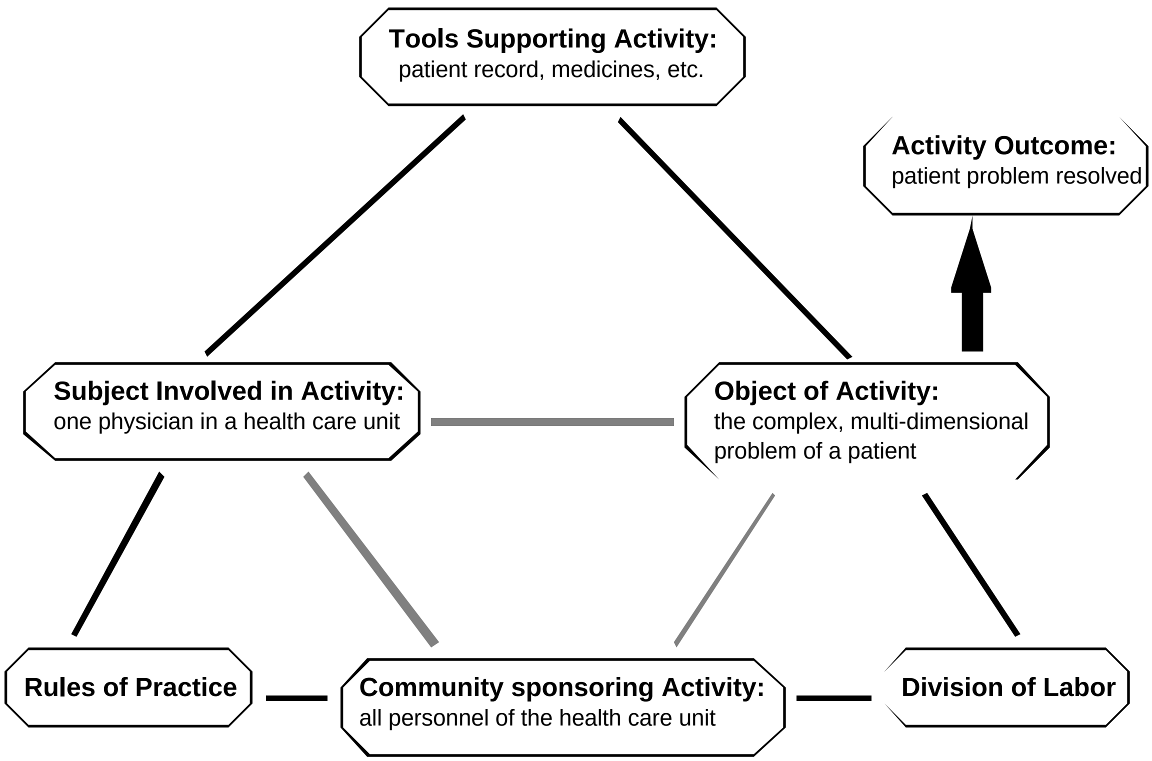


Figure 3.1: Activity Theory Analysis of a Health Care Center (after Kuuiti and Arvonen, 1992)

Activities of a Health Care Center: Activity Theory (AT) offers a view of individual work that grounds it in the goals and practices of the community within which the work takes place. Engeström (1987) describes how an individual (the subject) works on a problem (the object) to achieve a result (the outcome), but that the work on the problem is mediated by the tools available (see Figure 3.2m). An individual's work is also mediated by the rules of practice shared within her community; the object of her work is mediated by that same communities division of labor.

Kuutti and Arvonen (1992; see also Engeström 1990; 1991; 1993) applied this framework to their studies of a health care organization in Espoo, Finland. This organization wished to evolve from a rather bureaucratic organization with strong separations between its various units (e.g., social work, clinics, hospital) to a more service-oriented organization. A key assumption in doing this was that the different units shared a common general object of work—the "life processes" of the town's citizens. This high-level goal was acknowledged to be a complex problem requiring the integrated services of complementary health care units.

The diagram in Figure 3.1 summarizes an AT analysis developed for one physician in a clinic. The analysis records the shared object (the health conditions of a patient). At the same time it shows this physician's membership in a *subcommunity*, specifically the personnel at her clinic. This clinic is both geographically and functionally separated from other health care units, such as the hospital or the social work office. The tools that the physician uses in her work, the rules that govern her actions, and her understanding of her goals are mediated by her clinic. As a result, she has no way of analyzing or finding out about other dimensions of this patient's problems, for example the home life problems being followed by a social worker, or emotional problems under treatment by psychiatric personnel. In AT such obstacles are identified as *contradictions* which must be resolved before the activity can be successful.

In this case, a new view of community was developed for the activity. For each patient, email or telephone was used to instantiate a new community, comprised of individuals as relevant from different health units. Of course the creation of a more differentiated community required negotiation concerning the division of labor (e.g. who will contact whom and for what purpose), and rules of action (e.g., what should be done and in what order). Finally, new tools (composite records, a "master plan") were constructed that better supported the redefined activity.

Figure 3.2 will appear here, a copy of the figure provided by Hughes et al. in their ethnographic report. Need to get copyright permission.

Team Work in Air Traffic Control: An ethnographic study of British air traffic control rooms by Hughes, Randall and Shapiro (CSCW'92) highlighted the central role played by the paper strips used to chart the progress of individual flights. In this study the field workers immersed themselves in the work of air traffic controllers for several months. During this time they observed the activity in the control rooms and talked to the staff; they also discussed with the staff the observations they were collecting and their interpretation of these data.

The general goal of the ethnography was to analyze the social organization of the work in the air traffic control rooms. In this the researchers showed how the flight progress strips supported "individuation", such that each controller knew what their job was in any given situation, but also how their tasks were interdependent with the tasks of others. The resulting division of labor was accomplished in a smooth fashion because the controllers had shared knowledge of what the strips indicated, and were able to take on and hand off tasks as needed, and to recognize and address problems that arose.

Each strip displays an airplane's ID and aircraft type; its current level, heading, and airspeed; its planned flight path, navigation points on route, estimated arrival at these points; and departure and destination airports (see Figure 3.2). However a strip is more than an information display. The strips are *work sites*, used to initiate and perform control tasks. Strips are printed from the online database, but then annotated as flight events transpire. This creates a public history; any controller can use a strip to reconstruct a "trajectory" of what the team has done with a flight. The strips are used in conjunction with the overview offered by radar to spot exceptions or problems to standard ordering and arrangement of traffic. An individual strip gets "messy" to the extent it has deviated from the norm, so a set of strips serves as a sort of proxy for the orderliness of the skies.

The team interacts through the strips. Once a strip is printed and its initial data verified, it is placed in a holder color-coded for its direction. It may then be marked up by different controllers, each using a different ink color; problems or deviations are signaled by moving a strip out of alignment, so that visual scanning detects problem flights. This has important social consequences for the active controller responsible for a flight. She knows that other team members are aware of the flight's situation and can be consulted; who if anyone has noted specific issues with the flight; if a particularly difficult problem arises it can be passed on to the team leader without a lot of explanation; and so on.

The ethnographic analysis documented the complex tasks that revolved around the flight control strips. At the same time it made clear the constraints of these manually-created and maintained records. However a particularly compelling element of the situation was the controllers' *trust* in the information on the strips. This was due not to the strips' physical characteristics, but rather to the social process they enable—the strips are public, and staying on top of each others' problem flights, discussing them informally while working or during breaks, is taken for granted. Any computerized replacement of the strips must support not just management of flight information, but also the social fabric of the work that engenders confidence in the information displayed.

