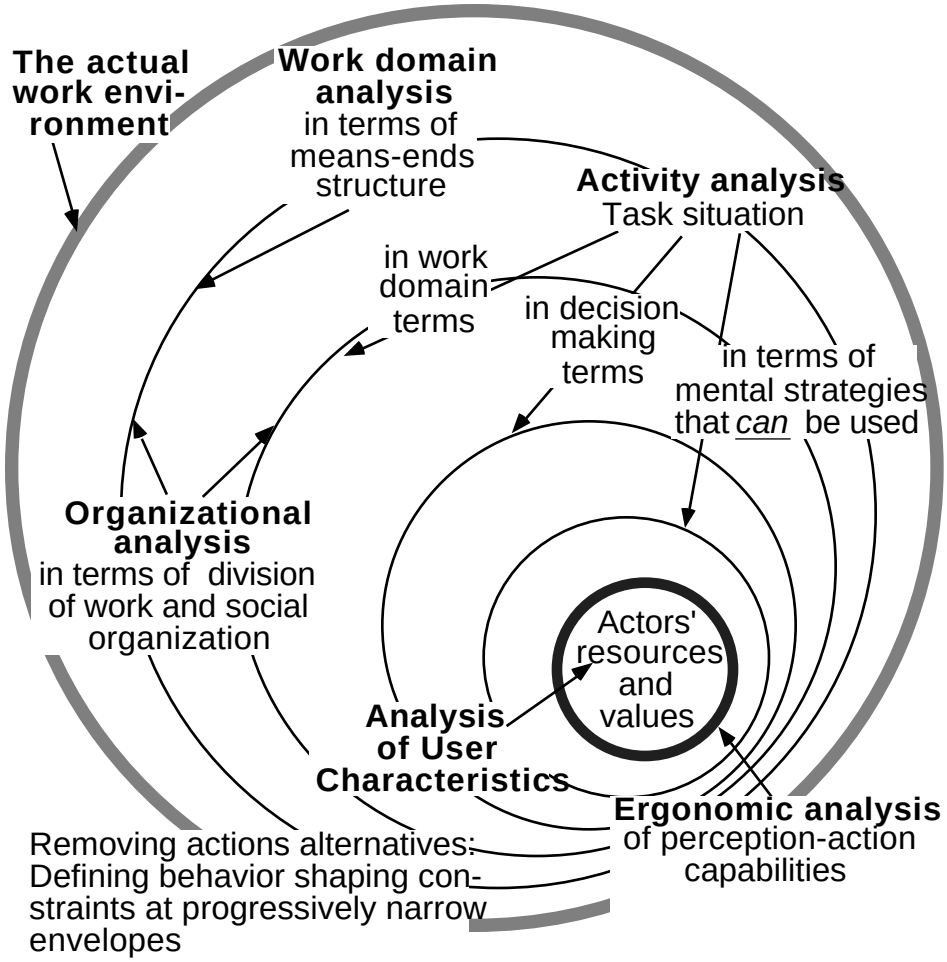
FRAMEWORK FOR COGNITIVE WORK ANALYSIS



A FRAMEWORK FOR WORK CENTERED EVALUATION AND DESIGN: A CASE STUDY OF IR ON THE WEB

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A Cognitive Framework for Analysis and Evaluation of the Work Context

Introduction

A comprehensive evaluation of a computer system requires a well-structured evaluation sequence. Such a sequence should be based on a set of boundary conditions that clearly define the various work domains and system components. Only with such explicit and clear set of conditions is it possible to evaluate a system comprehensively, including all its components. This report presents a framework to guide the definitions of boundary conditions that can be used in empirical evaluation studies. First, we briefly describe the framework. We then demonstrate how it can be used in an actual work situation by analyzing a case of students searching the Web for homework assignments. Finally, we evaluate Web's performance for this task by analyzing systematically problems the students had in carrying out their task.

The report is organized into three major parts. The first (Section A) provides the description of the framework in conceptual terms. The second part (Section B) translates the concepts introduced in Section A into questions that should be asked in studies. The third part (Sections C & D) describes the case study according to the framework. For example, In section A. we explain what are information processing strategies. In section B. we present questions to be asked about users' strategies and about criteria they use for strategy choice. Section C in turn, describes the strategies and the criteria used by the high school students in the case study.

Both Section A and Section B include two parts each. The first addresses the framework for the ***analysis*** of the work context, and the second the cognitive framework for system ***evaluation***. Similarly, Section C is an ***analysis*** of the work context of the case study, and Section D is an ***evaluation*** of the Web for the task of completing homework assignments in high school. Section E briefly describes an additional example: A full-scale library system for which a variety of evaluation studies have been carried out.

THE COGNITIVE FRAMEWORK FOR WORK ANALYSIS

The analysis of work context requires several levels, as presented in Figure 1.

This gives structure to the analysis and the description of a situation by decomposing the situation in modular elements along the part-whole level of analysis, starting with the individual actor and ending in the actual work environment. In addition, this decomposition makes it possible to identify the potential means and ends at several levels of abstraction, moving from the most concrete to the abstract. That is, covering means and ends for

physical form and anatomy, and moving upward through physical processes, general functions, abstract value functions and, finally, covering the goals and constraints with reference to the environment. A means-end analysis explicitly identifies the *why* and *how* attributes of any function, and the *what* aspects. Examples of such *why, how* and *what* questions are given in Section B, and results of such analyses in Section C.

These different levels of analysis and their significance for the analysis are briefly described in the subsequent segments.

A COGNITIVE FRAMEWORK FOR ANALYSIS OF THE WORK CONTEXT

Analysis of the work context is a top down process that begins with the analysis of the task domain and moves on to the user. Evaluation is a buttom up process that begins with the user and moves on towards the broad work context. Hence, this report will follow this sequence and switch between having the work domain or the user as the starting point of the analysis.

The Work Domain

This level of analysis, or dimension, of the framework defines the boundaries, or *delimits*, the system to be analyzed. It is employed to represent the landscape within which work takes place. It serves to make explicit the goals and constraints which govern actors' work activities, independent of particular situations and tasks, in order to have a first delimitation of the actors' degrees of freedom. This analysis of the basic means-ends structure is particularly well suited for identifying goals and constraints which have been hidden in established practice and for finding possible alternative means-ends relations, which are customarily neglected.

This dimension of the analysis is particularly important for the categorization of work domains and the approach to work support. Analysis within this dimension identifies the structure and general content of the global knowledge base of the work organization. It also uncovers the organization of the work and coordination functions in the various levels of means-ends analysis.

It is important to note, that the analysis along all the other dimensions of the framework will have to relate to the means-ends description of the wok domain.

Activity Analysis, Task Situation

This level of the analysis further delimits the focus to the degrees of freedom left for meaningful activities as bounded by a particular task

situation or work function and their constraints posed in time and functional space. This dimension requires a means-ends analysis which is relevant for a particular task. It is important to realize that 'a typical task sequence' will not normally exist in a modern, advanced work setting. Therefore, generalization cannot be made in terms of work procedures found by a classical task analysis. Generalization should be made at the level of the individual decision situation. Further, the generalization should be expressed in *domain terms* so that one can identify a set of prototypical task situations which, in various combinations, can be used to represent the activities to be considered for information system design.

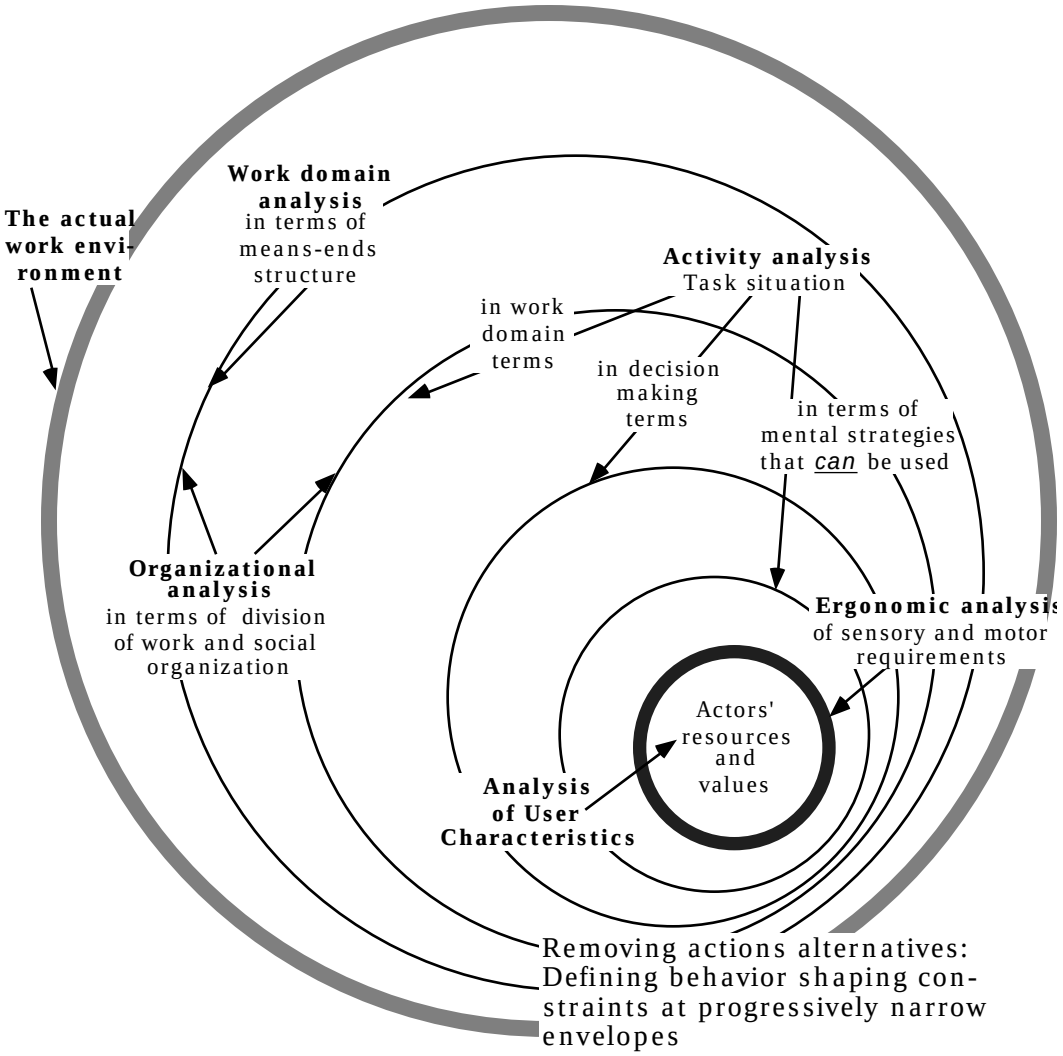

Figure 1. Several levels of analysis of work activities are necessary with corresponding shifts in representation language in order to relate properties of a work environment to the cognitive resource profiles of the actors. In the framework the work space dimensions used for the design input are compatible with those work space dimensions used for evaluation of the design output.

For interface design and evaluation, this part of the analysis brings out the information that should be available for support tools and interfaces that will serve adequately an actor during the relevant work situations. That is, the interface that is necessary to serve an integrated set of tasks and to coordinate the support of cooperating actors.

Activity Analysis, Cognitive Decisions

For this level of the analysis, a shift in representational language is made. For each of the activities defined in the previous segment, the relevant tasks in terms of decision-making functions, such as situation analysis, goal evaluation, or planning, are identified. This representation breaks down work activities into subroutines which can be related to cognitive activities. At the same time, it punctuates activities by "states of knowledge," which separate different information processes. These are normally the nodes used for communication in cooperative activities.

The information gained in this analysis will identify the knowledge items which are relevant for a particular decision task, together with the required information about their functional relationships. In addition, it identifies the queries posed by actors when they make decisions.

Activity Analysis, Mental Strategies

This dimension introduces the concept of mental strategies. A strategy is a category of cognitive task procedures which are based on a particular kind of mental model and the related interpretation of information, and on a particular set of tactical rules.

Further analysis of the decision functions requires a shift in language in order to be able to compare task requirements with the cognitive resource profile and the subjective performance criteria of the individual actors. For this purpose, the mental strategies which *can* be used for each of the decision functions are identified first. This is done by detailed analysis of actual work performance of several individuals in different situations (e.g., by protocol analysis). The characteristics of the various strategies are identified with respect to subjective performance criteria such as time needed, cognitive strain, amount of information required, and cost of failure.

Analysis of the available effective strategies is important for interface design because it supplies the designer with several coherent sets of mental models, data formats, and tactical rule sets which can be used by actors of varying expertise and competence. In the following phases of analysis, constraints on meaningful activities depending on the role and preferences of the individual actor are analyzed.

