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Introduction

The World Wide Web has implied an explosion in network-mediated information exchange. Its ubiquitous nature and technical strengths, in particular the flexible hypermedia document format and the general communication protocol, have given users a powerful infrastructure for sharing knowledge as well as for interactive communication. This has created new research questions with respect to how people conceptualize the Web, and how the use of this medium is embedded in their professional activities.

This chapter investigates implications of Web-based information exchange for people within knowledge-oriented professions. Our point of departure is a current project on knowledge, communication and context in electronic networks (KnowHow). People in knowledge-intensive professions, such as researchers, technical developers, teachers, and librarians, typically have a continuous need for updated knowledge within their area of expertise, which necessitates contacts with others both inside and outside their local organization. Furthermore, workers in such areas are often responsible for their own competence development. This has been found in an interview study that preceded the present project (Lantz & Severinson Eklundh, 1999). These observations motivated investigation of their use of the Web as a medium for self-selected knowledge development.

Among the unique characteristics of the Web is the fact that it enables fast and global communication among its users. A range of new contact patterns and special collaboration forms have been developed on the basis of the Web infrastructure. It is an open question how these increased possibilities of contact affect individuals' strategies of information exchange, both with respect to providing and acquiring information.

Our focus in this chapter is therefore: what are the implications of the "social Web" for the daily information exchange of knowledge workers? In particular, how has the Web's potential for communication and its accessible information infrastructure affected their strategies for acquiring and spreading professional information? We will deal with the following aspects of Web use:

- (1) sharing knowledge on the global network
- (2) sharing knowledge within an organization
- (3) active collaboration within work groups.

These three aspects are not independent, since the Web's global character affects its use also for organisational and group purposes. However, we attempt to maintain the distinction between them as far as possible below. We will both review research that we have come across, and describe some of our own studies in relation to these areas¹.

The need for research about Web use

The World Wide Web as a research area is still new. Most of the work published so far concerns technical issues (e.g. different communication protocols, document formats and Web programming tools), or issues about the design of Web sites from a usability perspective (see, e.g., Buckingham Shum & McKnight, 1997). In a workshop on the topic "HCI and the Web" (Instone, 1996) the following research areas were mentioned as important: users' models of the Web, navigation in large amounts of information, and document design for the Web. More recently, there has been a growing interest in the design of Web-based collaborative environments, and generally, the social potential of the Web is increasingly recognized and taken advantage of (see e.g. Munro, Höök, & Benyon, 1999b).

In the growing literature on the Internet and the Web, there is a notable lack of empirical research about how people actually use these media in their daily work activities. Many of the existing studies of Web use are based on automatically gathered usage data, which is relatively easy to collect by adding registration functionality to Web sites, or on large surveys about navigation patterns. For example, studies have been made focusing on how users revisit Web pages (Tauscher & Greenberg, 1997), and of the use of bookmarks when navigating the Web (Abrams, Baecker & Chignell, 1998).

In contrast to such quantitative studies of Web usage patterns, qualitative studies involving interviews or observations related to a specific work context are hard to find. (See, however, Järvelä and Häkkinen, this volume.) In fact, there are many challenges in studying the use of Internet technology in this way. The Web is growing rapidly and new technical solutions are developing continuously, as well as new usage forms. This makes qualitative, longitudinal studies necessary for an understanding of the research issues we are interested in.

Sharing knowledge on the global network

In many ways, the Web is unlike any other medium existing previously, and it is natural that research about the use of the Web has touched on many different areas. In fact, the view of the Web itself is subject to constant change, as both the contexts of its uses and the technology itself develop further. We will review some implications of these perspectives for Web use among knowledge professionals.

The Web as a new, interactive reading medium

The dominating view of the Web has been as a medium for presenting and retrieving information. As such, it differs from traditional screen-based media in many ways. In

addition to just locating and reading particular documents, users can navigate in a world of inter-linked information. In fact, the vision of the global hypertext formulated by Vannevar Bush (1945) is quite close to the Web as it works today.

Computer screens are well-known for providing a less optimal reading environment. In this respect, Web use cannot be expected to bring new research findings, at least from an ergonomic perspective. In fact, it is unclear to what extent people actually read lengthy Web pages on screen, compared to just browsing through relevant parts, printing out the document and reading it off-line.

On the other hand, the Web can be seen as a more social, interactive reading environment than traditional, paper-based media. Since both authors and readers are online, they can potentially communicate in a fast and interactive manner. Also, other users are visible through their personal home pages, where their interests and activities are often explicitly described. One may ask: can the social nature of the Web outweigh the negative aspects of reading information on screens? Or is the interactive nature of the Web as a reading medium sometimes felt as a burden, so that people need to protect themselves against unwanted communication?

Carleson, Lundberg and Nässla (1997) presented a study of the introduction of a web-based information channel to a local Intranet for a telecommunications company. A survey and interviews were made to assess the acceptance of the channel and to compare it with an existing paper-based workplace magazine. With respect to design and readability of the material, the paper-based magazine was found to be superior. It was also seen as more flexible by encouraging reading at home, which was not possible for the Web channel. However, the authors argue that a Web channel could be more attractive in other aspects, especially by offering a more interactive relationship between writer and reader.

A similar result was found in a study by Balsvik (1999), who interviewed a group of journalists about their experience of Web publishing (see also Balsvik, this volume). E-mail was the communication tool used most frequently by these journalists, and was used for interviews, for information exchange and for making a first contact. The results indicated that Web-published papers could foster a closer relationship between the journalist and the reader. The journalists reported a feeling of having got a more extended all-round education through the use of the Internet, though it seemed that they had to develop their ability to sift information due to the use of the Internet.

However, the advantages of paper as a reading medium prevail, even in contexts where both original text input and final reading are on-line. Bellotti and Rogers (1997) found in a study of Web-publishing journals that the paper medium had important roles as a form of intermediate representation during the production process, e.g. for overview of the current state of a page, coordination of activities, and passing information in a newsroom. Similar results have been obtained in other studies focused on management of documents in organisations (see e.g. Sellen & Harper, 1997).