User Involvement

Who are a system's target users? Clearly this is a critical question for a user-centered development process. It first comes up during requirements analysis, when the team is seeking to identify a target population(s), so as to focus in on the activities that will suggest problems and concerns. Managers or corporation executives are a good source of high-level needs statements (e.g., reduce data-processing errors, integrate billing and accounting). Such individuals also have a well-organized view of their subordinates' responsibilities , and of the conditions under which various tasks are completed. Because of the hierarchical nature of most organizations, such individuals are usually easily to identify and comprise a relatively small set. Unfortunately if a requirements team accepts these requirements too readily, they may miss the more detailed and situation-specific needs of the individuals who will use a new system in their daily work.

Tradeoff 3.3: Management understands the high-level requirements for a system, BUT is often unaware of workers' detailed needs and preferences.

Every system development situation includes multiple *stakeholders* (Checklund, 1981). Individuals in management positions may have authorized a system's purchase or development; workers with a range of job responsibilities will actually use the system; others may benefit only indirectly from the tasks a system supports. Each set of stakeholders has its own set of motivations and problems that the new system might address (e.g., productivity, satisfaction, ease of learning). What's more, none of them can adequately communicate the perspectives of the others — despite the best of intentions, many details of a subordinate's work activities and concerns are invisible to those in supervisory roles. Clearly what is needed in requirements analysis is a broad-based approach that incorporates diverse stakeholder groups into the observation and interviewing activities.

Tradeoff 3.4: Workers can describe their tasks, BUT work is full of exceptions, and the knowledge for managing exceptions is often tacit and difficult to externalize.

But do users really understand their own work? We made the point above that a narrow focus on the steps of a task might cause analysts to miss important workplace context factors. An analogous point holds with respect to interviews or discussions with users. Humans are remarkably good (and reliable) at "rationalizing" their behaivor (Ericsson & Simon, 1992). Reports of work practices are no exception — when asked workers will usually first describe a most-likely version of a task. If an established "procedures manual" or other policy document exists, the activities described by experienced workers will mirror the official procedures and policies. However this officially-blessed knowledge is only part of the picture. An experienced worker will also have considerable "unofficial" knowledge acquired through years of encountering and dealing with the specific needs of different situations, with exceptions, with particular individuals who are part of the process, and so on. This expertise is often *tacit*, in that the knowledgeable individuals often don't even realize what they "know" until confronted with their own behavior or interviewed with situation-specific probes (see *Tacit Knowledge in Telephone Trouble-Shooting*, below). From the perspective of requirements analysis, however, tacit knowledge about work can be critical, as it often contains the "fixes" or "enhancements" that have developed informally to address the problems or opportunities of day-to-day work.

One effective technique for probing workers' conscious and unconscious knowledge is *contextual inquiry* (Beyers & Holtzblatt, 1994). This analysis method is similar to ethnography, in that it involves the observation of individuals in the context of their normal work environment. However it includes the perogative to interrupt an observed activity at points that seem informative (e.g., when a problematic situation arises) and to interview the affected individual(s) on the spot concerning the events that have been observed, to better understand causal factors and options for continuing the activity. For example, a usability engineer who saw a secretary stop working on a memo to make a phone call to another secretary, might ask her afterwards to explain what had just happened between her and her co-worker.

Tacit Knowledge in Telephone Trouble-Shooting: It is common for workers to see their conversations and interactions with each other as a social aspect of work that is enjoyable but unrelated to work goals. Sachs (199x) observed this in her case study of telephony workers in a phone company. The study analyzed the work processes related to detecting, submitting, and resolving problems on telephone lines; the focus of the study was the Trouble Ticketing System (TTS), a large database used to record telephone line problems, assign problems (tickets) to engineers for correction, and keep records of problems detected and resolved.

Sachs argues that TTS takes an organizational view of work, treating work tasks as modular and well-defined: one worker finds a problem, submits it to the database, TTS assigns it to the engineer at the relevant site, that engineer picks up the ticket, fixes the problem, and moves on. The original worker is freed from the problem analysis task once the original ticket, and the second worker can move on once the problem has been addressed. TTS replaced a manual system in which workers contacted each other directly over the phone, often working together to resolve a problem. TTS was designed to make work more efficient by eliminating unnecessary phone conversations.

In her interviews with telephony veterans, Sachs discovered that the phone conversations were far from unnecessary. The initiation, conduct, and consequences of these conversations reflected a wealth of tacit knowledge on the part of the worker--selecting the right person to call (one known to have relevant expertise for this apparent problem), the “filling in” on what the first worker had or had not determined or tried to this point, sharing of hypotheses and testing methods, iterating together through tests and results, and carrying the results of this informal analysis into other possibly related problem areas. In fact, TTS had made work less efficient in many cases, because in order to do a competent job, engineers developed “workarounds” wherein they used phone conversations as they had in the past, then used TTS to document the process afterwards.

Of interest was that the telephony workers were not at first aware of how much knowledge of trouble-shooting they were applying to their jobs. They described the tasks as they understood them from company policy and procedures. Only after considerable data collection and discussion did they recognize that their jobs included the skills to navigate and draw upon a rich organizational network of colleagues. In further work Sachs helped the phone company to develop a fix for the observed workarounds in the form of a new organizational role: a “turf coordinator”, a senior engineer responsible for identifying and coordinating the temporary network of workers needed to collaborate on trouble-shooting a problem. As a result of Sach’s analysis, work that had been tacit and informal was elevated to an explicit business responsibility.

Requirements Analysis with Scenarios

As introduced in Chapter 2, requirements refers to the first phase of SBUE. As we also have emphasized, requirements cannot be analyzed all at once in waterfall fashion. However some analysis must happen early on to get the ball rolling. User interaction scenarios play an important role in these early analysis activities. When analysts are observing workers in the world, they are collecting *observed scenarios*, episodes of actual interaction among workers that may or may not involve technology. The analysis goal is to produce a summary that captures the critical aspects of the observed activities. A central piece of this summary analysis is a set of *requirements scenarios.*

The development of requirements scenarios begins with determining who are the *stakeholders* in a work situation — what their roles and motivations are, what characteristics they possess that might influence reactions to new technology. A description of these stakeholders' work *practice* is then created, through a combination of workplace observation and generation of hypothetical situations. These sources of data are summarized and combined to generate the requirements scenarios. A final step is to call out the most critical features of the scenarios, along with hypotheses about the positive or negative consequences that these features seem to be having on the work setting.

Introducing the Virtual Science Fair Example Case

The methods of SBUE will be introduced with reference to a single open-ended example problem, the design of a *virtual science fair* (VSF). The high-level concept is to use computer-mediated communication technology (e.g., email, online chat, discussion forums, videoconferencing) and online archives (e.g., databases, digital libraries) to supplement the traditional physical science fairs. Such fairs typically involve student creation of science projects over a period of months. The projects are then exhibited and judged at the science fair event. We begin with a very loose concept of what a virtual version of such a fair might be — not a replacement of current fairs, but rather a supplement that expands the boundaries of what might constitute participation, project construction, project exhibits, judging, and so on.

Stakeholder Analysis

Checklund (1981) offers a mnemonic for guiding development of an early shared vision of a system's goals — CATWOE analysis. CATWOE elements include *Clients* (those people who will benefit or suffer from the system), *Actors* (those who interact with the system), a *Transformation* (the basic purpose of the system), a *Weltanschauung* (the world view promoted by the system), Owners (the individuals commissioning or authorizing the system), and the Environment (physical constraints on the system). SBUE adapts Checklund's technique as an aid in identifying and organizing the concerns of various stakeholders during requirements analysis.The SBUE adaptation of Checklund's technique includes the development of thumbnail scenarios for each element identified. The table includes just one example for each VSF element called out in the analysis; for a complex situation multiple thumbnails might be needed. Each scenario sketch is a usage-oriented elaboration of the element itself; the sketch is points to a future situation in which a possible benefit, interaction, environmental constraint, etc., is realized. Thus the client thumbnails emphasize hoped-for benefits of the VSF; the actor thumbnails suggest a few interaction variations anticipated for different stakeholders. The thumbnail scenarios generated in this analysis are not yet design scenarios, they simply allow the analyst to begin to explore the space of user groups, motivations, and pragmatic constraints.