User Characteristics, Individual Actor's Resources

At this stage, the degrees of freedom in work performance of the individual have been delimited by identifying the work-related constraints down to the level of mental strategies which individual actors can use for making decisions. In order to judge whether a given actor is able to meet the requirements and determine the approach to work which might be chosen, the resource profile, i.e., the level of expertise, and the performance criteria of an individual agents should be analyzed.

Organisational Analysis, Allocation of Decision Roles

In addition to the constraints given by the work domain and to the subjective choices made by individual actors, the principles and criteria that determine the allocation of roles among the groups and individuals involved should be identified. The work domain is considered a loosely coupled system under the control of a set of cooperating actors, and allocation of roles can refer to sub-spaces of the work domain or roles in decision functions. This allocation of roles to actors depends on ever-changing circumstances and is governed by criteria such as agent competency, their access to information, the need for communication for coordination, sharing of work load, complying with regulations (e.g., Union agreements) etc..

This phase of the analysis identifies the scope of the information window which should be available for an actor during a particular work situation and the information exchange with cooperators needed for coordination. The constraints posed by the work domain and the criteria for role allocation specifies the *content* of communication necessary for concerted activity.

Social Organisation, Management Structure

While role allocation determines the content of communication necessary for coordination, the "management culture" of the organization determines the form of communication, i.e., whether the coordination depends on orders from an individual actor, on consensus in a group decision making, or on negotiation among the actors involved. Clearly, management structure heavily influences the subjective performance criteria of the actors and therefore, indirectly, the formulation of goals and constraints. Therefore, the identification of the communication conventions underlying the social organization is necessary to determine the communication formats of an integrated information system. In particular, identification of the actual role of communicating social values, subjective criteria, and intentions which are necessary in the particular work setting for coordination of activities, for resolution of ambiguities, and for recovery from misinterpretation of

messages, is very important for the allocation of functions to an information system and to face-to-face communication, and for the design of the information communication formats.

A Cognitive Framework For System Evaluation

PURPOSE OF EVALUATION

An evaluation of a system is usually carried out to determine if the system meets the goals for which it was designed, and how effectively and efficiently it does so.

Does System Meet Design Goals?

To answer this question, one identifies needs for improvement. The issues of which goals, methods and measures to choose depend on the context of the system design, and on the approach to the experimental design of the evaluation. It is outside the scope of this report to suggest particular experimental designs and objectives for evaluation. Usually, a combination of methods, measurements, objectives and evaluation techniques are likely to be required.

Compare Alternative Approaches

An evaluation may include a comparison of alternative approaches. The main issue here is: Should several system solutions be chosen for evaluation? An evaluation is *comparative* if several systems are checked for a differential result to support choice among design alternatives. It is *absolute* when it tests whether a single system is able to achieve a given goal and level of performance. Comparative evaluations are useful, for example, when several systems will be integrated during use, and consistency in representation is required to reduce the amount of resources needed for learning the systems. To be useful, comparative evaluations should be based on an exhaustive list of clearly defined and compatible qualities and functions of the different systems to be compared, which are then correlated with identical performance measures. The cognitive framework described in this report is a tool that can guide systematic comparative evaluations and generalizations among different design solutions.

TYPES OF EVALUATION

There are two types of evaluation:

Verification asks the question Does the system meet the design specification? That is, *Is the design right?*

Validation asks Does the system actually serve the needs of the end users. That is, *Is it the right design'?*

EVALUATION OBJECTIVES, MEASURES AND METHODS

To determine the objectives, measures and methods to be used in an evaluation study, the evaluator should answer the following questions:

- What is to be evaluated: a product, a concept, a partial solution, a prototype with surface levels of the total functionality of the system, or a prototype with full functionality of only a part of the system?
- What constitutes an unambiguous definition of goals and objectives which can be transferred to the evaluation level (what is the evaluation supposed to establish)?
- What are the (categories of) situations to be evaluated?
- How will performance be defined and how will it be measured?
- What will be the linking between evaluation *objectives* and *measurable performance variables?*
- What are the effects of the intermediate variables (training, experience, task, environment, etc.)?
- Who will participate in the evaluation? Real end users, test subjects, design team members, colleagues? In iterative design, a distinction should be made between use of subjects from the work place in a work situation, test users in a laboratory, and the testing done among the design team members and colleagues in the project group.
- Where to perform the evaluation? In a laboratory or at the users' work place?
- What evaluation data should be collected? Subjective user/expert judgments, qualitative? Objective, quantitative measures of objective performance criteria? Both?
- What quantitative data should be collected? Quantitative measurements can be performed as *objective measures* or as *subjective measures.*
- What quantifiable performance measures are relevant? Quantifiable measurements may include time to do a task, error rate, number of features actually used, number of features never used.
- What methods to use to capture data? Synchronized audio recording and videotaping, questionnaires, interviews, logging of observational data, of

the actual use of the varied functionality of a product. Automatic data logging.

- What methods to select for data analysis and data encoding to obtain reliability? What statistical methods and what data integration method for coding, sampling and analysis?
- What methods to choose for qualitative analysis of case studies?
- What methods to select for presentation of results for customers or test subjects?

EMPIRICAL AND ANALYTICAL EVALUATION

A systematic evaluation of complex systems should be well structured and performed at several well-defined levels of user-work place interaction. At each of these levels, evaluation should be performed either *analytically* or *empirically,* or both approaches should be applied. An analytical evaluation depends on a structured comparison of work requirements as defined by a work analysis with the design specifications. In contrast, empirical evaluation involves tests of the performance of a system with reference to design objectives, or with reference to its actual performance in a laboratory with test users, or its actual performance in the ultimate context of use in a real work place. Issues related to the *contents* of the information and the functionality of the system can be evaluated analytically, while issues related to its *form* involve context, user experience and preferences, and therefore, very likely will need an empirical approach.

Empirical Evaluation Approaches

For empirical evaluation experiments, it is necessary to establish an experimental work situation that creates a well defined boundary around the subject, and to study whether subjects' responses to this boundary leads to the mode of behavior which was assumed as the design basis. For proper integration of the results, such experimental evaluation scenarios should be compatible with the structure of the work analysis underlying design as well as with the design specifications. Empirical evaluations pose special problems with respect to validity and generalization of results. To enable *generalization* and the *transfer of findings* among actual work analyses and different experimental designs, a consistent framework is necessary.

The Cognitive Framework for Analysis of the Work Context (Figure 1 and 2) is a comprehensive tool that guides the design of an empirical evaluation that examines the match between a new design and the work domain, including the characteristics of its users.

A Cognitive Framework for System Evaluation

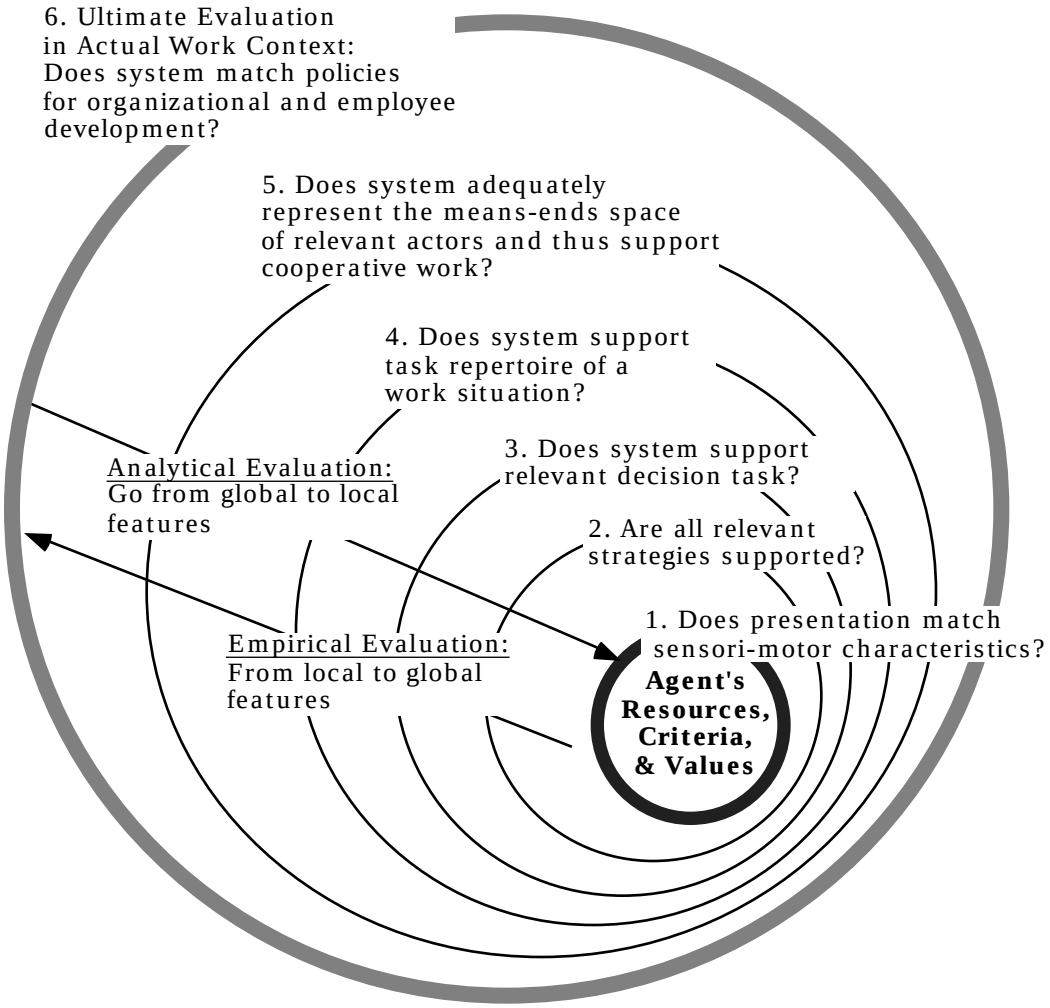

Figure 2. The figure demonstrates how different evaluation questions can and should be asked at the various levels described in the framework for work analysis. It defines the boundaries of evaluation and helps to avoid zapping among boundaries. In addition, it is shown that a different ordering of the evaluation questions should be considered for an analytical and for an empirical approach to evaluation.

Section B

QUESTIONS FOR ANALYSIS OF THE WORK CONTEXT AND SYSTEM EVALUATION

Introduction

A COGNITIVE FRAMEWORK FOR ANALYSIS OF THE WORK CONTEXT

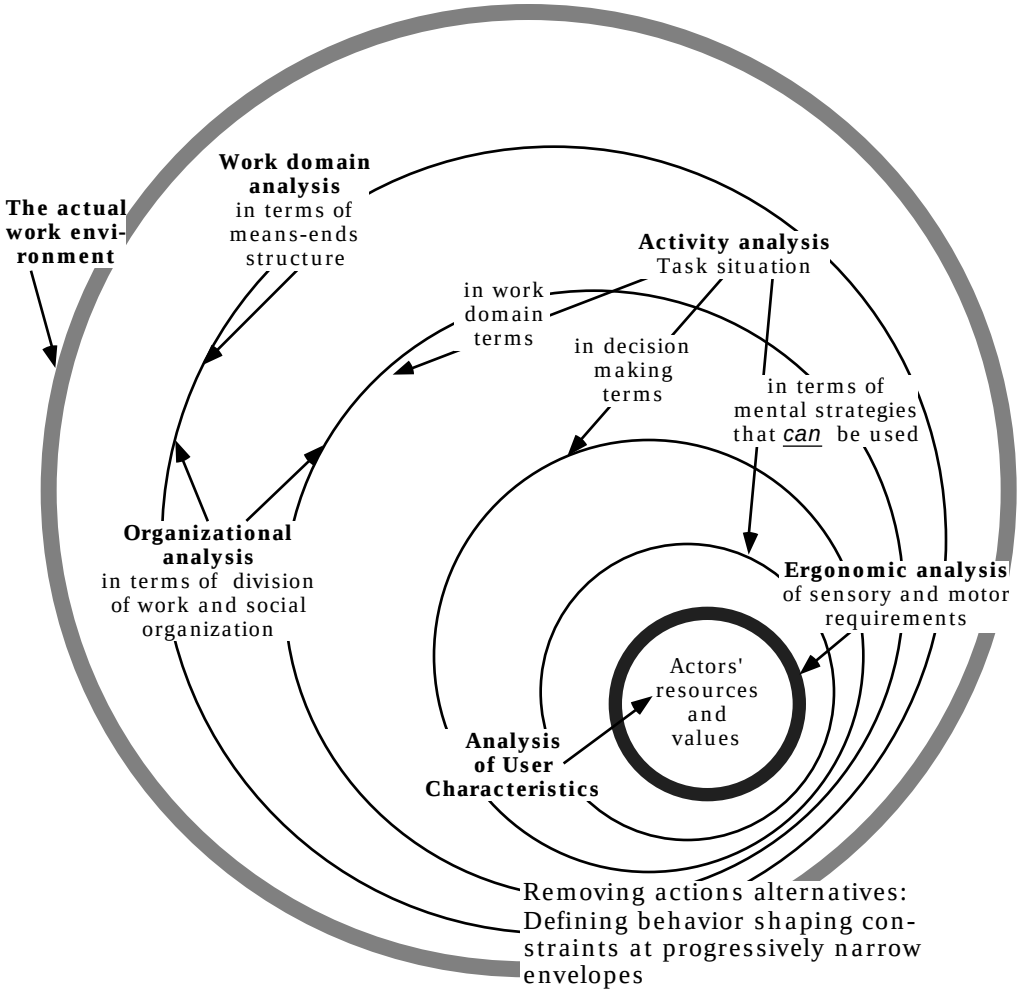

Figure 3. Several levels of analysis of work activities are necessary with corresponding shifts in representation language in order to relate properties of a work environment to the cognitive resource profiles of the actors. In the framework the work space dimensions used for the design input are compatible with those work space dimensions used for evaluation of the design output.