Searching for information on the web: from individual to social navigation

Among the main problems with the use of the Web are orientation and overview of the information available on the net (see e.g. Instone, 1996). This applies both to searching and navigation through hypermedia links.

In the background is the threat of information overflow, e.g. by the multitude of hits that are often rendered by ordinary search engines. A related aspect is “lost in hyperspace”, pertaining to the lack of orientation and overview of users navigating via hypermedia links on the Web. These problems have led researchers and developers to investigate alternative metaphors for describing parts of the Web, and to design various techniques of visualization to facilitate navigation and overview (cf. “The Web book and Web forager” (Card, Robertson & York, 1996). However, these alternative models for navigation do not seem to have reached wide-spread use.

A more recent development in Web navigation emphasizes the social nature of people’s information seeking activities (Munro, Höök & Benyon, 1999a, Dourish, 1999). The general idea is to provide possibilities for users to keep track of the activities of other users, with whom they may have common interests, in order to find their way through the immense space of hypermedia information. The term “social navigation” was originally introduced by Dourish and Chalmers (1994), to describe how users’ navigation through an information space is guided and structured by the activities of others within that space. According to Erickson (1996), using other people’s home pages as sources of information is a kind of social navigation. There have also been efforts to provide special navigation possibilities on the Web based on the visibility of other users’ presence in real-time, or “footprints” showing how they have navigated (Munro, Höök & Benyon, 1999b). In many cases, there is a possibility to open a direct communication channel among users who are “co-located” in this way.

So-called recommendation systems may be seen as building upon social navigation principles. For example, a web site may be constructed by automatically collecting the addresses recommended by other users in online discussions, and providing links to these sites (a system with this capability is described by Hill and Terveen, 1997). Other readers may subsequently contribute by suggesting changes to the structure thus built up.

Dourish (1999) takes the concept of social navigation further, to stand for a general paradigm of collaboration through technology. His discussion emphasizes two aspects of collaborative activity as distinctive for social navigation: awareness of the activities of others to provide a means for interaction, and the conceptual distinction between “places” and “spaces”, where a place-centric view implies that there are other people inhabiting the information space, providing opportunities for mutual interaction and information sharing.

Visions of the Web as a universal medium for knowledge work

The unique possibilities of exchanging knowledge and drawing upon others’ work have been the source of many visions about the World Wide Web for knowledge workers, following in the trace of Bush’s “memex” (1945). In fact, the original idea of the Web was to support distributed collaboration and exchange of ideas between researchers (Berners-Lee, Cailliau, Luotonen, Nielsen, & Secret, 1994). One vision could be the

Web as a platform for constructing places of information resources but also of knowledge where experts in a topic can be contacted. Shneiderman (1998) uses the term "genex" for describing a development of the concept "memex" applied on the potential of the web. He proposed:

"appropriate genex design would enable problem solvers to locate and build on previous work easily, explore numerous alternatives rapidly, consult conveniently, and propagate solutions widely" (p.99).

A similar vision, presented by Holtzblatt (1999), is the "knowledge crystal". By describing skills, knowledge and procedures within the field of customer centred design, researchers are invited to jointly represent knowledge using the new medium, Internet.

These examples should be seen as ideal models of shared knowledge among researchers on a global network. There are already numerous examples of knowledge communities on the Web, where researchers voluntarily share information about their field. Web-based environments are also being designed for educational purposes, supporting both document repositories and synchronous text communication within distributed groups of professionals².

Buckingham Shum (1998) discusses methods of enhancing the Web with special mechanisms aiming to support the collective development and use of scientific knowledge. According to Buckingham Shum, "the Net, particularly the Web, provides an unprecedented opportunity in scientific history to locate, interconnect and analyse ideas and documents." But also, "The Web is becoming a more chaotic place every day. As the signal to noise ratio gets worse, research communities need better support for tracking developments and finding relevant documents." The solution proposed by Buckingham Shum is to supply metadata schemes that describe semantic relationships between scientific documents, and that enable a researcher to search for general patterns of ideas and arguments within a large space of related contributions.

Dilemmas of sharing knowledge

It is clear that the Internet and the Web are potential tools for knowledge sharing and competence development among knowledge workers. Our point of departure in the KnowHow project is a democratic model where all participants can use the medium on the same terms. Communication, and maybe even more, competence development on the Web, build on an implicit assumption that everyone wants to co-operate and contribute, to both give and take. However, it can be expected that some users will only take without giving, since it in many situations is very hard to make people contribute (Kollok & Smith, 1996). This does not always have to be a problem, at least not as long as this group does not grow too large.³ To contribute with information implies taking responsibility with respect to its quality, so that misleading or false information is avoided. These different aspects of co-operation are relevant for individuals, groups and organisations.

A particular tension on an individual basis exists in the desire for obtaining Web information in relation to one's own willingness to be visible on the net. If you are visible, people will notice you and perhaps offer information. However, there is a cost

in being visible; e.g. people will expect you to continue providing information and to keep existing information updated.

A pre-study of Internet communication

In a pre-study to the KnowHow project in 1997 (reported in Lantz and Severinson Eklundh, 1999), we performed in-depth interviews with a group of 10 individuals from research, development, and information areas about their use of electronic networks for communication and knowledge exchange. The study was explorative, and aimed to identify relevant research questions for the project. The following issues were addressed:

- How do the users conceptualize the Internet? How do they distinguish between the Internet and an intranet?
- To what extent are the users willing to fetch and collect material on the global net? How do they manage to find the information they look for?
- What is their attitude to being visible on the net?
- Do users give hints to each other about relevant information and contacts? To what extent are new contacts established on the network?
- How is the Internet used for communication and for supporting the individual's development of competence?

The participants (four women and six men) all had academic education and were researchers, teachers, technical developers and information professionals. All of them had occupations that involved a large amount of information acquisition, for themselves and for others. Typical work tasks were writing documents, communicating with other people, searching for information, distributing information and attending meetings. Most of the participants had a role that allowed them to organize their own work and plan for future activities themselves.