The CATWOE thumbnail scenarios begin the iterative process of identifying and analyzing the background, motivations, and preferences that different user groups will bring to the use of the target system. This initial picture will be elaborated throughout the development process, through analysis of both existing and envisioned usage situations.

CATWOE Element	VSF Element	Thumbnail Scenarios
Clients	Students	A high school student learns about road-bed coatings from a retired civil engineer.
	Community members	A busy housewife helps a middle school student organize her bibliographic information.
Actors	Students	A student imports an Excel spreadsheet containing her analysis of acid rainfall.
	Teachers	A teacher checks over the 10 projects underway by students in her class.
	Community members	A retired pharmicist hears about the VSF over email and visits it for the first time.
Transformation	Ongoing community-wide access to student projects	A student browses comments left by his friends, his father, and his former Boy Scout leader.
Weltanschauung	Learning benefits from community involvement	After exhibiting a project on heat transfer, two students show up at a town meeting to discuss concerns about the new school.
Owners	School district	At a regional meeting, the school district reports on the number of visitors and comments contributed to the online fair.
Environment	Computer labs	Several students stay after school and work on their separate projects together in the lab, chatting while they work.
	T1 lines to public meeting places (e.g., library)	A regular user of the town library sits down at the public terminal for the first time and is drawn into the online fair.
	Home modems	A mother logs on after dinner to visit with her friends and check in on her son's project.

Table 3.1: Catwoe Elements and Stakeholder Thumbnail Scenarios for Science Fair

Observing Current Practice

The CATWOE analysis sets the scene for the study of current practice. With a shared understanding of major stakeholders and general project goals, the team can begin to analyze the activities that will be transformed by the system. In doing so, attention should be given to the needs and concerns of all parties. In the case of our VSF example, this implies analysis of students, teachers, community members, and the school organization. Although the CATWOE analysis is intended as a scoping and planning aid, note that new stakeholders, motivations, or environmental factors may emerge through these studies of practice.

Preparing for Data Collection

The CATWOE analysis is just one initial activity that is useful in preparing for data collection. The process of identifying stakeholders and discussing orienting goals will raise many questions about the situation a team hopes to impact. For the VSF, the analysts might wonder what sorts of projects students currently develop and exhibit, what resources they draw on for project development, how the projects are exhibited and judged, how and when parents contribute to project work, and so on. These sorts of *scoping discussions* serve an orienting role, and for new teams can help group members learn about one another — personal background, interests, biases, as well as skills and aptitudes.

Guide for Interviewing Student-Participants in a Science Fair
Remember that our goal is to understand *how* and *why* students participate in the science fair. We want to know the things they do as part of the fair, and the sorts of resources (both physical and human) they use. We also want to learn something about the individuals we talk to—their history, and especially their use of or reactions to technology associated with science fairs.
Open-ended prompts (follow the interviewee's lead):
How long have you been in science fairs; have you exhibited before?
How did you get involved in this year's fair?
Tell me about your exhibit; can you show it to me? What did you do create it?
Did anyone else work with you on this project? How?
Tell me about the other people you have interacted with as part of the fair.
How will (or has) the judging take place?
What do you like about this science fair (or about your exhibit)? What are you unhappy with?
Specific things we want to know (ask directly if they've not yet been covered):
What technology (computer or otherwise) have you used in this project?
What technology would you have liked to use if it was available?
What background do you have in using computers?
How could an expert from the community contribute to your science project?
How could your parents contribute?
Can you imagine an online version of this science fair? What would it be like?

Table 3.2: Interviewing Guide for Field Study of Science Fair

In addition to developing a shared understanding of project scope, the team must consider its own *organization.* It will help of one member takes on a leadership role, ensuring that decisions are made about activities to be carried out, a schedule is constructed, everyone understands his or her responsibilities, and so on. It may even be useful to have two types of leaders, one who attends mostly to the content and results of the analysis task, another who makes sure that everyone knows their role, stays on schedule, and so on. Other team members can take on the job of identifying and making contact with individuals will to be observed or interviewed. Others can focus on creating and assembling an interviewing guide and data capture tools.

An *interviewing guide* should be created that will support but not over-constrain how team members observe and question individuals in the work setting. It may be necessary to produce different guides for different stakeholder representatives. The guide should begin with an introduction that reminds the interviewer of what he or she hopes to accomplish in the questioning. Because the goal is to learn what the participants think about their own activities, the guide should not suggest specific and pointed questions early in the interview. Instead, begin with open-ended prompts that ascertain the interviewee's general background and how they think about their work ("tell me about what you do"). List specific questions that emerge from group brainstorming at the end, so that the interviewers will be certain to address these issues if they are not raised by the interviewee. A guide for talking to student participants in a science fair appears in Table 3.2.

In addition to preparing an interviewing guide(s), the team must decide how to document their observations. If the work setting involves considerable physical manipulation of objects, a videotape may be helpful (though you should first check with participants to see if they are comfortable with this). Otherwise, a small tape recorder might be used to record conversations. In either case, plan in advance how you will use the recording equipment (e.g., where you will place the camera(s) or the microphone, how many tapes you will need), and be sure to get participants' permission.   It may also be useful to bring along a camera to capture interesting visual elements of the situation. Finally, one or more team members should be assigned the job of taking detailed written notes. Be very clear that all recordings, photos, or notes will be treated *confidentially*, reviewed and discussed only by your analysis team.

Observations, Interviews, and Artifacts

An important element of successful workplace studies is creating a comfortable relationship between the team and the workplace participants. In some settings, workers may have been selected by management and may be resentful at having to spend time with outsiders observing and interviewing them about their activities. In others, participation may be voluntary, but they may be intimidated by the thought of interacting with "technology-savvy" individuals. The team must be sensitive to social factors like this and focus first on establishing a friendly and non-judgmental tone to the exchange.

Figure 3.3, a photograph of a science fair in progess will appear here. It shows a student demonstrating an exhibit to a small group of visitors. It has not been included in this file because it is a color photo and makes the file too big! If you are interested, there is a link to it on the class website.

Whenever possible, visit a workplace instead of bringing participants to you. This puts the burden on you rather than the individuals you are studying, as well as giving you the opportunity to observe authentic work activities. If there is time and a participant is willing, observe her as she carries out one or more typical tasks. If you are collecting video or audio tape, remember to get the participant's permission before turning it on, and be sure to identify the tape with date, time, place, and participant. Take notes conscientiously, writing down everything that happens, not just things that catch your attention. If something happens that you cannot understand, or if task details aren't apparent (e.g., a computer activities that involve a sequence of data or procedures), interrupt briefly, just enough to get a summary of what is happening. After the observation period, interview the participant according to the guide developed in advance. Prior to launching into the material in your guide, ask the participant to comment on what they have just been doing; this provides a seamless transition from the observation period to the interview.

The photo in Figure 3.3 was taken during a visit to a science fair and documents interesting elements of current science fairs. For example, the student is using a computer as part of his exhibit, and is showing his project to several people at the same time. The observers appear to be a family group, with members ranging in age from a small child to an adult. Also in the room are other non-computer artifacts, posters that have been pinned up on the walls; in the picture it isn't obvious what relation the posters have to the computer exhibits, but interviews with the students indicate that although only some projects have computer exhibits, all projects have a physical poster display.