Questions to Ask about the Workplace

Could you draw a map, explain it, ask person to identify the functions she is involved in, redraw the map of what is done, why it is done, what tools are

used. Or can you just tell me about your workplace. The questions below about the task situation are just to probe users if their initial description does not cover all the aspects of the means ends model. Figure 4 shows a drawing of a task situation in a "natural" environment, that is not a computer system at a workplace. From this cartoon it is possible to answer the questions you have to ask in order to make a means-ends description of the work domain. See figure 6 for a real life example from the high school domain. These questions address five different abstraction levels.

1. Why? What are the goals and constraints?
2. Why? What are the priorities and value criteria?
3. What? What are the general work functions?
4. What? What are the specific work processes?
5. How? How are the work processes performed, which tools and physical attributes?

If we look at the cartoon, the answers to these questions will be the following:

The actor's goal is to go to sleep. In order to do so, the room has to be dark. In other words, he has to make a priority judgment with respect to darkness and light. The general function to be performed in order to achieve the goal is to switch off the light. The specific work process to be performed is to pull the string. The tools used in the work process are different everyday objects like a boot, a spoon etc.. Important is not only the description at these different levels. There are relationships among these entities. Level one is an end for level two, level two is a mean for level one. Level three is a mean for level two, which is an end for level three, and so on for each level.

Questions to Ask about the Task Situation

What task do you do and what is it called?

What physical activities are you involved in (what are you actually doing)?

What functions do your activities fulfil?

Why are you doing these activities? For what purpose?

What are your constraints? We are interested in constraints in the environment, not personal limitations such as lack of skills

What are your priorities? What are your priorities for the successful completion of the task.

In general, what are the priorities of the Company? Which priorities relate to your job?

What tools do you use to do your job?

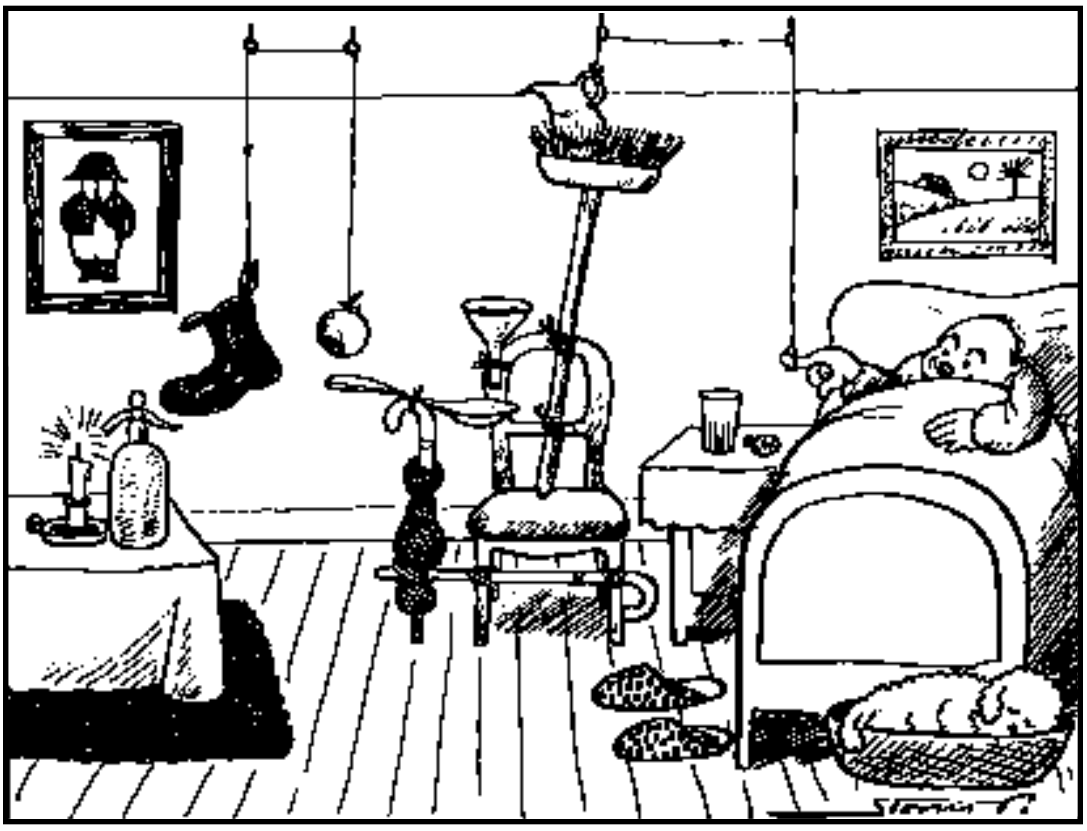

Figure 4 A natural environment, that is not a computer system at a workplace. The cartoon illustrates how the " work domain" can be illustrated in a drawing at several levels of abstraction.

Questions to Ask Users about their Decisions

What decisions do you make?

What questions do you ask?

What information (data, analyses, video, audio, and so forth) do you use?

what information do you need?

Questions to Ask Users about Mental Strategies

How do you make decisions?

What are you looking for?

How do you look for information? (Interviewers: Do they plan? Do they look the same way all the time (like, they have a “trick” they always use)?)

Why do you do it in this way?

Where do you look for information?

Why in these places?

Do you have any preference about where to look for information?

Why?

Do you have any preferences about how to look for information?

Why?

Question like How do you do/what information are you looking for.

Questions to Ask to find Criteria for Strategy Choice

What determines the way you look for information? Examples are: time, intellectual effort, fun, get better results than my colleagues, impress boss, social interaction, learning new things, confidentiality, reliability or availability of information (least effort)

Questions to Ask to find a Mental Model

Can you explain how the Internet works? Please draw a diagram or picture of it?

Questions to Ask Users about their Characteristics

What formal training and education do you have?

What is your area of expertise?

How long have you worked as an engineer?

How long have you worked in your current task?

How often do you perform this task?

Does this task require you to follow routines that were set ahead of time?

Have you developed any procedures or routines yourself? Can you explain, or show examples?

Does your current task require much use of your knowledge? Can you explain, or bring examples?

What type of tasks do you like best? Those that follow set procedures, or those that are more knowledge demanding. Also, new or familiar tasks?

Does your task require much new information?

Questions to Ask about Organisation and Roles

Who gives you the task?

Why did you get this task?

Do you give tasks to others?

How is the work divided among members of your group?

What criteria are used to divide the work?

Questions to Ask about Social Organisation and Management

How do you communicate with your peers?

How do you communicate with your boss?

With whom do you cooperate?

Who decides when the task is done?

Is your work important

FRAMEWORK FOR SYSTEM EVALUATION

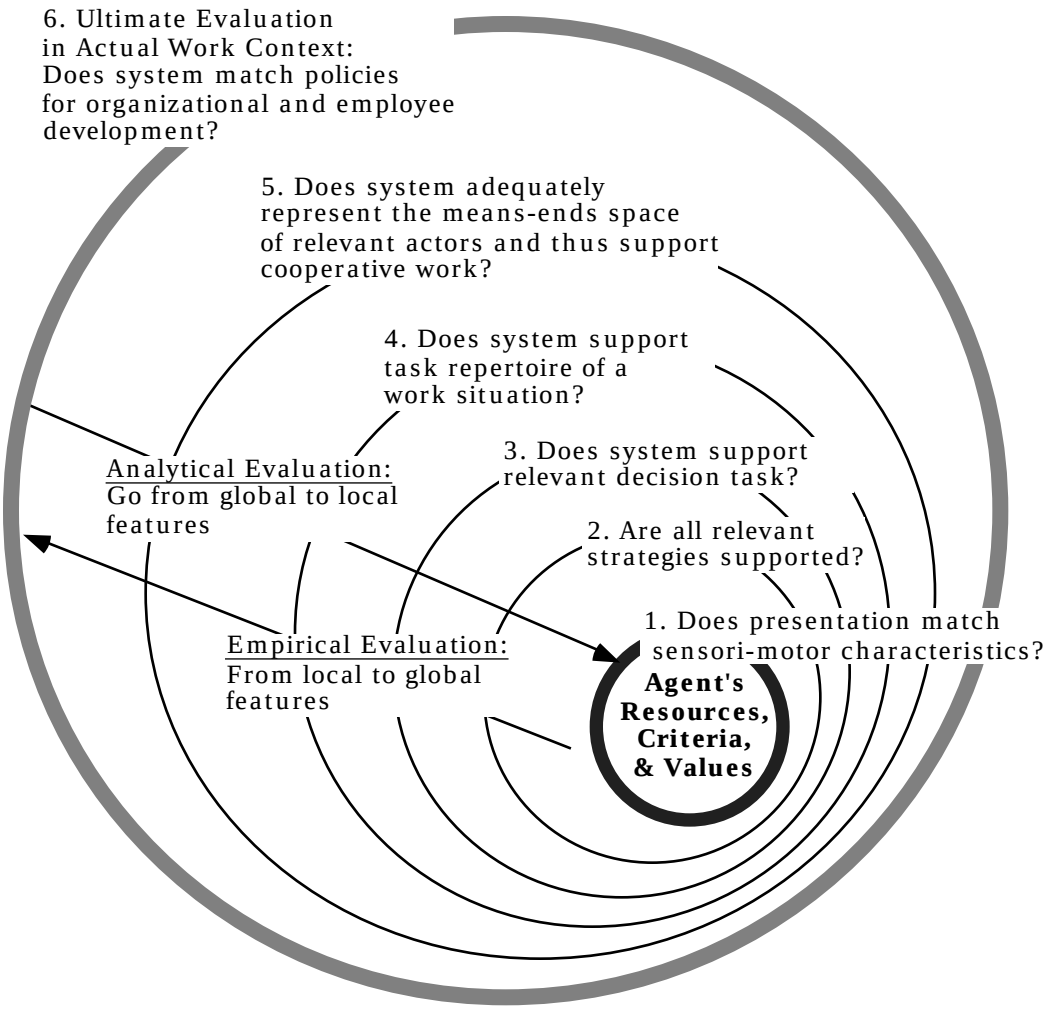

Figure 5. The figure demonstrates how different evaluation questions can and should be asked at the various levels described in the framework for work analysis. It defines the boundaries of evaluation and helps to avoid zapping among boundaries. In addition, it is shown that a different ordering of the evaluation questions should be considered for an analytical and for an empirical approach to evaluation.

Both analytical and empirical evaluation should be considered for all the levels of Figure 5, but the sequence of the levels considered will be different for an analytical and an empirical approach. For analytical evaluation of design objectives, a natural approach will be top-down from global system properties to detailed task functions. For empirical evaluation, a path from details to global features will be the best approach. Complex experiments involving entire task situations will be meaningless if the system does not match user characteristics at the elementary level. For example, if experiments are planned to evaluate the functionality of a prototype before interface readability is tested. The various boundaries of evaluative experiments are summarized below with reference to figure 5. These boundaries "move" the context successively further from the actor to encompass more and more of the total work content in some kind of increasingly complete simulation and field evaluation.

Match with Users' Resources and Characteristics

This level addresses the sensory - motor characteristics as well as perceptual and cognitive resources. Evaluation of perceptual and cognitive resources will focus on the size of letters, the readability of the typography and the graphics of the displays, display composition, consistency, coherence, use of colors, icons, wysiwyg interfaces, etc. This level also addresses evaluation principles that are important to examine how understandable is the information flowing in the communication between the system and the user.