The respondents had reached such a level of expertise that they had to take responsibility for their own competence development. They visited conferences, read literature, participated in relevant courses and seminar series, and they regarded Internet as a competence supporting tool.

The view of the Internet

The Internet was described by the respondents as a protocol or a language that is necessary for enabling communication among the connected computers. When asked to use a metaphor for describing the Web, the telephone or a net was used. When asked to compare the Internet with intranets and explain the differences, the respondents first laughed. Then they explained: "Well, one is world wide and one is local".

Security was felt to be higher on an intranet since it is closed. Because an intranet can be specifically designed for a group, co-operation can also be facilitated in a different way than it can be on the Internet. On the other hand, it is only a support to people who have access; everybody else is excluded. Some participants felt isolated behind the

"fire-walls", not being able to communicate freely with others outside their own organisation. One respondent gave the example: "When I visit a conference, others sometimes give me their home page URL but I can never do the same since I am on an intranet".

Search and navigation

When navigating on the Web, users collect bookmarks of sites that they want to return to. After a period of Web use with a growing collection of bookmarks, the latter must be structured in some way, and organisational problems may sometimes emerge. These may be similar to those appearing in e-mail communication (Whittaker & Sidner, 1997; Bälter, 1998; Lantz, 1998) and lead to a need for cleaning and filing of bookmarks, an activity that is not well supported according to Nielsen (1997).

Bookmarks are used when the user knows where to go; otherwise search engines are used. Some of the respondents reported that they had noticed that search tools have specialised in different topics. When the respondents have learned which search tools are reliable, and if they also have other sources of information on a certain topic, the result can be more complete. One given example was a librarian asked to search for information about a very uncommon disease. The results were to be delivered to a doctor who had just received a case. In addition to literature in the area found at the library the librarian could also add information found on the Web. This information consisted of an information sheet about the disease, names of contact-persons, and, a homepage for children with the disease. The doctor and the sick child's family could then take part of all this information.

Home pages

Most of the respondents had a personal home page, on which they were careful to include only professional information. For certain respondents there were difficulties in constructing a home page and they needed technical help. Some organisations had home pages with links to all employees, and standards were emerging for the build-up of these.

To be visible on the net was experienced in different ways. Some respondents reported that they were afraid of receiving too much information or too many contacts if appearing on the Internet. Others preferred to use traditional publishing media for increasing their professional visibility in an effective way.

Communication and cooperation

For the participants in the study, e-mail was the primary communication tool in their daily work. This meant that e-mail was used irrespective of whether the receiver was in the next room or across the world. However, if a response was needed quickly, the telephone was used. Also, home pages can be used for communication, and email can sometimes be sent directly from the home page. Contrary to our expectations, it was not felt to be necessary to meet face-to-face first. In fact, we have seen several examples of contacts started via Internet where the involved subjects first met after several years.

For the main part of the users in the study the Internet was not primarily seen as a tool for co-operation. However, an example was given by a respondent about a project group spread over Sweden and working in libraries. They had a co-ordinator that

administered the homepage and a number of persons responsible for different areas. The homepage was the uniting node, and communication was managed via email and distribution lists. What is demanded for such co-operation is that everyone feels responsible and that one person acts as a co-ordinator.

Co-operation on the Internet would often be more indirect, such as by users giving each other hints about relevant information. However, some users never did this and did not receive hints from others either. Giving hints can sometimes be excluded because of the climate at work, or that the fear of overloading colleagues is greater than the wish to offer information. Often a work group knows about the different group member's interests and forwards relevant addresses and information.

The experiences from the pre-study confirmed that the Web has a potential as a platform for sharing of knowledge across geographical boundaries. The study opened the way for more specific studies within the KnowHow theme, investigating how people use Internet and the Web for professional collaboration, and how the technology supports these activities.

Knowledge communities on the Web: a study of the Oester'96 project

People working in knowledge professions often have a number of obligations in several projects. This leads to working with different colleagues in different settings, with regard to both type of group and context. Often the colleagues are at other work sites and the interaction between these experts are mostly formal meetings. Hence, it is easy to see that an expert's work situation often is very isolated: there is no one to ask for advice or initiate a discussion with.

The most obvious need is to communicate with other experts in the same area and to develop one's competence, not only by reading a book, giving a course or visiting conferences. Face-to-face meetings, formal as well as informal are very important, but there are cases when a mediated way to communicate is a good substitute or even a better solution.

One example of this is the Oester'96⁴ project, which has been the subject of a case study in KnowHow. The project started in 1997, involving 11 countries and working with different political aspects of the Baltic region. Here experts working within knowledge professions were offered to use the Web as a place to collect or present information, chat or use mailing lists. Part of the site is open to the general public, other parts are closed, only available for the members of the project group. These experts work in several projects, sometimes distributed via the Web site since the co-operating persons are located in different countries.

Results from the questionnaire sent to the project leaders showed that the site mostly was used as an open library, both internal and external. The respondents of the questionnaire knew that all reports were available at the site. The purpose of this Web site is not to develop the participants' competence - in fact this has never been discussed. The overall aim of the Web site is to signal democracy, i.e. to work very openly and present all final reports as well as the plans for the future of the different parts of the project.

In interviews with some of the respondents of the questionnaires, it turned out that the need of performing work with a democratic model in mind is helpful in co-operation among delegates in different countries. The idea of using the Web site as a place for competence development within a group can be viewed in terms of common ground (cf. Clark, 1996). As a new delegate enters the project, it is easy to read all previous documents on the Web site, to look at the lists of participants, the time schedules and organisation, which leads to fast capturing of the overall common ground (what everybody else in the project learned by participating).

In the questionnaire, there were also questions about an internal part of the Web site (i.e. the intranet, including facilities for communicating via chat and distribution lists). Only a few of the respondents reported that they had used the internal part, and it turned out that two years later it was closed, probably due to the low interest on the part of the participants of the project. One interviewee said that taking part of the information at the Web site contributes to the development of competence, since it enables an attendant to follow the ongoing work and also take part of the reports from the different parts of the project. It is one way to take part of others' knowledge.