The photo also displays various science fair *artifacts.* A science fair artifact is any resource that appears to play an important role in the task; it might be a computer program or data file, a poster, a registration or evaluation form, even a display stand. In some cases, these artifacts will be documented by videotapes or photographs; in other cases, the observation team will need to ask specifically for copies of relevant documents or other tools, or will simply make notes describing the object.

A process question for workplace studies concerns the amount of data to collect — how many visits and to how many different sites? Clearly this depends on the project's scope, with larger projects needing more analysis. As a rule of thumb, we recommend that you collect at least one set of observations and/or interview for each stakeholder group from your CATWOE analysis. For the VSF project, this means analyzing the science fair activities and perspectives of students, teachers, community members (including parents), and school administration.

Summarizing Workplace Data

The field observations and interviews should increase the project team's understanding of the *backgrounds*, *expectations,* and *preferences* of the stakeholders with respect to the technology that might be introduced into their workplace. The relevant data will have been obtained from a variety of sources: surveys or questionnaires administered in advance or after a visit, comments and behaviors of individuals, interviews, or public records of population characteristics. These data should be compiled to develop *user profiles* that will guide subsequent scenario development. A sample set of profiles for the VSF stakeholders appears in Table 3.3.

VSF Stakeholder	User Characteristics
Students	Background: mixture of experience with computing applications, ranging from extensive use of computer games and several years of programming to minimal keyboarding skills and basic use of office applications. Moderate to extensive experience with Web browsing, email, and Internet chat. Expectations: an online system should make construction of the exhibit easier and more fun. Likely to see the system as a variant of other (e.g., Web-based) hypermedia systems. Preferences: Most comfortable with PC-Windows platform, from either school or home setting. Enjoy multimedia systems, even when slow over a phone line or other low band-width connection.
Community members	Background: Bi-modal distribution with a few members having extensive computing experience through the work environment, and others with only modest (or no) exposure to email and a few Web applications. Many have visited their children's exhibits (not always science) in the past. Expectations: Many are unsure about how if at all they would contribute to creating a project, but able to imagine browsing exhibits online. No thoughts about encountering or talking to others while browsing the exhibits. Preferences: those with background are comfortable with AOL and similar ISP environments, generally on PC-Windows platform. Less patience than students for "fancy" graphics or multimedia. Want guides or help screens to work through new applications or services; willing to read manuals.
Teachers	Background: most are familiar with a range of computer applications, both Web-based browsing and discussion systems, as well as specialized courseware. A few have basic programming skills; most able to author documents in HTML and other hypermedia systems like PowerPoint. Expectations: online system will allow them to draw in other experts to guide students in projects, decreasing the general need for teacher-student interaction, allowing them to focus on special needs. Most expect Web-based authoring and browsing combined with email discussions with outside experts. Preferences: Mixture of PC and Mac users. Strong concerns about access rights and about ability to get overview information. Willing to work from online or written guides or reference material. Want example (starter) projects.
School administrators	Background: Familiar with Web-browsing, email, and standard office applications, especially word-processing and spreadsheet functions. Expectations: online system will increase visibility of science fair, create better connections between the school and the community. Emphasis will be on conveying to community the interesting things that students are doing. Like teachers, expect such a system to involve combination of Web and email. Preferences: Mixture of PC and Mac users. Concerned that system is state-of-the-art and attractive; will want to print colorful examples and summaries of the online materials to share with community groups and agencies.

Table 3.3: Stakeholder Profiles for the VSF

A second summary should be prepared for tasks that were observed or discussed. To do this, the team can begin with a list of tasks relevant to each stakeholder. For particularly complex or problematic tasks, it may be useful to develop a hierarchical task analysis to represent documenting a finer level of detail. A summary of the tasks of VSF stakeholders is in Table 3.4, with examples of hierarchical task analysis in Figure 3.4 (Figure 3.4a shows exhibit construction, Figure 3.4b shows exhibit judging).

VSF Stakeholder	Science Fair Tasks Observed or Discussed
Students	Reviewing participation requirements; Proposing a project; Carrying out the project; Constructing an exhibit; Demonstrating the project
Community members	Browsing projects at a fair; Interacting with students at their exhibits
Community members acting as judges	Volunteering to be a judge; Studying the evaluation form; Evaluating a specific project; Developing and reporting summary results
Teachers	Helping a student refine a proposal project; Providing pointers to resources and other information; Critiquing a student’s project in progress; Helping a student create an exhibit
School administrators	Recruiting volunteers to judge projects; Summarizing participation in fair; Highlighting winning projects in annual report; Specifying resources needed for next year’s fair; Acknowledging student and judge participation

Table 3.4: Science Fair Tasks Carried out by Stakeholders

In addition to field notes and interview data, the requirements team may have collected task artifacts—data files, forms, software, brochures, and so on. These artifacts can help to document the information needs of the tasks they serve. A form used to purchase something indicates what information is needed to specify the product, the buyer, the form of payment, and so on. A poster used to advertise an event shows what features of an event are important to the intended audience. The labels on file folders suggest categorical information that is used to organize task materials. Each artifact collected should be examined for such insights. Figure 3.5 shows two artifacts from a science fair, a publicity poster and a judging form.

Other artifacts from this domain might include the registration form used by students to enter their projects, newspaper notices recruiting volunteers to serve as judges and later announcing the winners, the instructions provided to judges and to student exhibitors, the exhibits themselves, the prize ribbons, even the thank-you notes sent by fair organizers to the volunteers helping to set up and judge the exhibits. The role of task artifacts in current practice can be summarized as shown in Table 3.5 for the poster and the judging form — both the information needs and the science fair procedures implied by these two documents have been listed. From the publicity perspective, we assume that the poster emphasizes what the organizers believes are the most important characteristics of the event to possible attendees. From the perspective of exhibit evaluation, the judges’ form likewise highlights the characteristics thought to determine the quality of the exhibits. Note that the insights garnered by studying these artifacts may or may not match those obtained through interviews or observations; as noted in the section on Understanding