Support of Users' Strategies and Mental Models

At this level, the following questions are addressed: Does the system support several task strategies and can the user shift goals and tasks concurrently without loosing support from the system? Does the system provide the mental representations of novices and experts, and is the user's mental model of the work domain supported by the interface - also during distributed decision making?

Support of Cognitive Decisions and Processes

A basic question to be asked at this level is: Does the system effectively support the cognitive decisions that have to be made during task performance? Does the system support the actor's decision making: Are exploration, situation analysis, goal evaluation and planning supported for familiar as well as less familiar situations?

Support of Relevant Task Situations

The question here is whether the system supports the entire task repertoire: Are the tools adequate, their functionality sufficient and does the information cover the complete work task space? Is its capacity adequate? Experiments may serve to evaluate whether information is available about the basic concepts of the system and its overall architecture. Is it possible to navigate among tasks, and to pursue several, different task related goals?

Adequate Representation of Work Environment

Evaluation experiments here will investigate the relationship between the use of the system and users' intellectual and emotional style and their personal problem solving habits in the total work place context. For this boundary, the evaluation must be based on actual work scenarios generated from an actual work analysis, and the aim is not a *task* simulation but a *work place* simulation and must include not only the system's effect on a complex work place situation.

Field Evaluation in Actual Work Environment

Evaluation in the actual work context will address the question: Does the system match organizational policies and employee's acceptance and development? How is its impact on the work context and the quality of the work situation? Does the system support several coherent work task activities and the cooperative coordination of activities among several users, maybe in different departments of the organization, and does it support interaction and coordination with institutions outside the organization? In other words, it will answer the question whether the design approach and the assumed work organization does match the performance criteria and preferences of the users. *Will the system be used*? And do the users like to use the system, and do they actually use it over a *longer time span* in the daily task situations, for which it was designed and to the degree it was expected?

Section C

EXAMPLE OF FIELD DATA ABOUT THE WORK CONTEXT:

THE CASE OF IR ON THE WEB

Introduction

To begin explorations about human searching behavior on the World Wide Web, we examined the searching behavior of a group of high school students who searched the Web in order to retrieve information they needed for class assignments. The purpose of the project was to describe the students' searching behavior and to suggest changes in the design of the Web that may improve the students' learning experience.

THE RESEARCH METHOD

The study employed qualitative research methods. While every research project relies on both qualitative and quantitative analyses, a study that is primarily qualitative is different in nature from one that is primarily quantitative. The methodological foundations of these approaches are also different. In information science, qualitative studies are usually carried out in the field, rather than in the lab. They use observation and interviews as techniques for data collection, and investigate searching behavior as it occurs in real-life, not in the lab.

Qualitative analysis often results in descriptions of recurring patterns. The framework presented here can guide qualitative studies, but it also provides an analytical tool for data analysis, as is described later in this report. Following is a description of the research method used in the Web case.

To study the searching behavior of high school students, a research team carried out a field study at West Seattle High School, Seattle, WA, using observation and interviews. The research project was part of a course about the analysis of searching behavior offered by the Graduate School of Library and Information Science at the University of Washington. The participants in the course, seven graduate students and the instructor, became a research team.

Field activities began after the team members had received training in qualitative and field research methods and after the initial communication with the librarian and the teacher at the high school had promised enthusiastic cooperation. Field activities included these activities: observation in class and at the terminal with students thinking aloud, interviews with various participants, team discussions, and writing reports.

Plans were developed for the team to observe three searching sessions. As part of the preparation, the team visited the school and met with the librarian, the teacher, and the students enrolled in the horticulture class.

During this first meeting with the class, the team introduced itself and explained the purpose and nature of the study.

The following week, the research team reported to the horticulture class and began the first formal observation of the eight student volunteers. The second and third observations occurred during the successive weeks. Each week the teacher explained the weekly assignment to the students in the classroom. The students then went to the library, and the research team accompanied them. The study participants used the computers in the new computer room, which is located in the library. The rest of the class used the computers or other resources in the library. Each team member sat beside the student she was observing throughout the project and audiotaped the student's narrating the search process.

At the beginning of each session at the terminal, each team member asked the participating student two questions: What do you plan to do? and What do you think you will find? At the end, students responded to three questions: Did you find what you were looking for? Is it what you expected to find? How do you feel about the search? Other comments were kept to a minimum and were as non-directive and non-judgemental as possible to avoid influencing searching behavior. Because not all students were present during the three weeks of observation, some performed only two searches in the team's presence. In total, the team observed 21 search sessions.

At the end of the observation period, each team member interviewed the student to obtain background information, insights into that student's searching behavior, and to uncover the student's perceptions about Web searching. The team as a whole developed the script for the interview, but individual members could ask additional questions. The team also interviewed the librarian and the school's principal. In addition, the team developed a script for the teacher's interview, which was carried out by one team member. All verbal protocols, think aloud as well as interviews, were transcribed.

After the first search, each team member wrote a description of the search he had observed based on the transcribed verbal protocols, notes he had taken during and after the search, and on available paper documents, such as printouts of Web pages the student had used or a copy of the notes the student took during the search. After the second search, each member wrote a report that described the searching pattern of the student as it appeared from observing two searches. At the end of the observation period, and after the interview with the student, each team member wrote a case report describing the searching behavior of the participating student.

Before the completion of the project, each student received a copy of the case report describing her searching behavior. Team members asked the students to make any comments they wished, but most importantly, to determine how valid was the description of their searching. All students were happy with the reports, and all claimed that the reports described them accurately.

The case reports, which were based on the transcriptions of the verbal protocols during searching, together with the transcriptions of the interviews with the eight students, the librarian, the principal, and the teacher are the basis for the description of the students' searching behavior that will be published as a journal article. Here we use some examples to demonstrate the framework. These examples are based on a partial analysis of the data using the framework for work-centered evaluation and design as shown in figure 1 and figure 5.

THE WORK DOMAIN

Means-Ends Analysis of the Work Domain

About Priorities

The Principle put high priority on relationships with the community, and on the image the school had. He had initiated projects that would increase the school's visibility. The computer lab was opened at night, and the school offered night classes in IT. All they did in the community worked very well for the school's public relations.

About Constraints

Half a year after the project was over, the city instituted a new graduation requirement: students will have to achieve a certain minimum grade in science courses in order to graduate. That is, new students in the horticulture class might be more interested in their grades than the ones we observed.

Goals and Constraints	Educate students to be informed citizens, active readers, and to have skills in information technology (IT). Budget limits; State of current technology; State of technology available in school, e.g., can school's computers retrieve maps; Regulations by the city's schools system, such as using a certain online catalog system, or graduation requirements; Quality control of teaching materials; Availability of teaching materials to students; Copyright laws; Work regulations on city, state or federal level.
Priority	Investment in IT and in teaching materials; integrating IT into the curriculum; image in the community. Quality measures: - level of library use; - level of positive publicity in media; - level of community use of the school's IT facilities; - city and State tests and statistics, such as demographics, average grade, -rate of students' participation in certain classes; and -scores on city, state and national tests.
General Function	Teaching; Development of policies; Purchase, organized and make books available; Communication with parents; Developing community projects
Work Process	Teaching courses in: IT; information retrieval; subject courses; Prepare class presentations and activities; Prepare assignments; Grade assignments; Advise students; Participate in training workshops; Information retrieval
Physical Resources	Teachers; librarians; staff; Teaching materials; library books; Computers; classrooms; library; Internet access in library; library homepage linked to course material

Figure 6 shows the means ends relations of the work domain of high school at different abstraction levels. It is based on interviews with the principle, the teacher and the librarian.

ACTIVITY ANALYSIS, TASK SITUATION

Prototypical task situations and work functions to be supported by a system. Here the user explains the job in his/her own words. What do you do, why do you do it, what tools do you use. Defines the information *sources.*

Information Retrieval Task Situation

In preparation for the class, the librarian gave a short hands-on introduction to Web searching, explaining how to log in and out. In addition, she often participated in class sessions, pointing to useful clues for the assignment of the day. The teacher was also available to help students when they were doing their assignments in the library.

- Teacher explained content of assignment in class
- Teacher explained how to search
- Librarian explained how to search
- Students went to the computers in library
- **Students searched the Web to find answers**
- **Students wrote down answers**
-Students handed in assignments to teacher

In this report we will focus on the two tasks emphasized above, but will refer to the others occasionally.

Students' Task Situation

The first assignment the team observed asked the students to identify a specific plant which grew in the Pacific Northwest and to answer questions about that plant such as the genus/species name, common names, its origin, uses and historical significance, as well as to provide a picture or a sketch of the plant.

Below in figure 7 is a an analysis of the assignment on writing a plant report in horticulture as laid out by the teacher for the students. It is structured as a means end description in order to illustrate the informAtion content and their attributes or dimensions that need to be presented and accessible in a database or on a homepage on the Web.

A Copy of the Assignment

Horticulture **PLANT REPORT**

Purpose: to learn more about a plant of your choosing. This will expand your knowledge of one specific plant amidst the many plants you are presently studying.

Requirements:

- minimum one (written) page
- computer printed using an eleven or twelve font size

sources properly documented on the last page or separate bibliography page

Discuss in your paper:

Genus/species name and common name
General description with a sketch or picture
origin...where did it come from
Historical significance (if possible)
Uses (Ex. ornamental, medical, landscaping, food, etc.)
Location around the world and in our area (if found here)
Growing specifics; the significance of its growing location
Personal comments about choice of this plant

Points for Assignment: 25

Means Ends Description of Student's Task Situation

Means-Ends Analysis of Students' Task
Why? Goals and constraints
- Learn about one specific plant
Why? Priorities and value criteria
- Comments on your choice of plant
What?: General Content
- Where did it come from? Location in the world and in our area
- Historical significance
What?: Specific content
- Growing specifics, genus/species
How? Form, physical attributes
- Sketch or picture, Name

Figure 7 shows the means ends analysis of the students' task situation based on the teacher's task description as illustrated above.

Teacher's Task Situation

The teacher believed that Web searching was very useful for the horticulture class because of the limited resources available at the school's library. His experience showed that students could find the information on the Web for the assignments, and that they became better at it as the course progressed. His purpose in the assignments was three fold: to help students find information that might not be available in other sources, to show them that the web had information about science in general and about horticulture in particular, and to help students practice Web searching.

Means-Ends Description of Teacher's Task
Why? Goals and constraints
Teach students: plants outside curriculum, what is on the Web on horticulture, to search the www
Why? Priority and quality measures
Integrate www into curriculum
What? General function
Information retrieval
What? Work process
Explain IR task, give instructions on navigation and error recovery
How? Physical resources
Internet, www, computers, networks, library, teacher, librarian.

Figure 8 shows the means ends description of the teachers' task situation based on an interview with the teacher.

COGNITIVE DECISION TASKS FOR INFORMATION RETRIEVAL

The information processes of the task decisions to be supported include analysis of task situation and information need; Idea generation; Planning a search; Evaluate alternatives among different search approaches and options; compare match of retrieved documents with information needs. This is a non sequential process with many iterations among these decisions.

This analysis defines the information *use and queries.*

Analysis of the Assignment

Students had many questions about the assignment itself. For example: Does it have to be a wild plant? Does it have to grow only in the Pacific Northwest

or can it grow in other areas as well? Can we use more than two sources to answer the questions in the assignment?

Analysis of Information Needs

During the search students pondered over issues such as: Do I want to get information about each question separately? Do I need to have the text and the picture on the same site?

Planning a Search

Answering questions such as: How to start? What to do next?

The interactive nature of the Web supported the students' belief that the progression of a search would be largely determined by what they saw on the screen, and that there was no need to plan ahead before they could see what was there on the Web. This principle was clearly reflected in their searching behavior, which was highly reactive. Yet, even though they claimed to have no plans, and most explained that they did not prepare for a search at all, they all had some idea how they would start to search.

All searches began with clicking on the search button after entering a string of characters, either keywords or a URL, most without selecting a search engine. No student had started a search by clicking on a subject category. To some students, the easiest search was a URL search, when the class assignment designated which sites to visit. Such assignments required no preparation at all, one just had to type in the address. A subject search, however, required some preparation. When no URL had been given, some students prepared themselves by thinking about the subject. One student explained: "I don't write anything down on paper; I'm thinking in my head, in my mind, 'Okay, this is what I need to look for, so as soon as I get on there, I am going to search for blah blah blah, and see what I get.'"