Another subject said about the same, but also saw it as direct and indirect competence development, where "direct" is related to the specific work task performed within the project and "indirect" is information about others to pose questions to. The Web site can be used for one's own reasons but also as a reference library for others who want to know more about the project.

Sharing knowledge in an organisation

The Web has great potential for sharing knowledge and fostering collaboration within organisations. So-called Intranets are established in many organisations as a channel for intra-organisational communication. Using the same protocol as the Internet, but with restricted access, they may provide both information archives and platforms for direct communication among the organization's members. This means that they can function as a kind of organizational memory.

Organizational memory

To support sharing of knowledge within an organisation, a collaborative system can be designed to store the knowledge in a large repository of information. Such systems are often referred to as organisational memory systems, or lately also knowledge management systems. The information can then be retrieved and used in the future.

Examples of organisational memory systems are gIBIS (Conklin & Begeman, 1988), and Answer Garden (Ackerman & Malone, 1990; Ackerman, 1994; Ackerman & McDonald, 1996). The purpose of the gIBIS system was to explore the capture of design history, to support computer mediated teamwork, and to investigate hypertext navigation of very large information spaces. In Answer Garden, commonly asked questions about an application domain are stored, together with the answer, in a common repository. In a newer version of Answer Garden there is also the possibility to find and interact with an expert directly.

The concept organisational memory has been criticised for not accounting for how remembering actually takes place in organisations (Bannon & Kuutti, 1996). Bannon

and Kuutti also point out that it is difficult to predict what knowledge, or information, within an organisation, will be of interest in the future and thereby is worth storing. This involves a trade-off between cost of storing and the cost of reinventing, but how is this trade-off to be decided? Bannon and Kuutti also argue that if the "activity" during which the "storing" takes place differs from the one in which the "remembering" takes place, then the information may be re- or even misinterpreted. It is a question of what needs to be stored and what can be left as taken for granted.

Asking for information

Bannon (1986) argues that people rather ask other persons for advice than search through a manual for information. He found, when interviewing administrative and clerical personnel, that the major source of information about the computer systems used were other users (see also Kraut & Streeter, 1995). One person in his study expressed that sharing office with a person more experienced within a certain area provides an ideal environment for solving problems related to the area. Bannon points out the importance of a common view of the problem, especially in the case of a novice-expert conversation (see also Clark, 1996, Ch. 1). In a face-to-face conversation, interruptions and follow-up questions can provide feedback about the participants' understanding of the current dialogue, and the conversation can change to an appropriate level of understanding. Thus, to meet a person face-to-face could help solving a problem.

There is also a difference between formal and informal sources of information. A formal source can e.g. be a computer system help desk, while an informal source can be a person who does not officially have the task of helping other persons. The reason that formal sources often fail in their mission is because the persons working at a formal source do not know enough about the particular topic and because they often are remotely located (Bannon, 1986). Instead, informal sources such as colleagues are chosen because they are physically available, they are personal friends, or they are known to be experts on the topic. Investigations show that people working in software design projects prefer to ask nearby colleagues rather than using formal information sources (Waterson, Clegg, & Axtell, 1997; Eveland, Blanchard, Brown, & Mattocks, 1994). The reason is that the colleagues better relate the question to the problem. Also, people outside the group can be important when searching for information (Kraut & Streeter, 1995).

Knowledge nets: an alternative approach for intra-organisational communication

One way to support the sharing of knowledge within an organisation is to present references to persons with the requested knowledge, as opposed to presenting the knowledge itself represented in some artefact. The knowledge net approach (Groth, 1999) is based on this principle.

The idea has similarities to social navigation, in that it builds on the importance of using other people as resources. However, a knowledge net builds on using the computer to store references to other persons, who are then contacted directly. A knowledge net can be viewed as a "time-window", i.e., the knowledge referred to is what is relevant today – the knowledge people have at the moment.

One characteristic of the knowledge net approach is that the given references should encourage and support on-going communication between individuals. This means that just providing a list or database of references is not sufficient. Another main characteristic is that the knowledge providers are also those who should benefit from the system. In other words, there should be a focus on what the individual is interested in sharing with others and not on, for example, what management is asking for. A crucial issue in the knowledge net approach is that the individuals' knowledge is described in an open-ended way. This makes it possible for the knowledge providers to decide how to describe their knowledge and how much of it they want to share with others. Still, technical support for the process of entering information should be available, e.g., using templates and forms.

However, the use of a specific system supporting people in finding "who-knowswhat" might not be the ideal solution. Rather, simple means for showing people's present activities and availability in combination with structured information about projects and other activities within the organisation might be even better.

The Web as a basis for a knowledge net

Some knowledge net like applications already exist and can be found on the Web. One such application is the Referral Web (Kautz, Selman, & Shah, 1997), which is an interactive tool on the Web that helps people find short referral chains between themselves and experts within a certain area. The Referral Web uses publicly available Web pages to create a referral chain. A referral chain is created by searching for names and following links on Web pages. If two or more names occur in close proximity on a Web page, then this is seen as evidence of a direct relationship between these persons. Hence, no information needs to be explicitly entered by the users. Unfortunately, the Referral Web was never used within the organisation it was created for, a domain of AI researchers.

The Referral Web was thus intended to be used within a specific domain of users. However, there also exists Web based tools for knowledge exchange between individuals that are globally available on Internet. One is Abuzz⁵, which "provides on-line communities with tools to share knowledge through people-to-people interactions". Another is Experts Exchange⁶, a knowledge sharing community on the Web where different topics are available for discussion. A third example is Six Degrees⁷, which is an on-line community with the possibility to interact, communication and share information and experience with others.

In addition to these specific systems supporting contacts between people, well structured personal home pages on the web in combination with search facilities may also serve as a simple knowledge net. This issue was addressed in a longitudinal study in the KnowHow project.