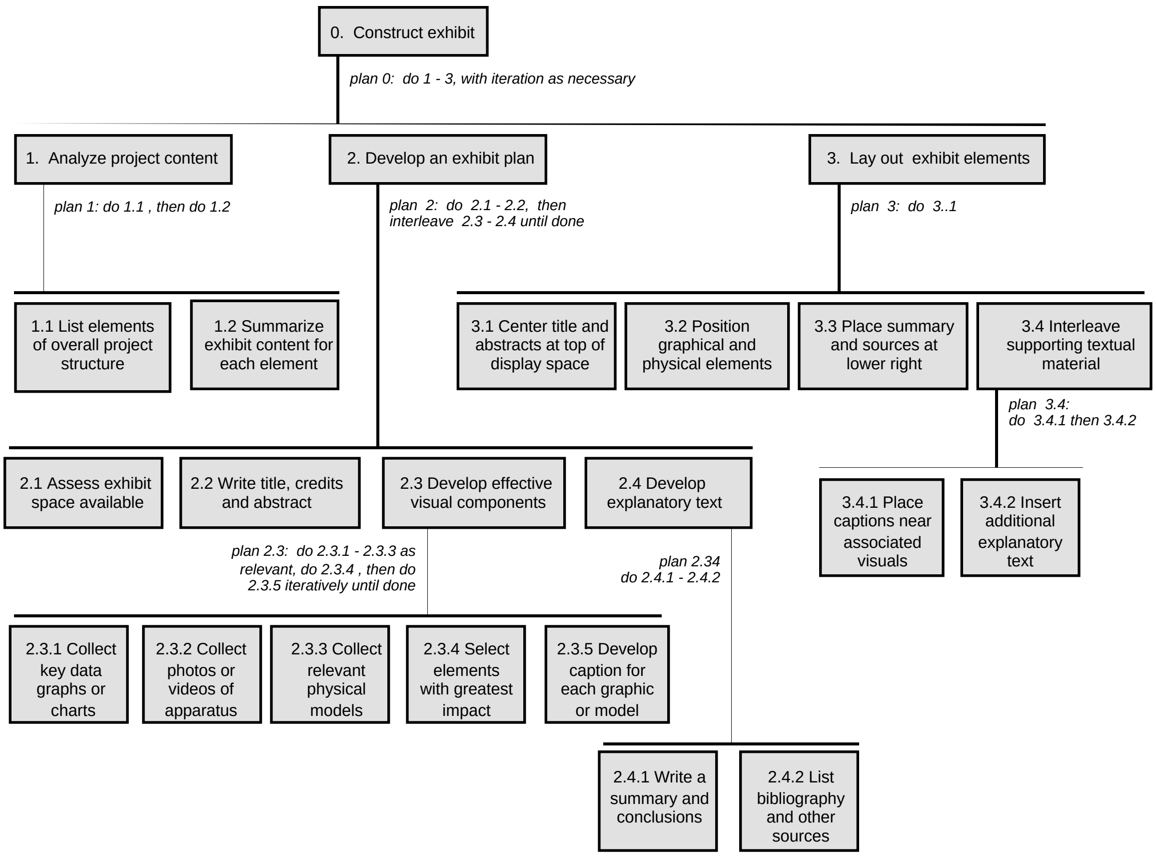


Figure 3.4a: Hierarchical task analysis for constructing an exhibit.

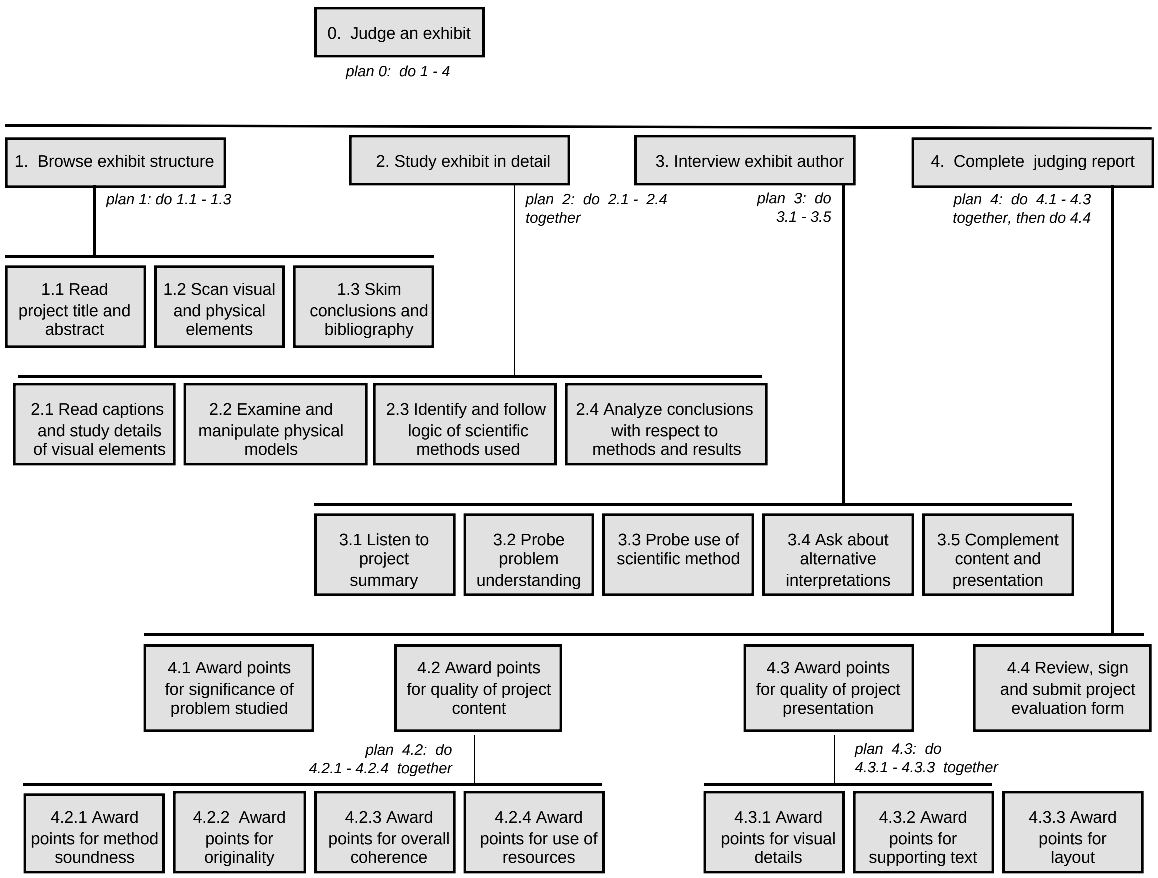
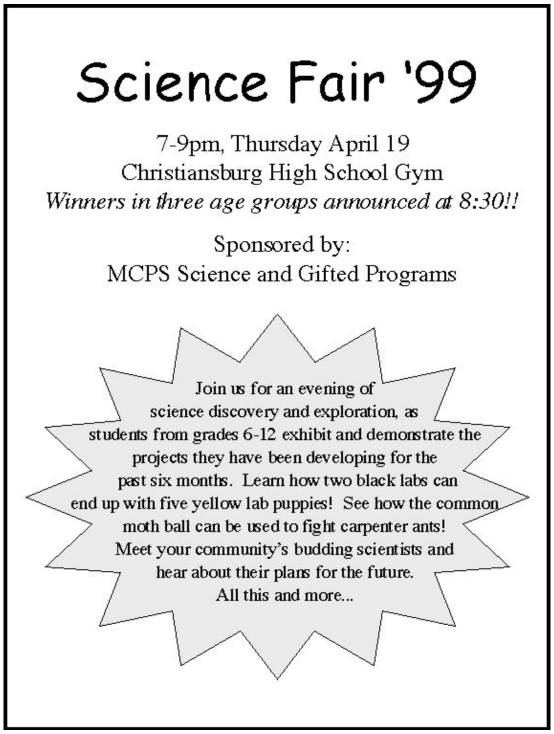
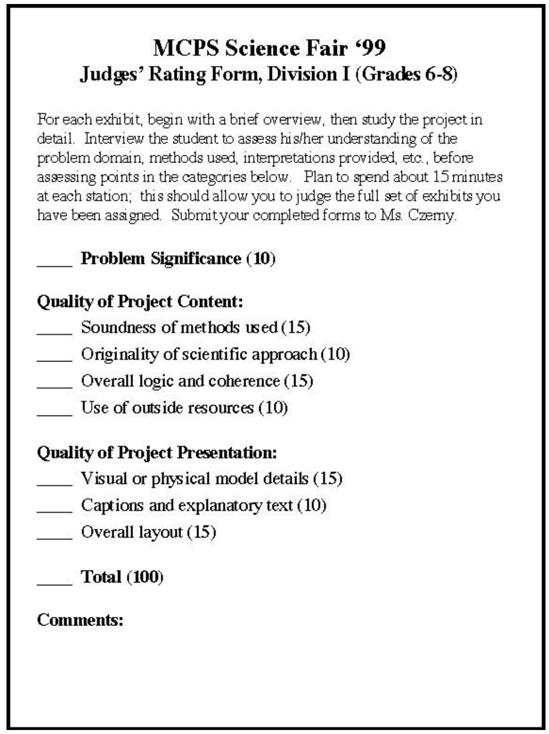


Figure 3.4b: Hierarchical task analysis for judging an exhibit.