For three students, subject searches meant a bit more planning. One claimed that he always liked to get a couple of ideas in his head about what he was looking for and just try to type in the topic, and if that one didn't work, he would try the other idea. Another student explained before embarking on a search that he would start with a name, and if it didn't work, he would make the search more specific by adding words in the search box. The third believed in the opposite approach. He first used the most specific combination of terms. He appeared to plan the search while typing and before clicking, assuming that the more specific the statement in the search box was, the more likely he was to find good sites.

Planning took place also in the middle of a search when students decided to start a new search. A new search required new search terms, and

students were very resourceful in finding such terms given the limited knowledge they had in both the subject matter and the search system. This was probably the most challenging and frustrating part of a search, and one that required most help.

At times students made attempts to express the same concept in different ways, and at others they started a new search with a new topic. Some students always entered the search terms that were given in class and would rather change the topic, say, look for another plant, than try to express the concept in different words. For those, a new search was always about a new topic.

Students who attempted to keep to a topic used two tactics:They entered more terms or different ones, and they typed in spelling and orthographic variants.

Comparison of Search Results with Need (evaluation)

To assess if the information retrieved is relevant to a particular question, students looked for the terms they entered. If they found them, they felt more confident in the text. Because of their lack of knowledge in the subject domain, they could not always decide whether or not the information on the screen indeed answered a question. They frequently asked the librarian or the teacher to tell them if the sentence on the screen answers a question they were trying to answer. For example, whether or not a certain sentence explains the growing specific of a rose.

Students recorded information of any type as long as it could answer the assignment's questions. Many sites retrieved for the plant assignments were commercial in nature, and were geared to the gardener, rather than to the student in a science class. Nevertheless, these sites often included information that was relevant to the assignments. For example, one student in response to a question about the growing specifics of Mistletoe wrote: "Grows by vibrating in coastal breeze." Another recorded on his assignment sheet that the Blueberry bush "makes a nice hedge," as an answer to a question about the uses of the plant.

Students also used the assignment requirements as filtering criteria. One student, for example, would not view any page that did not have graphics if the assignment required a picture of a plant. Content was not the only consideration; she was looking for a Web page which would best help her complete the assignment.

Dedicated to their aim to complete the assignments, almost all students made quick decisions about where to click next, and whether or not a site was relevant. Most scanned sites fast before they clicked to move to another.

If there were too many sites to look through, or if there was a lengthy text on the page, most students usually skimmed quickly through and then moved on. Situations where many sites had been retrieved, but none of those opened first were helpful, were frustrating. Students did not have much tolerance for long lists on the result page and moved to another place. As one of them explicated: "They are just giving me the run around."

Thus, searching for information involved much clicking and moving swiftly from one site to another. To keep up the pace, some students usually determined the relevance of a site by what appeared on the first screen of a site. They rarely scrolled down to the bottom of a Web page.

To uncover the clues they used to help them scan the information on the screen so quickly, the team asked the students to explain how they determined the quality of the information on the screen. Although a couple of students had difficulties articulating their criteria, we discovered that others employed methods to assess the potential value of the information on the screen quickly.

Most students used the graphics on a page as a clue to relevance and quality. As one of them explained: "If it looks like a good picture, I'll read it." While it was difficult to define the meaning of "good" in this context, one student claimed that pictures can give hints of what the page is about. Another student provided an example: "It depends on what you're looking for. Like if I wanted to look up music, I would type in "rock music" and the home page was a bunch of guys with guitars and the drums, and I like rock music, that's going to interest me to go to the next page and see what it is. But if I say "rock music" and all I see is an album cover, I'm hesitant to keep going."

In addition to the graphic clues, some students used the amount of information in the site as a quality measurement. They wanted a site to include all the information they needed. They did not want to spend time on sites that were only one paragraph, or gave only basic information but no details. The horticulture teacher had a similar approach. He said that he evaluated a Web site by whether or not it included the information he had expected it to include, and also by the graphics.

Choice of Information to Write Down

There was no selection of which relevant information to write down. The moment a student found a piece of information that seemed relevant he wrote it down. Usually, the students did not have several sites from which to choose.

For an efficient completion of the assignments, students most often copied the relevant lines from the screen directly to their assignment sheet or their note paper (which was used at times as the final version of the assignment to hand in). On very few occasions did they print out text, and usually not before they read the text carefully on the screen to make sure it included all the information they needed for the assignment. They printed out pictures only when the assignment asked for a picture of a plant.

ACTIVITY ANALYSIS, MENTAL STRATEGIES

Possible, effective strategies which *can* be used for decision functions and related resource requirements. Defines the *content* of communication.

To probe the students' preference and opinion about search strategies, we asked them to describe how they would explain to a grade-school student how to search the Web. One student maintained that he would teach by actually showing how to search, but added a general principle. Being concerned that a grade school student might be afraid of the computer, as he himself had been, he repeatedly emphasized the importance of assuring t-he novice that the search is simple and keeping it so. His recommendation: "Just go with the flow; just click on something."

The remaining five students were a bit more specific in their instructions. Four of them explained that a search would begin with typing in a word or a topic. One of those students suggested to precede the topic search with the selection of a search engine. The fifth student suggested that it is best to type in an address because then one can go directly to a site. His advice was to be aware of the addresses of sites while searching, and possibly writing them down, because one may want to go back to a site. The same student also observed that, when searching by topic, one should start with the most specific terms possible. The next step, they all explained, was to click in the results list on the title that best fitted what one was looking for.

Generally, students had difficulties describing search strategies. Only one student addressed the dynamics of the search process: "If you want to go back, press the button up here and you go back a couple of times, go home. Maybe you want to look at a different [site]."

Browsing

Intuitive scanning; following leads by association without much planning ahead.

Students use browsing very heavily. To support their browsing they tried to use landmarks. With a vast territory to cover on the Web, students boldly

forged ahead clicking on new links and looking for new sites. Yet the back button was used most frequently in almost all the searches we observed, because students spent a considerable amount of their searching time going back to safe and familiar sites.

The progression of a search was rarely linear with each site leading to one new site. A typical search progressed around a home base, or a landmark, to which a student would return to continue the search. Arriving at a landmark, students started an excursion in search for information. When they got lost, they returned to the landmark, using the back button, to start a new excursion. Students explained that when they got lost they clicked back to find home, their comfort zone, or their starting point. One student said she would click the home button if she thought she was too far away from the landmark, rather than going back step by step clicking the back button. Another explained: "I click back or click home ... until I can find out where I am."

A landmark could be changed during a search, and one search may have more than one active landmark. Some students used the same landmark for all their searches, such as the result page, and for others it was different for every search, they might select, for example, the last site that was useful, or a site with a search box. But students always used a landmark the same way: as a home base to which they could go back to get their bearings and start anew.

Several students used the result page as their landmark for most searches. Some clicked back to it, and others just started a new search with the same keywords, expecting to see the same results page as before. The latter approach usually did not work because search engines were selected randomly for each search and students received a different result page, with their landmark never to be found. Such situations generated anxiety and frustration even among the students who understood why they did not land on the same page. Thus, automatically changing the search engine during a search is not always beneficial to the searcher.

Although not always articulated, it seemed that having landmarks in a search was an important safe guard. One students explained: "I have a thing with like traveling everywhere, and then I will just forget where I was before, and then I can't find my way back, and that's the hardest thing." The fact that most students began a search with either keywords or a URL they had used before can also be interpreted as evidence of the students' strong need for a familiar home base.

Students frequently identified their landmarks through graphical clues. This they expressed in various ways. One student, for example, was clicking

back to "the one with the moving feet." Another student frequently selected as landmark sites that included a graphical search box, that is, a window and a button next to it. Yet he let sites with "Keyword Search" links pass by. In one search a student spent considerable time exploring unproductively a "wrong" site because it had similar graphical features and was also linked, to the landmark.

The Analytical Strategy

Explicit consideration of attributes of the information need, and of knowledge domain.

Students rarely used the analytical strategy, When they did, it was usually in the selection of new terms to use in a search. Entering additional words usually resulted in a more specific search, but students rarely searched for a topic more specific than their original topic. When a search for "onion" was unsuccessful, for example, a students entered "origin of the onion," which was one of the questions on the assignment sheet. Not all multi-word search statements were more specific, however. For instance, in the same search for information about the onion, which responded to the assignment about a plant from the Northwest, the student also tried "fruits of the Northwest"--a concept intended to be broader than onion. Whether narrower or broader terms, all were within the topic of the assignment.

When students entered different terms altogether they were either more specific or more general, but they were always within the confines of the assignment. After a search for "Northwest plants" was unsuccessful, for example, a student entered "Idaho plants"--a search that could still find a Northwest plant because Idaho is part of the Northwest. Finding such new terms presented a challenge to most students. In a search about the Oregon ash, for instance, a student wanted to enter a broader term such as "Oregon trees," "Oregon bushes," or "Oregon flower," but she did not know what kind of a plant would be correct in the ash case.

With such limited knowledge, a student might be ready for radical actions. Indeed, one student changed his whole search strategy because of a fruitless search. In the search about a Northwest plant, after repeatedly using the same strategy "<state name> plants," and coming up empty-handed, he decided to step back and try to obtain the information from a different angle. He decided to use the simple term "plants," find a plant, figure out what state it was from, and then go from there. Most students, however, tried a new search with spelling and orthographic variations. They changed the order of words in an expression, switched upper case letters to lower ones, or changed the spelling of a word.

The Empirical Strategy

Based on previous experience, using rules or tactics that were successful in the past.

Learn from past experience. Several students assumed that a previous successful search should guide them in a new search. In addition, past experience taught them which is the best way to start, and some would usually begin a search with a URL, and others with keywords. Frequently they entered a URL to a site they had visited before, or keywords that had worked well in a previous search. One student, for example, started a subject search with a URL that was given in the previous assignment, even though the URL was for a local daily newspaper and the new assignment asked students to find horticultural information about a plant. Another entered several keywords he had used in the previous search, even though the new assignment provided URL's and asked students to evaluate their sites.

Learn from others' experience. Most students were glad to be told where to start searching, that is, what were the best words to type in the search box. At times, they asked classmates for suggestions, or volunteered information themselves. A few students, however, used that approach as a strategy, and would not begin a search before they asked the teacher, librarian, or classmates where to start. This strategy, they assumed, would support efficient searching.

With no formal training in Web searching, most students had no information about the various search engines. Two were exceptions that stood out. One student always started a search with selecting the Webcrawler because this was the engine she learned in the Computer Applications class. She also changed search engines to speed up a search, a move that seemed to work, but she did not know what the other search engines were, nor their characteristics. Another student had very definite ideas about search engines and their attributes. He explained that Yahoo!, for example, is for entertainment and Magellan or InfoSeek are for more scientific material. When searching, he mentioned a couple of times that he could choose another engine, but in reality he always used the search button without selecting a search engine.

When all landmarks had been exhausted with no satisfactory results, and usually before, students went back to the initial page to start a new search. The teacher supported this approach whenever students asked him to help. He explained: "I've found, if they have a window that's not giving them very much information or not even in the right place I just go right back to start. I say, Let's back all the way out of this and start over. Because I feel, for

myself, that's my comfort zone... Let's go back to word search and try it again."

In addition, students who taught themselves Web searching did so by looking for information about various sports and entertainment fields in which they were interested. One student, for example, found out that if one cannot retrieve anything about a topic, one should try a related topic and the retrieved pages may include information about the original topic. He discovered this searching "trick" when looking for information about baseball players. Another developed some basic strategies when looking for sites about rock music.

Known Site Strategy

Based on understanding the structure of a URL, entering one to retrieve a site.

One student, for example, started a subject search with a URL that was given in the previous assignment, even though the URL was for a local daily newspaper and the new assignment asked students to find horticultural information about a plant.

Similarity Strategy

Find information based on a previous successful example that is similar to the current need.

Students wished they could use the similarity strategy but they did not know how to execute it, or there were no technical functionalities to enable them to do so. When looking for information about a plant from the Pacific Northwest, a student could not find enough information of the plant she selected. She wanted a similar plant for which she could get more information. Another assignment (different from the one discussed here) asked for pictures of five plants. A student found a picture of a tulip and wanted to do a similar search to find pictures for the other four plants.

Criteria for Strategy Choice

Choice of strategy will depend upon performance criteria. What determines the way you look for information? Examples are: time, intellectual effort, fun, get better results than my colleagues, impress boss, social interaction, learning new things, confidentiality, reliability or availability of information (least effort).

Social acceptance among students, High grades, Impressing teacher or librarian. These examples can be used for probing users.

The students in the study were very focused in their searching. They wanted to save time and intellectual effort.

Regardless of their beginning strategy, all searches, from initiation to end, were highly focused. The purpose was to find lines on the screen that would answer the questions in the assignment. In other words, students looked for information to fill in the assignment's "blanks" and did not deviate from this task.