A study of the use of home pages on the Web

Personal home pages⁸ give an individual user of the Internet, or of an intranet, an opportunity to present personal information to other users. These pages on the Web can, therefore, be seen as a source of knowledge about individuals within a network. The network is either global, i.e., available to everyone on the Internet, or local, i.e.,

available only to the specific users of a certain intranet (physically these individuals may be distributed).

According to Instone (1996) home pages constitute the most visible Web genre. People visit the “home sites” of other persons with interests that are close to their own topic of interest where they expect to find new information about the topic (either directly or via links).

Erickson (1996) claims that home pages are the very cornerstone of the social character of the Web: navigating via home pages is like asking someone else who is likely to know the answer to a question. Also, home pages provide a possibility to create an identity on the net by a portrayal of oneself in terms of interests, activities etc.

Given that personal home pages already contain information about individuals' knowledge and competence, it is of interest to explore the extent to which they can function as a knowledge net. With this question in mind, we performed a longitudinal interview study about the use of personal home pages among people from knowledge-oriented professions (Groth, 1999, Groth & Lantz, 1997). Although home pages are often available on a global basis, we were especially interested in their use for sharing knowledge within an organisation.

In 1996, a group of 22 persons from three different organisations were interviewed about their personal home page. In combination with the interview the personal home page was demonstrated. Two of the organisations were research organisations with personal home pages accessible from Internet. The subjects from the research organisations had been advised by their managers to have a personal home page. The third organisation was a software development company using an intranet where people voluntarily could present personal home pages. All subjects in each organisation belonged to the same department and they were chosen because they had a personal home page. After one year seven researchers, and three software developers were interviewed once again about the changes made to their home page. The home pages of all 14 researchers and of the three software developers were also examined. After yet another year the home pages of the 14 researchers and one of the software developers were once again examined.

At the beginning of the study, most persons interviewed had used the Web for more than a year. As many as 13 subjects had used it from the beginning of the Web, in 1993/1994. Also, most subjects used the Web every day, and the most common activity was to search for specific information, often related to the subject's work tasks. Eleven of the subjects, all from the research groups, searched for articles or research reports. The subjects also reported that they searched for other persons' home pages because they wanted to find, e.g., links to other sites about subjects that they knew the author was interested in, or information about the author such as a picture, contact information or written reports.

The Web was also used to find solutions to specific problems, to look for conferences, courses, or organisations of interest. Finally, it was used for looking up non-professional information such as weather reports, apartments, friends, movies etc.

About half of the subjects had had a home page for more than a year. The reasons reported by the subjects for having made a personal home page were because they found other persons' home pages useful, they wanted to distribute their publications, they wanted to try out the new medium, and because they considered it a good way to find information about other persons.

The results of the study showed that contact information and information about projects or work that the author was involved in were information items that the subjects both found interesting on other persons' home pages and included on their own home page. The reasons given for including project information were because they wanted other persons to know what they do, and to distribute information about projects. Contact information was included to give other persons the possibility to make contact.

In a similar study of personal home pages, Bly, Cook, Bickmore, Churchill and Sullivan (1998) found that most (75%) of the examined personal home pages contained project related information. Bly et al. mention that the authors of the home pages wanted to facilitate the access to project information and thereby provide pointers to their work. For a knowledge net, project-related information may be crucial. However, in order to get an understanding of the author's skills, the work/project related information needs to be more detailed. Contact information is important in a knowledge net like application because the "expert" needs to be contacted by, e.g., email, phone or in person.

In our study, only a minority of the subjects had not made any changes to their home page in 1996, and when comparing the home pages from 1996, 1997, and 1998 it was found that most people had made some changes to their home page. Reasons given for updating the information were that the information on the page was outdated, new interesting links had been found, new projects had been started, more information had been added which made a new layout of the page necessary, etc. The fact that the subjects tend to update the information on their personal home page is of interest for a knowledge net like application, where the validity of the information is important. Bly et al. (1998) reported that one of the authors in their study thought the work of having a personal home page was worthwhile because it was important that other persons had the possibility to find out about him and his work. This is interesting from a general perspective of the Web as a medium for sharing knowledge, and the dilemmas of equal participation discussed in the introduction to this chapter. It shows a willingness to provide personal information for others, although the author's own benefit from the work of supporting the home pages may be marginal.

Another finding was that some of the subjects said that looking at an unknown persons' home page made them feel more familiar with that person. Bly et al. (1998) mention that some of their subjects reported using personal home pages as an introduction to someone they were going to meet. They also found that the personalisation of a home page was important.

It seems that a main group of intended readers of people's home pages are colleagues. The respondents of our study thought that information about research projects, publications and contact information would interest such persons most. Also, students were mentioned as a possible group that could be interested in their home page. The

information on the home pages described, in most cases, what "project" the owner of the page is involved in and what areas s/he was interested in. The subjects presented what they had knowledge about rather than their opinions (although this may also be found on some home pages). They did not seem to be afraid of presenting what they knew, wanted to do, and had been doing in the past.

Also, the subjects found the information included on other persons' home pages of interest, which suggests that what is presented on personal home pages is of relevance for a knowledge net like application. It was mainly contact information, publications, and project or research information that was found interesting. Bly et al. (1998) found that personal home pages are often used by the author's colleagues to get access to other material. This, together with the findings that some of the subjects had been contacted about their information on their home page, shows the interest for personal information. In this regard, many people may have, consciously or unconsciously, used personal home pages as a knowledge net.

Group collaboration through the Web

In addition to its role as a medium for sharing knowledge in global and local networks, the Web is also increasingly used to support actual collaboration in small or moderate-sized groups. This is not a feature that is inherent in the standard Web protocol; instead, the demands of collaboration support usually require extensions in terms of either server or client software or both (Dix, 1997).