Users, much of what participants know or experience in a situation is based on tacit knowledge, or is the result of other stakeholders' views and concerns.





MCPS Science Fair '99
Judges' Rating Form, Division I (Grades 6-8)

For each exhibit, begin with a brief overview, then study the project in detail. Interview the student to assess his/her understanding of the problem domain, methods used, interpretations provided, etc., before assessing points in the categories below. Plan to spend about 15 minutes at each station; this should allow you to judge the full set of exhibits you have been assigned. Submit your completed forms to Ms. Czerny.

____ **Problem Significance (10)**

Quality of Project Content:
____ Soundness of methods used (15)
____ Originality of scientific approach (10)
____ Overall logic and coherence (15)
____ Use of outside resources (10)

Quality of Project Presentation:
____ Visual or physical model details (15)
____ Captions and explanatory text (10)
____ Overall layout (15)

____ **Total (100)**

Comments:

Figure 3.5: Sample artifacts from a science fair.

Science Fair Artifact	Implied Information Needs and Procedures
Fair publicity poster	Information: When and where fair is held; sponsoring organization; time when winning exhibits announced; sample projects; contact information Procedures: fair lasts about 2 hours; judging takes about 1.5 hours; projects take up to 6 months to complete; exhibits are entered and judged in three age-level groupings
Judging form	Information: judging may be age-level specific; exhibits are judged on three major dimensions; quality is a complex judgement broken into sub-categories; Ms. Czerny is the head judge who compiles the separate results Procedures: personal contact with students helps to assess project significance and quality; exhibits are judged in about 15 minutes; forms are not to be submitted until all judging is completed

Table 3.5: Information and Procedures implied by Poster and Judges' Form

The analysis of stakeholder groups, tasks, and artifacts, focuses on individual elements of the current situation. This helps a team organize their observations, but can also direct attention away from the social context in which the activities take place, the network of interdependencies among stakeholders and their roles in the workplace. One way to summarize this is to create a *stakeholder diagram* that conveys how the stakeholders are interdependent on one another. Figure 3.6 presents such a diagram for the science fair. For example, we see that one role of students in the science fair is to create projects that community members will browse and perhaps judge. These relationships can then be analyzed to understand the impact one group of participants has on others. For instance the number of projects developed for the fair will have an impact on the community members who judge the exhibits — perhaps affecting how many judges will be needed, as well as the challenge and satisfaction of the evaluation process.

Another technique for grasping the big picture is to collect together related observations or problems into a set of *workplace themes*. Different stakeholders will focus on different aspects of the current situation (e.g., based on their particular motivations or backgrounds), but issues raised by different stakeholders (or at different times by the same stakeholder) will be related. To find a useful set of themes, write interesting comments or observations on index cards or post-it notes, and then carry out a collaborative grouping exercise where team members search for related points. In some cases an issue will fit in more than one category; this is fine, simply make some indication that multiple copies have been made. Once a theme has been suggested, test its usefulness by trying to name it — if you find yourself with too many “Miscellaneous” or “Other Problems” groups, your work is not done yet! Beyers and Holtzblatt (1998) use such techniques extensively to create *affinity diagrams*, which are then reviewed, discussed, and elaborated with participating stakeholders. Figure 3.7 shows some themes identified in analysis of current science fairs.

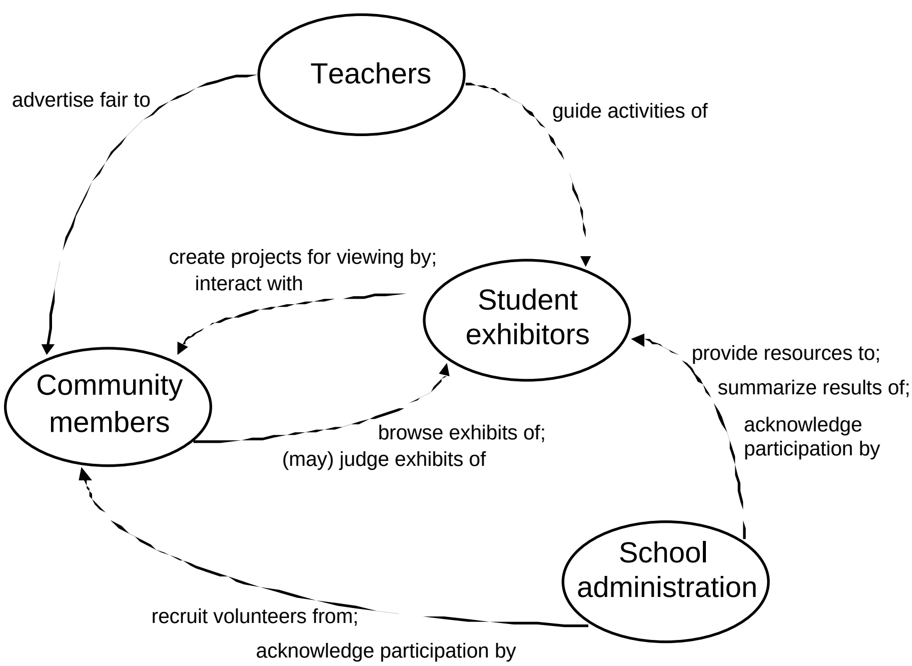


Figure 3.6: Roles and relations of stakeholders in science fair.