This assignment-centered approach was manifested in a variety of ways. The assignment sheets guided all searches, and students constantly referred to them. Students kept exploration to a minimum, and resorted to this path only when they assumed it to be useful for finding missing information. Similarly, they ignored entertaining diversions on the screen, such as moving images or scrolling news reports, because these usually did not contribute information relevant to the assignments.

In hope of finding an efficient route to the answers, some students took a conservative approach and consistently followed the teacher's instructions for the first search strategy, whether or not it coincided with what they would have done on their own. One student, for example, started a search with the school library's URL, saying "I think that's where they want us at," even though he regularly started a search with keyword searching. Another, closely followed what the teacher wrote on the blackboard and entered "Ash (Oregon)" in the search box even though he did not think the Web would have it the same way.

In some searches students took somewhat drastic measures to stay within the bounds of the assignment. For instance, they changed the topic of their search if they could not find the needed answers easily. This was clearly manifested in the two assignments in which the students were asked to choose a plan and then look for information about it. During the search, it was not unusual for them to change their mind about the selected plant if they thought they could not find the required information about the chosen one. In fact, some students tried several plants, one after the other, before they completed their assignment. The most important task was to find the information requested; what specific plant was involved was a secondary Issue.

Resource Requirements for Mental Strategies

Strategy	Time	Memory Load	Domain Knowledge	System Knowledge
Browsing	Much	Little	Little	Little
Analytical Strategy	Much	Much	Average	Much
Empirical Strategy	Little	Little	Little	Average
Known Site Strategy	Little	Little	Little	Little
Similarity Strategy	Little	Little	Much	Much

Figure 9 shows the difference in mental efforts to be used in different search strategies.

This Table report the resource requirements for each strategy that the students could have used. It clearly explains why the participants in the study, who were novices in both horticulture and Web searching, used most frequently the browsing and empirical strategies. Both can be executed with little or average knowledge about the domain and system and they require little mental effort. (AMP + RF: look in the overheads with remarks (the original ones), and see if we want to add explanation to the table.)

Mental Models

Can you explain how the Internet works? Please draw a diagram or picture of it?

When asked how the Web works, two students simply declared that they did not know. Among the remaining six, four thought that a central body deposits the information on the Web for the rest of us to search, and only two suggested that users can be authors as well. As one of them explained: "There' s like a master program or something and everyone just puts information in, and it can be sent out to all the computer systems that hook up to it." The other emphasized the existence of a central place to which all individual contributions were delivered, and this place then sent the information to all users' computers.

Given that Microsoft donated the computers the students used, and that they were searching with Microsoft's Explorer, it was not completely surprising to discover that half of the participating students believed that Microsoft was responsible for the information on the Internet. Four students

assumed that Microsoft collected or generated the information, and stored it on its computer, but their opinions varied about the control that was exercised by the company. While two saw Microsoft involvement on the technical level only, the other two suggested that the office of Bill Gates selected the information on the Internet and directly monitored its use.

ANALYSIS OF USER CHARACTERISTICS, INDIVIDUAL ACTORS' RESOURCES

The cognitive resource profile: education, skills, competency, level of expertise and subjective preferences.

Relates mental models of strategy with levels of expertise/resources and identifies performance criteria; which strategy *will* be used? Defines the *form* of interface communication.

Students

The librarian explained that students' knowledge of searching depended on how much the teacher who assigned work on the Web introduced them to searching. Indeed, the team found out that none of the students who participated in the study ever received formal training in Web searching. Half of them took a Computer Applications class, but only one student recalled learning something about the Internet. Similarly, half had computers-at home, but only one with Internet access. Most of the other students had access to a computer in the public library or in a friend's or a relative's home. Generally, all the participating students had experience with using computers in other classes, and all but one had searched the Internet for that purpose.

The eight students who participated in the study were typical of the three were in 11th. The six boys and two girls were from varied ethnic backgrounds, and half said they planned to go to college, three to the trade, and one to the army. Some of the participants had more experience with computers than others. Some were expert surfers and others surfed only occasionally or had no experience in surfing. Although all had used the Web for class assignments before, they had very little experience in information retrieval and had no knowledge about the subject area. Most did not like school most of the time.

Several participating students had experience with surfing and chatting on the Web. The task the research team observed them carrying out was very different: finding information for a class assignment. In other works, the team observed teenagers who had spent much time window shopping and hanging out in the information mall. Now their task was to get particular

items for their teacher, items about which they had heard for the first time A description of their searching behavior follows.

Students' characteristics
Educational background: grade 11 and 12 (age: 17-18)
Gender distribution: two girls and six boys
Varied ethnic origin
About half were college bound
Varied computer experience
Varied experience in Web surfing
Little experience in information retrieval
No experience in the subject domain

Figure 10 shows the characteristics of the users, who are high school students.

Teacher

Teacher believed that formal training in a classroom setting would have been highly beneficial. Unfortunately, no resources were available to carry out such training. He himself had very minimal experience in searching, and he wished he could have had time to built into his day to learn and practice more.

That is, the teacher had little Web knowledge. The depth of his domain knowledge is unknown.

Librarian

Librarian had received some training m the use of the internet, but she believed in hands-on learning: "The more time you have your hands on it," she explained, "the more it makes sense." She thought students did not receive enough training, and she did her best to guide and train them on the spot. Often she personally trained a student on a one-on-one basis. The pace usually became hectic, however, when many students needed help.

Commenting on President Clinton's inaugural promise that every 12 year old would be able to log into the Internet she said "Logging onto the Internet is not the deal; it's finding information on the Internet." Therefore, she promoted library and Internet use among teachers as well as advocating training for students.

That is, the librarian had average Web knowledge and little domain knowledge.

Individual Actors' Preferences

One of the great advantages of the Web, they explained, was the ease and speed of use: one could just type in the words and then click; no thorough preparation was necessary. In fact, one of the reasons students preferred the Internet to the school's library, they claimed, was just that: immediate access to information. One student summarized this approach: "It's easier on the Web, especially if you're lazy. It's easier because ... it's just sit and click, ... and just see what you get." Another elaborated: "[In the library,] first you have to find out what you're looking for. Like, maybe I want a book on baseball. Got to go through the card files, find the baseball, go through all the aisles, look for the book. It's boring! With the Web, just type 'baseball' and it just gives you a whole bunch of information about baseball."

Regardless of what portion of the assignment was completed during a session, students were always satisfied with their searches and the results. While they could point to general problems with Web searching, they never felt that they could have done a better search. In fact, when asked in the interview if they would like to learn how to search the Web better, most students thought they already knew what they needed to know, at least for that time. Some mentioned that maybe in the future they would be interested in learning more about Web searching.

In spite of the frustration that can be brought by Web searching, the students who participated in the study enjoyed searching the Web for several reasons.

Students mentioned that they liked the Web because of the diversity in formats and levels of specificity on the Web. In their searches for the horticulture class, for example, they found scientific as well as popular and commercial sources and appreciated being exposed to this variety. They liked the way the Web gave details of certain things one found and the interesting little sites they could look at, and they believed that the Web had all types of information.

Some students liked the Web because it showed pictures, and others liked it because of the multitude of subjects it covers. "It has everything about everything," they said. A couple of students enjoyed the Web because they felt it made them able to go around the world and look for anything, and then to get to see things and learn about things they never knew about.

To better understand the students' opinions about the Web, we asked them to compare library and Web searching. We also asked them to explain where they would look for information for their next assignment. All the students who participated in the study said they would use the Web for their next assignment. About one-half said they would go to books as well, either

after they finished extracting the information from the Web, or because they already knew certain books that could provide the needed information. It is important to remember that these students volunteered to participate in a study which required them to search the Web. Their response, therefore, might not have been typical of students in their class.

The main advantage of the Web over the library was the ease of accessing information. Following the law of least effort, students explained that one might need to look in several books to find information about a topic whereas all the information was in one place on the Web; it was in the computer. This one-stop-shopping convenience of the Web was extremely appealing to most students. But Web searching can also save physical efforts. If one closes a book, one needs to look through the index or table of contents and then turn pages to find the desired page. On the Web, one can just click and get back to that page.

Students also believed that information on the Web was more up to date than in books. This made sense, they reasoned, because it was very easy to update information on the Web, as opposed to publishing a new book. This argument, if not new, has played a central role in advocating the use of the Internet for students' homework because most school libraries are underfunded and are likely to have books with out-of-date information.

Students liked:
To surf the Web
That they could find information faster than in the library
That it was easy to search; just type and click
That all topics were in one place
The pictures and graphics
That information was updated
The access to sites from all around the world
The access to different kinds of materials
The access to material with different levels of specificity
The results they got on the Web
But, they got disenchanted with information retrieval on the web, and said that next time they will use the library as well

Figure 11 shows the students' preferences and the features they liked on the Web.

Organizational analysis, allocation of Roles

The purpose is to know how is the workspace is divided, how the work functions or specialization are divided.

What is divided among staff members and the students? Workspace, work functions or specialized work processes?

How is it divided, criteria by which people share work ? By organizational tradition, union agreements, work load, functional decoupling, skills, information access, social values and conventions, self-organizing interaction and allocation of roles ?

Identifies the shared information *content* for communication on task coordination

Role Allocation in the Task Situations

For the participating students, searching was both a social and an academic event. They conversed with one another while searching, asking questions and giving advice. The teacher encouraged this mutual assistance. Their interchanges covered many aspects relating to searching, ranging from technical pointers to tips about searching to interpretations of the questions in the assignment, and all intertwined with social intercommunications, mostly verbal, typical of students their age. These interactions made the computer room a lively and busy place.

Students: searched and gave tips to one another

Teacher: Explained the assignment; gave tips on how to search; and gave help during search about both content of assignment and how to search

Librarian: Gave tips on how to search; gave help during search about both searching and the assignment

It is clear that there was very little role allocation for this task situation.

Role Allocation in the Cognitive Decision Tasks

Students:

With all these obstacles to searching, it is not surprising that the students actively and constantly asked for help whether from the teacher, the librarian, or their classmates.

During the observed searches, the librarian and the teacher made themselves available to students. The librarian was busy all the time circulating among students and helping them. When looking for assistance, students most often asked whoever was closest to them, which frequently was another classmate because the librarian was helping someone else. In

reality, there was only one librarian but plenty of classmates around who might have the answers. The students explained, however, that their first choice for help would be the librarian.

Almost all students wanted to receive most directional and specific help. However, one explained that she would have preferred to be guided so that she would do the search herself, and two clarified that by observing how the librarian solved their problems they could learn new strategies that would help them in future searching.

That is: Students made all the cognitive decisions with no role allocation among students.

Teacher:

No formal or explicit role, instead a number of heuristics had evolved during practice.

Librarian:

No formal or explicit role, instead a number of heuristics had evolved during practice.

All along, both teacher and librarian gave ad-hoc tips related to all cognitive decision tasks, and so did the students among themselves.

SOCIAL ORGANIZATION AND MANAGEMENT STRUCTURE, STYLE AND CULTURE

Management style, hierarchically, authoritative or democratic, or culture values, social conventions. Identifies the form of communication, how do people communicate during the task performance?

The data collected in this study is incomplete, and cannot provide much insight into this dimension. We did not investigate the school's management style and culture even though it definitely affected the way the teacher organized the work on IT-related assignments. Here is the information we did collect.

It was the principle's attitude that the Web is just a tool to be used in the class like any other tools. This teaching therefore did not have special resources, but it was considered to be important for the image of the school and for the students qualifications and job possibilities after school. Very little financial resources were availble and dedicated to this special educational initiative.

Very little organization of tasks was found among the librarian, teacher and students.

There was very little organization of cooperation among students, and among teacher, librarian and students. Organisation of tasks and cooperation did not seem to be an issue that was discussed, but it semed to be part of the

cultural style at the work place that teacher, librarian and students would offer their help and assist as the need for help appeared.

Thus, both teacher and librarian encouraged cooperation of any kind.

Section D

EVALUATION OF IR ON THE WEB

Introduction

DOES SYSTEM MATCH USERS' RESOURCES AND PREFERENCES?

Students were very aware that spelling, in a URL or in a search term, could make or break a search, and they frequently checked their own spelling. Yet, difficulties with spelling prevented more than half of the students from pursuing a desired path at least once during the observed searches. Most encountered difficulties in spelling URLs, some of which were long, included both letters and numbers as well as unfamiliar strings of symbols. Several times students gave up trying to go to a promising site because of these difficulties. In addition, there were instances where students did not type in a term full of promise because they did not know how to spell it.