The research on computer-supported cooperative work in the last decade has so far yielded few widely used collaborative systems. However, there have been a number of important insights through the empirical studies of existing systems. Grudin (1988) showed that it is important that users who have to change their work due to a new system are also the ones that will benefit from it. Further, there must be a working infrastructure for collaboration, and it should be easy to switch from individual to group collaboration. The last two requirements suggest that the Web is a suitable basis for building cooperative systems.

Collaboration can be defined in different ways, which will have consequences for what would be included here. A weak definition of collaboration is assumed e.g. in Terveen and Hill (1998): "Links between web sites can be seen as evidence of a type of emergent collaboration among Web site authors". They conducted a quantitative study of such linking behaviour by using a special algorithm to detect the connectivity among Web sites in various domains.

A definition of collaboration in such terms would imply that almost all use of the Web is a kind of collaboration. Here, we will restrict the word collaboration in the way suggested by Dix (1997), i.e. that it requires a common task and a channel for direct communication between participants of a group. Thus, for a Web-based application to support collaboration, it should (1) provide some representation of the collaborative task and its artifacts, (2) make it possible for users to interact with and manipulate these artifacts, and (3) facilitate user's communication with each other about the task.

A central concept in computer-supported cooperative work is *awareness*. In its original form, it stands for the co-workers' ability to perceive and understand the activities of

others as a context for their own work (Dourish & Bellotti, 1992; Dourish, 1999). When people are working in the same building, they normally observe others' activities in subtle and straightforward ways. For example, when leaving one's own office, one may hear voices, or see someone passing at the end of the corridor, which makes it possible to infer the state of others' activity. In contrast, in mediated collaboration, awareness of other's activities must be deliberately designed for, in a way that is adapted to the users and their tasks.

The Web does not in itself support users' awareness of each other. In the context of searching for information, this has recently been argued as a weakness by proponents of the "Social navigation" paradigm, who have attempted to make traces of users' activity more explicit. Certain efforts have also been made to construct Web-based support for local workgroup awareness; e.g. @ Work (Sandor & Tollmar, 1996) which allows a group of users to extend their home pages with information about their current whereabouts on a day-to-day basis⁹. Furthermore, Web-based virtual environments have been developed in which users have an explicit representation as an avatar, and which are thought to encourage synchronous group interaction and support peripheral awareness (see further below).

Sharing and reviewing documents in working groups

A form of collaboration that is of particular interest for knowledge professionals is the use of the Web for co-authoring documents within working groups. Certain efforts to support collaborative management of documents on the Web have focused on creating a shared repository, including password protection and easy up- and downloading. A well-known example is the BSCW system (Bentley et al., 1997), which also supports communication between co-authors. However, it is less common that Web-based solutions explicitly support collaborative writing, in the sense of interactive user-document manipulation, support for awareness, and a user-user communication link.

There have been certain efforts in this direction. One example is the Alliance system, which is a structured cooperative authoring application for distributed collaboration (Romero Salcedo & Decouchant, 1997). The system has many interesting properties, but empirical evaluations seem to be missing so far. Sumner and Buckingham Shum (1998) presented a system for sharing and reviewing documents on the Web, as a part of a redesigned publishing process for scholarly work. The emphasis is on the encouragement of an ongoing discourse about the documents submitted. Easy-to-use facilities are offered for uploading a document and incorporating it into a reading environment enhanced with communication facilities. The design thus supports an interactive discussion between authors, reviewers and readers. The system has been evaluated in several case studies, including an online multimedia journal and a mixed-modality conference with a concluding face-to-face discussion.

In the KnowHow project, we have developed a series of prototypes for Web-based authoring and communication based on a concept of "four frames". The idea, first materialized in the Domain Help System (DHS)¹⁰, is that members of a group share and comment on a collection of HTML documents (or document parts), available through selection in a list of hyperlinks. When a comment has been made, it is available immediately together with the previous comments in a special window. The set of comments thus evolve into a dialogue between participants, aligned with the document,

which serves as communication channel throughout the reviewing process (see Rodriguez, 1999).

There are many obvious advantages of having a collaborative environment fully integrated with the Web, as in this case. The users have direct access to the whole Web and all of its uses - in other words, an existing infrastructure is built on. Links can be placed within the document and the comments, establishing references to locally or globally available knowledge sources. And the basis for the application is an ordinary Web browser, accessible everywhere.

There are also some disadvantages associated with this solution. For example, it is impossible to control in all aspects how information presented in the system will look to a user, as the users can normally change the appearance of a document through preferences made in their Web browser.

The DHS system has been evaluated in several case studies. At first, it was used in our own laboratory as a tool for updating our Web site. The lab members could read others' draft project descriptions and make comments on them. It turned out that comments often referred to the design of the system (described in one of the document sections) instead of the others' documents. Apparently, people with a computer or HCI interest were mostly interested in the novel aspects of the system and less motivated to comment on each others' texts. In fact, some members stated in interviews that they did not favour "public" criticism of draft project descriptions.

The DHS system has more recently been used in an educational context, for students to give feedback on each other's texts within a course. Through these trials, the system has been gradually improved with respect to usability. In one course, which had a HCI orientation, the same pattern of commenting on the system emerged, whereas this pattern was absent in another course dealing with writing scientific papers. Here, students made many comments on each others' papers, although the focus of their comments was often details of spelling and style rather than the content of the papers.

The problem of awareness was reflected through these studies in the time it took the author of a document to react to a comment. The only way that the system supported awareness was by showing the last comment made in the window (all other comments were available through scrolling). In this way, users could just check if they had read the comment before. In general it took 2-3 days on average, occasionally 10 days, for the author to reply to a direct question posed to him/her, and in some cases, the author never replied.

Recently, the DHS system has been developed further into a co-authoring system, called Collaboracio (Rodriguez, Kim, & Severinson Eklundh, 1999). The system supports not only shared access to HTML documents and comments, but also facilities for awareness, joint editing and versioning. The focus is on communication among distributed co-authors during the reviewing phase of a shared document.