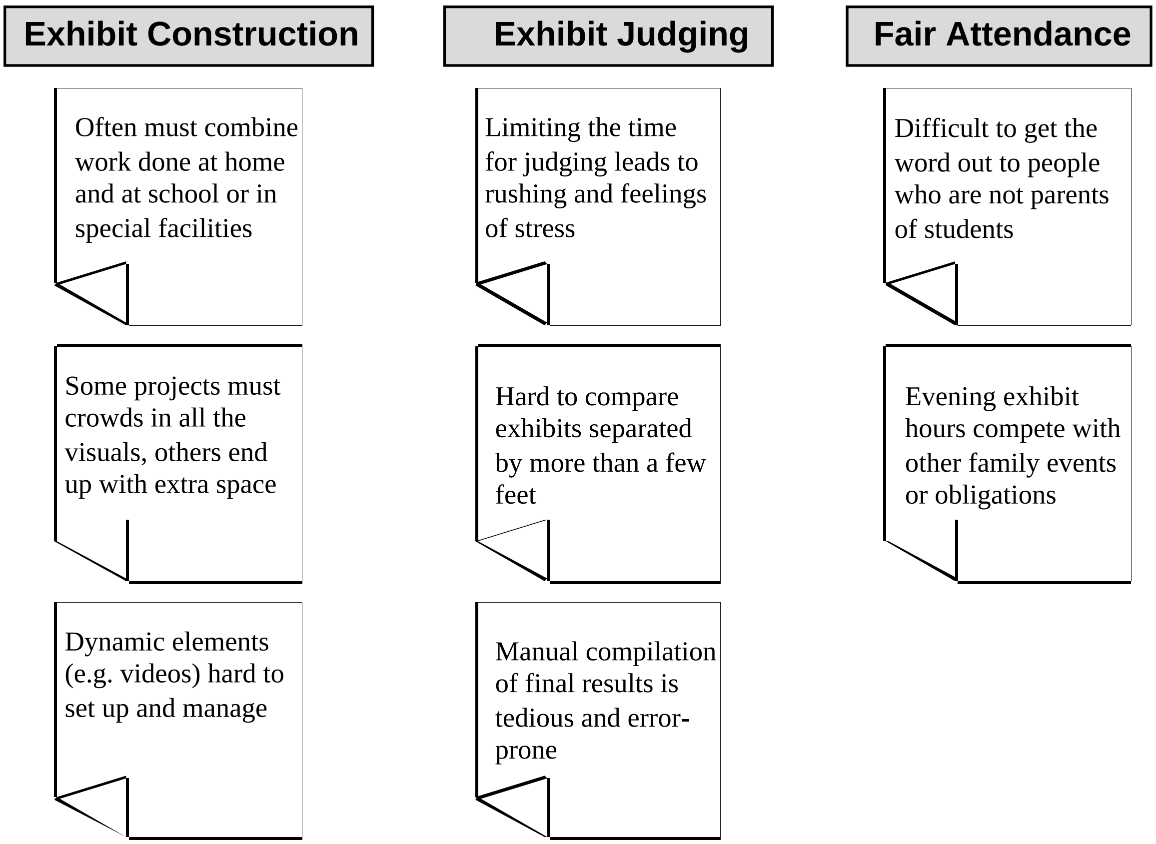


Figure 3.7: Themes summarizing issues raised in science fair study.

Developing Requirements Scenarios

User, task, artifact, roles, and theme analyses are the scaffolding from which requirements scenarios are synthesized. The goal of requirements scenarios is to express — in a condense and evocative fashion — the key understandings that the team has gained about the workplace. Other members of the development team (e.g., software engineers) should be able to read the scenarios and appreciate many of the work-related issues that your analysis has uncovered. Look across the perspectives generated by the user, task, artifact, and social foci and extract the issues that have the strongest implications (either opportunities or constraints) for design. Weave these issues together to build illustrative episodes of current practice.

Requirements Scenarios from the Science Fair
1) Ms. Smith helps Jeff plan his exhibit on heat transfer. Ms. Smith worked late on Monday evening so she'd have time to on Tuesday with Jeff, one of her top physics students, to help him plan his science fair exhibit. When she got to the lab, Jeff was already there and had blocked off a 6-foot rectangle on a lab table, simulating the space he'd get at the gym. He also had brought a sample poster board to use in laying out the three walls of the exhibit. They spent the first 20 minutes just listing possible project elements. Ms. Smith was impressed with the range of content Jeff had developed, including an extensive list of URLs on heat transfer, several charts graphing the effects of three different window coatings, and an Authorware simulation of heat diffusion. This last piece of the project concerned her, as last year there had been no computer hook-ups in the gym. But as usual, Jeff had already checked into this, and had gotten special permission to have this in his display, as long as he took responsibility for the set-up. As Ms. Smith checked through the visuals, she noticed that the captions for the color charts used a different font than those for the black-and-white drawings of his apparatus; Jeff explained that he had printed the former on his personal color printer at home, which has a different font set. Ms. Smith knew that the judges would notice even details like this, so she advised him to re-print the black-and-white drawings at home. They spent the rest of the time selecting and laying out the visuals that would make best use of the limited space.
2) .Mrs Sampson decides to go to the science fair. Mrs. Sampson's neighbor Jeff was in the science fair for the third time this year, and she really wanted to go, especially now that her seventh-grade daughter Erin seemed to be developing an interest in science. Jeff had mentioned the fair date, but she had forgotten about it until she saw the poster at Kroger's She mentioned her plan to her husband, who immediately reminded her that this overlaps with Billy's basketball game. They agreed to split their time that evening. On the night of the fair, her 5-year-old Christie decided she'd rather go with Mom than Dad and Billy, so the three of them headed off. But as soon as they got in the car, Christie started complaining that she never gets to do anything special on her own. Mrs. Sampson and Erin ignored her as much as they could, and started talking about who else might be exhibiting projects.
3) Jeff demonstrates his exhibit to Mrs. Sampson and her two daughters. When the Sampsons arrived at the fair, there were only a few other people around. They saw their neighbors, Jeff's parents, and a few other people they didn't recognize. Jeff's Mom chatted with them briefly, asking about Erin's summer plans, then summarizing some highlights of exhibits she'd seen so far. The Sampsons began browsing, starting on the right-hand side and working their way around, mostly just looking quickly and moving on, so they'd have time to see as much as possible. When they got to Jeff's exhibit, they stopped to talk to him, and he gave them his overview. Erin was very interested in his charts, and wanted to know just how he had gotten the data and graphed it, but Christie quickly became bored and started poking around at the computer on the table. Mrs. Sampson saw the list of URLs and thought Christie might want to look into them, so started copying them down; when Jeff saw this, he offered to print them out later and give her a copy. After the overview, Jeff started to show them the animation, but found that Christie had managed to crash the computer. While they were waiting for it to re-boot, Christie wondered whether there were any other exhibits related to heat transfer or building construction, but Jeff hadn't had time to look around, so didn't know.

4) Alisa judges the high school physics projects at the science fair.   For the last three years, Alisa—a retired civil engineer—has been a judge at the county science fair, so when the organizers contacted her, she readily agreed to do it again. In past years, she had occasionally been able to get advance information about the projects assigned to her, but this year the organizers had collected only titles and authors in advance. As in the past, she saw that she'd been given the high school physics projects, and knew she'd have to work fast to get all five evaluated in the 90 minutes allotted.   On the night of the fair, Alisa arrived promptly at 7pm, picked up her forms and began the process of studying the exhibits and interviewing the students. Her previous experience helped her to make the points assignment judgements, but as usual she found it hard to compare projects even within her set of five. At one point, she found she needed to evaluate two very nice projects in parallel, running back and forth comparing the details of the visuals and models, and annotating her scores with relative comparisons. She finally signed her forms and handed them in—she could tell she was almost the last to finish from the large stack of papers Ms. Czerny and her assistants were already compiling.
5) Superintendent Carlisle reports on th 1999 science fair to the school board.   School superintendent Mark Carlisle had heard wonderful reports about this year's science fair, so he decided to highlight it in next month's school board meeting. He wanted to do more than acknowledge the winners and the volunteers—he hoped that by giving the school board examples of the great work the students had done, he could make a case for increasing the resources allotted for extra-curricular activities such as this. He contacted Ms. Czerny, and asked her to collect sample materials from the best projects, so that he could construct a slide presentation. She and a colleague spent the next two weeks tracking down the winning authors and finding high quality visuals. Carlisle then cycled through these to find just the few that he could include in his 10 minute presentation, but he brought paper copies of many others in case the school board was interested. He highlighted Jeff's exhibit, noting that he had set up his own computer for demonstration, and pointing to several other exhibits that would have been much enhanced by such technology. Though the pitch was well-received, by the time that budget discussions took place the board members had forgotten many details and were reluctant to increase the funds for technology support of events like the science fair.

Table 3.6: Requirements Scenarios from the Science Fair Analysis

Scenario writing is a creative act involving judgment and the integration of multiple issues. A scenario may narrate the experiences of several stakeholders if collaborative activity is involved, or it may focus on an individual. The scope of a scenario is *meaningful activity*; every scenario should be motivated by and contribute to the overall work context. Begin with one scenario for each stakeholder, focusing on a central (or particularly problematic) activity for that group. Develop a scenario around this activity, using the themes analysis to insert an overall "message", and then elaborate with issues raised by artifact analysis, role relationships, and so on. Some issues will fit naturally into many scenarios, suggesting an overarching concern to address in design. After developing one scenario for each stakeholder, review your workplace analyses and find issues not yet covered. Are any remaining issues important enough to add into an existing scenario or create a new one? If so, continue to elaborate the set. If it is possible, invite your stakeholders to participate in scenario construction, review, or elaboration. In the end, not all issues will be covered by the scenario set, but the important ones will be. Table 3.6 lists some requirements scenarios generated for the science fair problem.