To add to the students' frustration, the search system and some sources had obscure rules that interfered with searching without any explanation. For example, a search for "Ash" produced an "error" message because the source did not accept search terms with fewer than four letters (the team discovered later). The same horticultural source had no matches to "water lily," a term which the student entered with several orthographic and spelling variations (this is still a puzzle). Another barrier was the categories used in certain sites which did not correspond to the assignments' questions. This was specially apparent when some sources were designed for gardeners looking for seeds or gardening ideas and suggesting links such as "flower color" or "bloom season." Such links were obviously not helpful when students looked for academic information about flowers of the Northwest.

About half of the searches were completed in one session. For the rest, students needed to look for some more answers. Some explained they would perform another Web session later on, but most unfinished searches continued with books. As the course progressed, students became aware of useful print sources that were either recommended by the teacher or by their classmates. They knew which print sources in the library included the information they needed for the assignment and had an idea of what type of information each source had. Some decided to switch to these printed sources instead of searching the Web, and others wanted to complement Web searching with information from print sources.

As reflected in their searches and attitudes, one of the most appealing qualities of the Web to the students was the speed in which they could find information. It is no wonder, therefore, that their greatest frustration was caused when the Web failed to produce results quickly. This happened when

response time was too long or when they could not find the information, even though in their opinion it was there.

All students understood that searching the Web required patience. Yet they all were highly impatient with slow response. "This is making me mad!" or "I don't like to use the Internet because it's slow; I hate it!" were typical and immediate answers to our question about problems with searching the Web. It was not uncommon for a student to abandon a search and begin a new one if a response did not appear in a reasonable time.

Similarly, students were frustrated, and at times impatient, when a search was not successful after what they thought was a reasonable time. "It is frustrating when you cannot find something that you're looking for," explained one student, and another mentioned that it was particularly difficult when one knew the information was there but one had to search and search and search.

Some students became highly irritated when a click on a link brought them to a site under construction, to one that had been moved, or when a browser could not open a site. "I hate it when they have something up there and it ain't there" asserted one of the students after he patiently waited for a slow response which led to a dead end. "If they don't have it, they should take it off" he declared. An additional hurdle to fast searching is the public nature of the computers at school. Although West Seattle High School was relatively endowed with computers students at times had to look for a free computer or to wait till other students were finished. With strong feelings about the lack of immediate access, one student protested: "There are too many people in there and you gotta wait forever just to get in or you just can't get into it. That's foul."

Another hardship for some students were the URLs. Some were difficult to type, and a few that were given to them were simply wrong. While these might appear as minor technical problems that could easily be collected, they were a major source of frustration because they brought a feeling of helplessness. There was no way for the students to work around or reason through problems such as these.

That is, students had problems *with*:

Spelling and typing “long” URLs.

Understanding the searching vocabulary. For example, they did not understand what “keyword searching” meant but knew that a window and a button is a search box.

Understanding the searching rules of a particular site. This was an important issue when a query retrieved zero hits.

Reading a homepage at a glance.

Understanding the functions of scrolling a homepage. They often did not scroll beyond one screen of a page, and thus missed the bottom of pages.

Understanding what the site is about after looking at the homepage.

Understanding the meaning of links (or to what they would lead). This was particularly a problem when the links used vocabulry that was different from the one in the assignment.

Having no information about what strategies were available.

Having no information about what strategies were available.

Navigational links when they were at the bottom and thus were not apparent and easy to miss. This made it difficult to browse, a strategy that was heavily used.

Planning a search because there was no representation of search strategies.

Understanding the role of the different search engines. For example, one of the students thought that Yahoo! was for subjects related to entertainment but InfoSeek was for science-related searches.

Having no information about options in analytical searching. For example about Boolean or proximity searching.

Navigation because they could not find out where they were in a search as a whole. They could not see a trail of their search in one glance.

Students had problems *when*:

URLs that were given to them were wrong.

Homepages did not reflect the information in the site.

Homepages had attractive features, but sometimes they did not reflect the content. Students had to browse through a whole site to find out that it did not have information about a plant that they selected, but about another one instead.

There was no information about the subject domain of the site on the homepage.

The homepage included no words that were entered as keywords

Students got confused then because they did not understand why the homepage had been retrieved.

A homepage did not have graphics.

The representation of information on a homepage was cluttered.

Response time was too long.

A link brought them to a site under construction, or to one that had been deleted.

It took them too long to find the information they needed.

They had to wait before they could access a computer.

Does System Functionality Support Users' Strategies?

Problems with Browsing

It was difficult to browse when links on the homepage did not relate to the task domain or subject. For example, when they arrived at a gardening homepage which used language that was different from that used in the assignment.

All the time, they were getting lost during browsing because of the large amount of links.

Problems with Analytical Strategy

When trying to conceptualize the search within the subject domain, they were in trouble. Finding new terms presented a challenge to most students. In a search about the Oregon ash, for instance, a student wanted to enter a broader term such as "Oregon trees," "Oregon bushes," or "Oregon flower," but she did not know what kind of a plant would be correct in the ash case.

Problems with Empirical Strategy

This occured, when a previous tactic did not produce the same results. For example, they often entered the same search term to go back to the beginning of a search. Because the browser selected search engines randomly, they never got back to the beginning of their search, but instead had to start a completely new search.

It was not clear if students always recalled tactics and rules that could have helped them.

Problems with Known Site Strategy

When a URL included unrecognized string of characters, they lost control of writing the address. They had problems when trying to look for a homepage by attributes others than a URL. For example, when trying to locate a homepage by the graphics it had, the layout or the color.

When looking for a landmark. Landmarks are usually recognized by graphical features, but students had difficulties at times finding their landmarks when they used the *back* button.

Problems with Similarity Strategy

Not supported at all. Some search engines support similarity search by topic, but no support by any other attributes. For example, there is no support if someone wants to find a similar picture for a different flower.

Strategy Shifts

They had often problems in applying a strategy and therefore shifted to another strategy. Most searches started with the empirical strategy and shifted to browsing.

Problems with Shift of Strategies

Sometime they rapidly changed topics, or the search engine, because they could not shift to another strategy. It was difficult to shift from browsing to analytical, or any other strategy, without starting a search from the beginning

Navigation

It was difficult to figure out where one was, where one is, and where are one's landmarks, and where can one go.

Two students suggested improvements in navigation, so they could go directly to where they needed to be. One even declared that she did not like to browse. Although both were unfamiliar with concepts or terms associated with navigational structures, one suggested a hierarchical structure using an example, and the other asked for clustering within lists of results.

DOES THE SYSTEM SUPPORT COGNITIVE DECISION TASKS?

It seems they believed that the librarian knew all the answers. In addition to questions about how to find information, students asked her questions about the assignment and about the topics they investigated. These were common questions "Does this sentence talk about the uses of a tulip?" "What is the difference between yellow lily and water lily?" or "Did I do enough to finish the assignment?"

Most frequent, however, were questions about how to find the information they needed for the assignment. When students asked for help, most often they wanted to step back and let someone else direct their action. Some also believed that the librarian knew exactly where the information was and could lead them directly to it. Students, therefore, asked questions such as these: "Where do I go from here?" "What do I type here?" "Where am I supposed to go, what page?" "Which URL should I try?" "Where should I start?" or "What do I need to do to get the information I need?" They also believed that the

librarian knew what were the best sites for them. One student remembered in the interview: "When I was looking up flowers, I'd go in the flower place. But ... [the librarian] suggested something better that you could probably find more information. She suggested me to go in the Virtual Garden, and there was more information there, so I thought that was helpful."

A testimony to this difficulty surfaced during the searches we observed when one of the most challenging tasks was to find a picture of a certain plant. Students arrived at various sites with pictures, but often could not find the specific picture they needed. Because they saw pictures of other plants, they assumed that a picture of their plant must be on the Web, but they often could not find it.

Yet, one student observed that harder questions are easier to search on the Web than easier ones. His experience in the class taught him that if the assignment was about a well-defined and specific topic, such as a Latin name or the growth area for a certain plant, it was difficult to answer; but that it was easier to search for information about more general concepts, such as how an information source was laid out, or for those concepts for which they could use their own decisions and judgements. In other word, it was difficult to find information on the Web if one knew what one wanted, but if one was not completely sure, finding information was easier because one could decide what is relevant based on what one could retrieve.

One student claimed that whether to use the Web or a book depended on the nature of the question. He explained that if he needed to find some information about, say, Martin Luther King, the library would have a book, and it would take him two seconds to find, say, King' s exact date of birth. But to find the same information on the Internet would take several trials and much clicking

Among all the praise for the Web, one student suggested that it was easier to find pictures in books. He mentioned that if one used an encyclopedia, for example, one would most often find the picture needed, which was not the case with the Web.

Several of the participating students also had experience in surfing the Web. They all agreed it was much more fun when they were not there to look for a specific thing. They definitely preferred to have the time to go there to just surf and not to have to concentrate on one thing, like an assignment for a teacher.

A third student lamented the large amount of useless information one encountered on the Web. He felt that some central authority should develop standards or guidelines by which all Web pages would be evaluated and approved before publication online.

In summary, students had difficulties in:

Analysis of the Assignment

Students had problems in understanding the assignment. For example, what sources can they use for the assignment? Are they allowed to use an encyclopedia?

Problems in understanding the topics of the assignment was another issue as the students had very little domain knowledge. For example, what was the difference between "Yellow Lily" and "Water Lily" when the assignment asked for a picture of a water lily and the student could find only a picture of a yellow lily.

Analysis of Information Needs

The students had many problems before and during searching with analyzing information needs. When they were thinking aloud they addressed this issue frequently and also asked for help from librarian and teacher. They had problems with analyzing the information need. That is, problems with understanding the assignment with all of its components, and the attributes for which to search.

They had problems in having no information about what strategies were available. They had problems when trying to retrieve by a specific attribute (e.g., a picture of a plant). And they had problems in knowing what type of resources are available in horticulture.

Planning the Search

There was no planning before the search begun. There were many difficulties when planning during the search which generated many requests for help from librarian and teacher.

Comparison of Search Results with Need (evaluation)

Because of their lack of knowledge in the subject domain, they could not always decide whether or not the information on the screen indeed answered a question. They frequently asked the librarian or the teacher to tell them if the sentence on the screen answers a question they were trying to answer. For example, whether or not a certain sentence explains the growing specific of a rose.

At times there were difficulties in deciding whether a certain sentence on the screen answered a question on the assignment, and students asked the librarian for help.

Confusion was a frequent reaction, when it was not clear, if the results corresponded to the keywords used in searching. This usually happened when the students could not find words identical to their query in the text of a retrieved site. They had difficulties in comparing a URL on the screen with the one entered.

Choice of Information to Write Down

There was no selection of which relevant information to write down. The moment a student found a piece of information that seemed relevant he wrote it down. Usually, the students did not have several sites from which to choose.

DOES THE SYSTEM SUPPORT TASK SITUATION?

The system did not support the teacher when he explained the content of the assignment. While not a retrieval problem per se, this is an important issue. How should the system support the teacher in this task? The study here did not address this issue, but other studies should look into the use of IT in teaching and education in addition to the role of IT in information retrieval tasks.

The system did not support the teacher or the librarian in explaining how to search when the assignment was first given.

The system did not support the teacher or the librarian when they helped students during the search. The teacher always told students to start a new because he was confused if he had to help in the middle of a search.

Students wrote down sentences from screen, word by word, on assignment sheet, or on a piece of paper. This took a long time. Also, they constantly had to check spelling.

There was not always enough space on the assignment sheet for the answers

DOES THE SYSTEM SUPPORT ROLE ALLOCATION AND COOPERATIVE WORK?

There was no functionality in the system that supported these but the teacher encouraged cooperation among students.

There was no communication over the Internet among librarian, teacher, and students. For example, when students gave advice to each other and suggested they see examples, they had to shout to one another but did not always see each other's screen.

Does the System Support the Work Context?

What impact did the Web have on the work context?

School's Goals

Did the students acquire skills in the use of IT? IT was integrated into the Horticulture curriculum but the library homepage did not correspond to the course.

But the circulation of library material tripled.

Teacher's Goals for the Assignments

Did the Web help students to learn more about plants? The assignment helped students very little to know what is on the Web on horticulture.

Did students learn to search and learn to use the web? It helped students very little to learn how to find information on the web. The students learned very little about Web searching.

Did the users accept the system in the work situation? Students accepted and liked searching the web when they had the freedom to decide what to look for, but had great difficulties when they needed to find specific, well-defined information.

Students became disenchanted with the Web for the work context because it took much time and required much mental effort, rarely with complete success.

It was easier to find specific information in a book than on the Web. They had to wait long for graphics to upload.