The work in this project was preceded by a series of interviews with academics about their co-writing practices (Kim & Severinson Eklundh, 2001). The people taking part in this study did not use any specific collaboration software. Instead, they cooperated by

exchanging emails and commenting on paper versions of their articles. It was clear from this study that users lacked a common infrastructure for collaboration.

<Insert Figure 1 about here>

Figure 1 shows the interface layout of the Collaboracio system. The links to the left correspond to sections in the document being written. When a section is selected, its content appears in the upper right frame. The middle right frame is where the comments are displayed, and the bottom right frame contains buttons for available commands. Each section can be edited by the participants who have access to that section, by pressing "Edit section" and changing the HTML code in a separate window. This function does not allow for flexible authoring, but is aimed at supporting small changes rather than original composition of the document.

The awareness of changes to the document is supported in the following way. As soon as a new comment has been made by one participant, the other participants receive an email message containing the comment. The same thing happens when a new section has been added, or a section has been deleted. In this way, the user does not have to enter the system to check if something important has happened in the collaborative task.

We have evaluated the system in 6 different writing tasks in which groups of 2-9 people from an academic background participated. These case studies showed that co-authors used the system for an ongoing, asynchronous dialogue about the writing task, which served to coordinate their actions and negotiate about changes. In their communication, users often took account of the whole history of comments (including how people had reacted to each other's comments) made between members of the group. While other writing tools often lack this feature, we found that having access to the comment history is important to promote communication and awareness among co-authors. Also, the notification about new comments via email played an important role to create a sense of other members' current activities and the overall state of the task. Since most users read email on a daily and frequent basis, email notification appears to be a good way of supporting awareness with minimal effort and delay.

However, email notifications can easily get overwhelming in periods of intense activity. It emerged early in the case studies that it is not suitable to make every new change in a document section cause a new email message. In fact, even with the present design, it should be possible for users to change the level of awareness set by the system, depending on the task context and their own preferences.

Altogether, the experiences of DHS and Collaboracio point to the conclusion that groups with an existing common ground (Clark, 1996) in relation to a task, and who are motivated to collaborate, have considerable use of a Web-based tool for communication about shared documents. On the other hand, for groups with less incentive to collaborate, or whose collaboration serves merely to acquire course credits, sharing knowledge in this way may sometimes be perceived as an extra burden or task, which means that their participation will not reach a critical level for the group's benefit.

Web-based collaborative virtual environments: a new meeting medium

In many organizations experts work mostly alone. Nevertheless, they need to meet colleagues for discussions, knowledge exchange, and competence development. In such contexts, computer support for distributed real-time collaboration may be a relevant work tool.

Web technology enables distributed storing of information, and support for synchronous as well as asynchronous communication using text, audio and video. Moreover, it is possible to build "Collaborative Virtual Environments" (CVE:s) with relevant information for a specific group i.e. experts in a domain (cf. Lea, Honda & Matsuda, 1997). Apart from synchronous communication – usually by text-based chat – the system offers a graphical representation of a shared environment and participating users. The graphical representation of a user is referred to as his or her *avatar*.¹¹ Users of CVE:s can be seen as *visitors* who need visual embodiments to provide mutual awareness and orientation in the virtual environment (Hedman, 2001).

Not many groups of experts use CVE technology, although it is available relatively easily, and studies in natural settings are rare. Research on CVE's has mainly been performed in experimental settings, focusing on presence, enjoyment and feelings of group accord, and subjective reactions such as shyness and conflict (Slater, Sadagic, Usoh, & Schroder, 1998) and leadership (Tromp, Bullock, Steed, Sadagic, Slater, & Frécon, 1998).

In a recent case study by Lantz (2001), a workgroup consisting of four researchers were observed under three conditions: face-to-face, chat and CVE, as they had regular meetings. The CVE was an open world in Active Worlds™ consisting of a building with an exhibition area, surrounded by trees on a lawn, and a blue heaven.

Results from the analysis of the data, collected via observations and questionnaires distributed after each meeting, showed that both chat and the CVE were experienced as very slow. This could be explained both by limitations in the technology itself, and by the fact that the participants were not skilled "chatters", i.e. they had not developed a language of "shorthand" efficient in a chat environment. Another reason for delays could be that participants were performing other parallel activities during the meeting, such as talking on the phone, to a visitor, or reading e-mail. This has also been discussed by Bowers et al. (1996b).

Ratings of efficiency were obtained by asking questions about overall efficiency, task oriented work and the number of items handled on the agenda. It turned out that the CVE was rated as more efficient and task oriented than face-to-face meetings. This can be explained by the fact that social talk was a substantial part of the face-to-face meetings while meetings in the chat and CVE focused on the tasks to be performed. Regarding communication and the representation of each participant by her/his name, the chat environment was very difficult to communicate in. Extreme discipline was necessary, and a set of rules for how to communicate was developed. It was necessary to follow only one thread of discussion, and rules were needed for organizing the turn taking among participants. In the CVE, the discipline and rules were not as important. Since participants were represented by avatars, their position in the CVE and their spatial relations in the group made turn taking more or less transparent. People would

usually talk in the order of their spatial positions in the environment, and discussing one topic at a time was facilitated.

Overall, the participants were able to enter, navigate and communicate in the CVE although they did not have any previous experience of using this particular technology. Using a common meeting spot in the CVE seemed to be preferred compared to just using the built-in chat function. All three ways to perform meetings were rated as being enjoyable, although the level of enjoyment decreased for the chat and CVE after the first meeting.

The results indicate that face-to-face meetings are needed in order to facilitate learning and competence development, e.g. for brainstorming. Also, participants are in favor of knowing each other before starting to communicate in the CVE. Bowers et al. (1996a) state that the overall design of CVE:s should be considered with respect to how they afford social interaction and not just in terms of navigability, capability of presenting information or aesthetic appeal. Our study also indicates the following design elements of a CVE as important for distributed meetings: improved communication facilities (e.g. speech interface, support for turn-taking); support for common material, (e.g. documents), and support for parallel activities (e.g. writing).