Several points are worth noting about these scenarios. They deliberately *reuse* actors and artifacts (e.g., Jeff and his exhibit, the head judge). This adds to the overall coherence of the scenario set: the analysis of Jeff's project that is appropriate for the exhibiting scenario must also make sense in the context of the planning, mentoring, judging, and archiving activities. It also encourages a more expansive analysis of the people and artifacts in the domain, by considering their contributions to more than one high-level activity. Of course, this comes with a cost of *not* illustrating the contributions of contrasting people and artifacts—perhaps a student who wants a computer demonstration but is unable to set it up, or a judge who had no prior experience and was unable to complete her work on time. It is in this sense that requirements scenarios should be seen as only as an illustrative set of "stakes in the ground". They are suggestive, not exhaustive.

The scenarios also include details about participants' *real world situations* that do not contribute to the science fair activity itself. It is important to express concretely who the actors are and to convey the many forces that are influencing their behavior in the situation. The teacher helping Jeff is very busy; this is typical but has nothing to do with the science fair itself. Mrs. Sampson's family life, her problems with her young daughter, have no direct impact on the fair or its operation. However, these details provide bits of context that help the analyst think about these actors' motivations and experience. Specific details like these also encourage analysts to think about other situations in which different factors are in play, for example a case where Jeff's neighbor lives alone and has no other obligations. This is one of the important benefits of writing and sharing scenarios in requirements analysis.

Analyzing a Scenario's Claims

Writing a scenario is a creative act, but it is an act that is informed by many things. The studies of the workplace educate the requirements team, and scenario creation enables the team to synthesize and express their new knowledge. Implicit in these analysis and design activities are the tradeoffs present in the problem situation — features that can be understood to have both positive and negative consequences for use. These tradeoffs may not be directly conveyed in the requirements scenarios, but taking the time to consider them can help you begin to reason about how you might transform the current situation. In general the design goal will be to increase (or add new) positive consequences and to decrease (or remove) negative consequences.

SBUE employs *claims analysis* to reason about tradeoffs in observed or imagined usage situations. Analyzing a claim begins with the identification of an "interesting feature" of a scenario, some aspect of an activity that seems to have one or more important impacts on task participants. Because we are interested primarily in information technology, we tend to focus on features of work-related artifacts, particularly artifacts that are or could be computer-based. Example features from the science fair artifacts might include the size of the space allotted for individual exhibits, the physical lay-out of exhibits in the hall, or the science fair information advertized on the poster.

Scenario Feature	Possible Upsides (+) or Downsides (-) of the Feature
The fixed area allotted to each project exhibit *(from Scenarios 1 & 3)*	+ constrains the complexity of individual exhibits + simplifies planning and layout of the total space available + creates a grid that can organize browsing and judging activities - but many exhibits will have genuinely different needs for space - but too regular a grid may make the layout seem routine and boring - but physical constraints will limit the grouping possibilities for related exhibits
The date, time, and location advertized on the science fair poster *(from Scenario 2)*	+ makes the event seem more concrete (tied to a specific place and point in time) + sets clear boundaries on students' exhibition responsibilities + enables planned or opportunistic simultaneous visitors - but may lead some to skip the fair due to competition with other events
Handwritten judges' forms *(from Scenario 4)*	+ are a familiar technology for recording information and decisions + support personalized handwritten annotations and qualifications + offer a natural authentication function (i.e., by signature) - but may be hard to modify in response to unexpected issues or characteristics - but will lead to significant paper-processing requirements at the end of judging
Physical exhibits *(from Scenarios 1, 3, & 5)*	+ encourage the use of many diverse exhibit elements + allow for direct interaction and engagement by visitors and judges - but abstract or dynamic elements may be difficult to express in physical form - but large physical elements may be difficult to construct or display - but physical exhibits may be difficult to archive, transport, copy, or share

Table 3.7: Claims from the Science Fair Requirements Scenarios

The second piece of claims analysis is hypothesizing the consequences a feature has for the stakeholder(s) in the scenario. How does the feature make the activity easier? Harder? More or less pleasant or satisfying? Some consequences will be readily apparent in a scenario as written. Sometimes a set of consequences can be seen in different scenarios touching on the same feature of the workplace. Some may not be part of a scenario at first but are added as an elaboration after thinking about some other scenario. Yet others will be part of some *other* story, a scenario version where things work out a bit differently than imagined. These are the hardest consequences to realize, but are critical to include. They reflect a kind of "what if" reasoning about the situation that expands the scope of the analysis as well as encouraging analysts to look ahead to situations that a new system might support.

An important feature of claims analysis is that *both* positive and negative consequences (informally termed the "upsides" and "downsides") are considered. When examining a current situation, it is easy to focus on just the problems imposed by current technology; later on, when analyzing the impact of new technology, it will be easy to focus on just the advantages provided by the new system. However we cannot emphasize enough that all design involves tradeoffs—you rarely get something for nothing. By imposing the discipline of documenting upsides and downsides for every claim, you'll be more likely to understand and address both sides of a design issue.

Table 3.7 summarizes claims analyzed for several VSF requirements scenarios. Each claim considers a range of possible positive and negative consequences of a feature impacting one or more scenarios. Some consequences are evident in the narratives as written: Jeff and his teacher are well-aware of the constraints of the exhibit space; Alisa is able to annotate her form with notes concerning the two projects of similar quality; the Sampson family is clearly engaged by the physical characteristics of Jeff's exhibit. Other consequences emerge from what-if reasoning inspired by these scenarios: Jeff is able to select project elements that fit into the space allowed, but some students may find they must leave out interesting elements; the 2-hour time period of the fair tells the Sampsons when to visit, and at the same time puts well-defined boundaries on the responsibilities of student authors managing their own busy schedules; Ms. Czerny was able to collect a nice set of samples for the superintendent's presentation, but some projects might not have been saved in a form suitable for this purpose. In this sense, a claims analysis allows a requirements analysts to point to scenario elaborations without developing the corresponding narratives. More importantly, it documents the analysts' conclusions about tradeoffs in the current situation that should be addressed by the new design.

Scenarios and Claims as Requirements

In what sense do scenarios and claims convey requirements? Clearly a set of requirements scenarios is *not* a specification. It captures insights gleaned about the *current* situation. Subsequent design reasoning will develop a response to this analysis, creating and refining a design specification that is eventually implemented as the final system. The requirements expressed by the scenarios relate to the needs and possibilities suggested by analysis of current practice: The scenarios narrate instances of typical or critical goals and activities. Specific features of these activities are seen to have impact, and associated claims analyses articulate what might be good or bad about such features. The implicit assumption is that the design process will respond to these needs and possibilities, hopefully maintaining or improving on the positive characteristics and diminishing or removing the negative.

This textbook deliberately presents a simplified view of SBUE. In practice analysis and design will take place in a tightly interleaved fashion: As soon as requirements analysts recognize a problem in the current situation, they will begin to develop possible design approaches to solving the problem. There is some evidence of this in the VSF examples, because the analysis focused almost immediately on the problems and opportunities most likely to be influenced by online activities (e.g., eliminating scheduling and space constraints). At the same time, because the entire process is iterative, we know that the scenarios and claims developed as the result of this initial requriements analysis are only a first pass at understanding the problem. The development of requirements will continue as design ideas emerge and are considered through new scenarios and tradeoff analyses.