Section E

EVALUATION EXAMPLE : A LIBRARY SYSTEM

Introduction

EVALUATION EXAMPLE : THE BOOK HOUSE LIBRARY SYSTEM

Evaluation at the different boundaries of figure 5 can be illustrated by a selection of evaluation tests from the evaluation of a full-scale library system. The system design was based on a work following the framework for work analysis, and then tested in laboratory experiments, and evaluated at the work place within the framework boundaries of figure 2. Extensive experimental validations in the laboratory were performed to ascertain that the system could meet the work requirements before the evaluation of the system took place in the actual work context in a library. The subsequent evaluation of its use by the general public was thus an attempt to validate whether or not the system actually is the right design for supporting actual library users. The test took place over six months in a public library in order to evaluate whether the information system: 1) could be accessed and was accepted by the general public and professional librarians; 2) could provide the books asked for to the users' satisfaction; 3) would impact the library work in a way that was satisfying to the public and the professionals, and cost/effective to the organization.

USER CHARACTERISTICS

One of the tests conducted to pursue the first goal was an evaluation of the iconic interface at boundary 1 and 2 of figure 5. The efficiency of use, the comprehensibility of icons and the subjective user satisfaction was evaluated at the work place in a full scale prototype system by 1030 users, who responded to on-line questionnaires which appeared automatically on the screen, after the user ended his/her session with the system. The questionnaire adapted to the individual user's navigation trajectory and displayed those icons, which the user had met at the interface and actually employed during a search. It contained questions about the understandability of icons, which were used both as action buttons, and as a means to express the topics contained in books. Fifteen different icons used as action buttons were displayed together with a textual list of action possibilities, and users were then asked to select the action that would match the icon. Evaluation of the associative relationship between the message of the icons and the contents of the books in the database was measured on a scale that expressed the users' perception of degree of match. Finally, users' subjective

satisfaction with an icon-based interface was evaluated relative to a similar text based interface. The result of the quantitative test at the work place was then tested qualitatively by 75 observations and interviews with library users after they had used the system.

USERS' STRATEGIES IN LIBRARIES

Field studies of task strategies before the design showed that several different strategies were employed such as analytical search by attributes, search by analogy and similarities with previous examples, browsing strategies etc.. At the work place, 7100 on-line logging of all dialogue events (mouse clicks, etc.) tracked the users' strategy choice, and 220 questionnaires gave answers to their reason for choice of strategy, its ease of use, their strategy preference etc.. During use of the system over a longer time span, the analytical strategy became the most popular strategy: users and librarians adapted their strategy choice to the most effective strategy in the new environment. Field studies before the system was introduced showed that the analytical strategies were very rarely used in a library due to its high demands on knowledge, time, and memory resources etc..

DECISION TASK IN LIBRARIES

The second goal was pursued by an evaluation at boundary 3 (figure5) of users' subjective satisfaction with the books that they had retrieved from the database by use of the classification scheme. The classification scheme used had been developed from extensive field studies, and now the support of this classification scheme, its keywords and book descriptions employed for retrieval of relevant books was evaluated from structured questionnaires by 120 end users based on their reading of books. The most important performance measure was the precision of retrieved books based on users' comparison of the database classification of book contents with their own estimation of the book content and its relevance in a use situation.

WORK DOMAIN IN LIBRARY SYSTEM

Another type of experiments were used to pursue the third goal and aimed at an evaluation of the impact of a new retrieval system on user behavior and preferences, on the means and ends required and the impact on the total work situation. Professional intermediaries working with a new computer system in information retrieval and cultural mediation tasks reported in

questionnaires and focus group interviews at boundary 4 (figure 5) how the system changed their roles and left more resources for cooperation and a thorough dialogue with the users. The system supported their cultural mediation strategies, and allowed a shift to the role as a consultant analyzing task problems, evaluating the quality of alternative proposals, and assist in choice of solutions. Secondly, they reported how important it was for the professional image and pleasure of use that errors did not occur as the system supported exploration of alternatives, and no error messages occurred.

ORGANIZATIONAL WORK CONTEXT IN LIBRARIES

The possible positive or negative impact on quality of work and the system's potential deterioration of professional skills during changes in role allocation among users and librarians was evaluated at boundary 5 and 6 in figure 5. Whether the new system would lead to a simplistic interpretation of users' needs, an impoverishment of their reading experiences and, as well, an impoverishment of the librarian's domain knowledge. A computer logging of librarians' and users' use of the system was implemented and combined with focus group interviews with the staff and user groups. Both types of data were compared with records of librarians' and users' book descriptions from earlier field studies, to make sure that the database information exceeded in number and breath their book knowledge. This was done to make sure that both users and librarians through the use of the system would increase their competence and knowledge about the document collection.

The impact on cost/effectiveness was measured by the increase in number and distribution in loan of high quality books, as the ultimate institutional goal for public libraries is to promote education and cultural values. A more even distribution of book loans means more effective use of the book stock, which has economic implications for a library's costs for book acquisition.

Section F

CONCLUSIONS

Introduction

The work-centered framework for analysis and evaluation shows that once the evaluator takes into consideration all facets involved in an information retrieval task, evaluation is much more complex than an evaluation guided by the Cranfield-style approach. Unlike the Cranfield approach, in which the whole system is tested at once and with the same measurements, the work-centered evaluation touches upon many different facets. Each facet, sub facet, or combination of facets requires its own criteria for evaluation, and its own measurements.

In addition, the framework has several attributes that makes it a promising tool for the analysis, evaluation, and design of information system.

GENERALIZATION

The Framework facilitates the identification of patterns that are common to several work domains Because each work situation, prototypical user, and task are investigated with the same construct, it is possible to make generalizations when the same patterns appear in a variety of work domains. For example, many similarities were found between the searching behavior of the users in the BookHouse study and the students. In both studies, for instance, users employed graphics for recognition and recall and for relevance assessment. Another study of electrical engineers who used electronic filtering system also found the importance of graphic to these users. It is plausible to hypothesize that graphic representations of information are indeed important for information retrieval tasks because they help users browse and determine relevance.

TRANSFER OF FINDINGS

Using similarities between work domains or tasks, one can transfer design ideas from one system to another. A solution in one system can be transferred to another system because the analysis with the framework showed that these are the same problems. The study of Web searching of high school students suggest that knowledge tools, such as encyclopediae and glossaries would help them select more effective search strategies. This solution can be transferred to a case of concurrent engineering when engineers in the production side of a product have to deal with issues that relate to marketing.

comparisons of results from various studies

The framework provides the grid on which one can compare behaviors in different domains. For example, one can compare searching behaviors of different users in the same domain and task situation, or by the same users in different domain and the same task situation. This makes it possible to gain insight into the effect of each type of domain.

Researchers can also use comparisons in order to generalize over differences. Such generalizations are usually on a higher level of abstraction than the attributes being compared. For example, we can compare the value criteria used by the students and the electrical engineers with regard to filtering. For student it was most important to: give something to teacher so he is satisfied with their work. The electrical engineers wanted to contribute to their project and company. As described here, students and engineers had different value criteria. But both criteria had a common attribute: both are focused and well-defined criteria. One can generalize then and observe that searching for both groups of users was highly focused (even though different value criteria led to focused searching). The Framework facilitates such comparisons because it provides a construct that suggests points for comparisons.

POINTS TO NEW AREAS OF RESEARCH

The framework points to new area of research that need to be investigated that otherwise might have been overlooked.

This is because the Framework analyzes cognitive decision making, and considers all the factors that are involved in the cognitive processes and suggests investigating all of them. In addition, analyzing and evaluating with the Framework requires investigations in other areas such as interface design, or graphics. This combination of a work-centered, information-science driven approach to related areas (e.g., cognitive science, communication helps discover new areas of research. For example, the high school study suggested a new area of research: how people use graphics to infer the content and quality of the text that is attached.

POINTS TO NEW CONCEPTS IN RETRIEVAL SYSTEMS

Because the framework uses the cognitive approach, it is possible to analyze observed data independent of current technology and practice. This independence is necessary to consider new concepts in retrieval systems. Another contributing factor is the fact that all the constraints, and from all

points of views (user, task, domain), are explicitly enumerated. What is left after the constraints have been addressed is all the degrees of freedom to plan and design. In other words, because one looks explicitly and in great details at what one cannot do, one has a large freedom to decide how new concepts can be integrated into system design.

COMPATIBILITY BETWEEN DESIGN AND EVALUATION

The framework, which is based on the systems approach, provides dimensions that are used both for design and evaluation. For each dimension, one first examines the design possibilities, and then for each dimension finds ways to evaluate how the design performs in relations to the design goals.

ANTICIPATES THE EFFECTS THAT CHANGING WORK SITUATION WILL HAVE ON PEOPLE'S BEHAVIOR

The framework identifies explicitly the criteria that lead to each path of action. It identifies the criteria that form the basis of human behavior. This is possible because the framework is work-centered, it explicitly identifies all the constraints, and it asks "why" questions, not only "how." For example, the students who participated in the study used the empirical and the browsing strategies because their performance criteria were to minimize time and mental effort. With the new graduation requirement (a minimum grade in science courses), their performance criteria is likely to change. They may value high grade more than saving their mental effort. This is likely to change their selection of strategies, using the analytical strategy more often because although it requires more mental effort, it is more effectice in finding answers to the assignments' questions than browsing.

MAKES IT POSSIBLE TO RECOGNIZE FACTORS THAT ACTUALLY AFFECT SEARCHING BEHAVIOR

One of the problems in retrieval experiments that involve human subjects is the large number of variable that need to be controlled. When one attempts to explicitly account for all the factor that may affect searching behavior the number of factor become unmanageable very fast (Fidel & Soergel, 1982). With the framework it is possible to identify the factors that are important for each situation because it deals with prototypical situations, rather than an attempt at an exhaustive coverage of all possible situations. This enables the

evaluator and designer to deal with a manageable number of factor and to ignore those that are not typical.

CREATES A UNIFIED LANGUAGE

The framework has one construct to guide analysis, evaluation and design, it provides a unified language that facilitates communication and co-operation among the various experts involved in the design of a retrieval system such as IR researchers, database designers, software designers, interface designers, and indexers. All parties involved can examine a specific task situation in a specific work domain and with specific users. The boundaries in each dimension are well defined and, therefore, can be understood by all.

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References

FIDEL, R. 1984. The case study method: A case study. Library and Information Science Research, 6(3):273-288.

FIDEL, R. 1993. Qualitative methods in informaiton retrieval research. Library and Information Science Research, 15(3):219-247.

FIDEL, R. et al. In press. A visit to the information mall: Web searching behavior of high school students. To be published in JASIS.

PEJTERSEN, A. M. and RASMUSSEN, J. (1997): Effectiveness testing of complex systems. In: Handbook of Human factors and Ergonomics. Ed. by G. Salvendy, Wiley. In Press.

PEJTERSEN, A. M. (1996): Empirical work place evaluation of complex systems. In: Advances in Applied Ergonomics. Proceedings of the 1st International Conference on Applied Ergonomics. (ICAE'96), Istanbul, Turkey, May, 21-24, 1996. (Eds.): Ozek, Ahmet F. and Salvendy, G..USA Publishing Coorporation.

RASMUSSEN, J. PEJTERSEN, A. M. and GOODSTEIN, L. P. (1994). Cognitive systems engineering. (John Wiley, London).

PEJTERSEN, A.M. (1994): A Framework for Indexing and Representation of Information based on Work Domain Analysis: A Fiction Classification Example. In: Knowledge Organisation and Quality Management. Proceedings of Third International ISKO Conference, Copenhagen, 20-24 June 1994. Eds: Albrechtsen, H. and Ørnager, S. Indeks Verlag. Frankfurt. 1994. pp. 251-264.

PEJTERSEN, A. M. (1993): Designing Hypermedia Representations from Work Domain properties. In: Hypermedia. Proceedings der Internationalen Hypermedia Konferenz. (eds): Frei, H.P. and Schauble, P. Springer Verlag. Heidelberg.

PEJTERSEN, A. M. (1992). The Book House. An icon based database system for fiction retrieval in public libraries. In: The Marketing of Library and Information Services 2. Ed: Cronin, B., (ASLIB, London). pp. 572-591.

PEJTERSEN, A. M., (1992). New model for multimedia interfaces to online public access catalogues. The Electronic Library, the International Journal for Minicomputer, Microcomputer and Software Applications in Libraries. Vol. 10, No. 6.

PEJTERSEN, A. M. (1991): Interfaces based on Associative Semantics for Browsing in Information retrieval. Risø M-2794. p.143.

GOODSTEIN, L.P and PEJTERSEN, A.M. (1989): The Book House. System Functionality and Evaluation. Risø National Laboratory, Risø-M-2793.

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