More recently, an experimental study has been performed by Sallnäs and Hedman (2001) investigating to what extent and in what way collaboration in CVE is affected by an audio or video connection in comparison to text chat. This study gives additional evidence of the properties of text chat in comparison with other ways of communicating in a CVE, by analysing dialogues conducted in each medium.

Thirty pairs of subjects performed a decision-making task that was presented to them as a written scenario. A CVE was constructed in the ActiveWorlds system, and had the appearance of a simple exhibition with information stations (see Figure 2). The stations included posters with pictures of cars of different models, and corresponding movie clips with information about the cars. Humanlike avatars represented the subjects. The task was, for each pair of subjects, to go through the exhibition, and decide on a car together. This involved discussing both the information available in the CVE and the subjects' individual preferences, based on prior knowledge that was relevant to making the decision.

<Insert Figure 2 about here>

Twenty-seven dialogues out of thirty were transcribed. These dialogues were coded into twelve categories according to Bales' (1976) Interaction Process Analysis (IPA) by two people independently. Results show that the amount of communication and thus the number of code units was significantly lower in the text-chat condition than in the other conditions. However, no significant difference was found between the voice and video conditions with respect to the amount of communication between subjects; the number of code units was almost the same.

The IPA analysis showed that the subjects' verbal behaviour in the text-chat condition differed in several respects from the other conditions. Subjects both provided more information and asked for more information in the voice and video conditions than in

the text-chat condition. This was mainly because they investigated and discussed more of the information displayed in the CVE. Many of the questions and much of the information shared in the audio and video conditions concerned personal issues, such as how large subjects' families were, or personal experiences relevant to the information displayed. Subjects also explored the CVE more completely, and consequently had more to discuss. Furthermore, subjects shared more opinions in the voice and video conditions as they negotiated more extensively in those conditions than in the text-chat condition. They often discussed and analysed the information carefully, while at the same time communicating their personal preferences. In the text-chat condition, on the other hand, negotiations were crude and were more based on appearances of cars than on information about functionality and preferences in this respect. Subjects did not seem as engaged in the discussion in the text-chat condition and the dialogues exhibited numerous misunderstandings.

Subjects showed more agreement in the video and voice conditions than in the text-chat condition. This might be because it was easier to give fast feedback in the voice and video conditions than in the text-chat condition. Subjects also showed more tension-releasing behavior in the voice and video than in the text condition. They were joking more and often expressed satisfaction regarding individual or cooperative behaviour. However, there were examples of this in the text-chat condition also. Smileys (emotionally expressive symbols created with standard keyboard characters) were used by the subjects in order to communicate a joke or feelings of satisfaction.

When studying the percentages of dialogue acts, it emerged that a substantial part of the communication in all three conditions was focused on problem solving. The reason why more than half of the dialogue is focused on problem solving in the text-chat condition might be that, since communicating in this medium is harder, most of the effort is put into actually solving the task.

The communication in the voice and video condition, on the other hand, was more socially oriented than in the text-chat condition. More feedback was given in the voice and video condition, that either intervened or was communicated in parallel to the other persons' utterances. This is evidently hard to accomplish in the text-chat condition.

Video as an added information channel did not seem to make a great difference in comparison to the voice mode. This result is in agreement with previous research about the use of video communication in problem-solving tasks (see Whittaker, 1995; Whittaker & O'Conaill, 1997). It was noticed, however, that the video channel was used in certain typical situations:

- During long pauses in the conversation--to attract the partners attention, or to see if the partner was busy, or ready to interact.
- When problems were encountered, i.e., navigational, or interface-related--to establish mutual awareness of pressing situations.
- During greetings, and during discussions prior to important decision-making, to establish eye-contact, according to traditional social norms.

Thus the video-channel, while not used heavily, did serve important functions. It was used to structure the conversation, to establish and maintain mutual awareness, and to allow certain kinds of social interaction that would otherwise not have been possible.

Conclusions

Through the work in the KnowHow project, we have begun to look into the complexity and the promises of the Web as a medium for communication and knowledge exchange. The area is vast, and the studies reported here should be seen as just a beginning. However, we do feel that using a combination of empirical studies and explorative design work is a promising approach that may lead to new insights as well as to concrete recommendations for the design of collaborative tools on the Web.

The Web is constantly changing, both in terms of contextual and technical conditions. It is difficult to state general conclusions from the work presented here, and it is clear that longitudinal studies are necessary to increase our understanding with respect to some of the questions studied. Nevertheless, the research reviewed and our own studies support the picture of the Web as a potentially powerful social infrastructure for knowledge work, the actual realization of which depends on contextual conditions well known from previous studies of collaborative work. Web technology can help people accomplish tasks together in new ways, across geographical boundaries, but the extent to which such cooperation actually takes place is dependent on a range of situational factors. These include participants' motivation to share knowledge and be visible to others, the constraints of their tasks and the cooperative climate in their everyday work situation. In addition, Web-based tools must be designed to fulfill usability requirements and be easily integrated with people's existing work tools – factors that currently meet considerable challenges for developers as well as researchers.

For example, the studies of home pages and the experiences from the Collaboracio design work show that the Web affords truly new ways of collaboration, using technology easily available to virtually everyone. At the same time, it seems clear that people will only accept a new Web-based tool if they gain something particular from it. There is not always a balance between individuals' need for updated information and their own willingness to supply such information. More stable patterns of collaboration may emerge slowly, under the influence of certain well-known examples of constructive Web use, and with the emergence of a new generation of network-oriented users.

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NOTES

¹ As we are focusing on professional communication, many issues concerning Web and Internet usage are not covered in this chapter. For example, the area of on-line commerce is mainly outside the scope of this paper. Furthermore, computer-mediated communication is only dealt with insofar as it occurs as part of Web-based activity.

² One example is Tapped In™, a shared teacher professional development workplace, patterned after a real world conference center. It began developing its community in the summer of 1997 and had grown to over 8500 members and over 15 partner organizations by May of 2000. Studies about the use of Tapped In show that teachers benefit from using them as a place for informal discussions and collaboration, to exchange tips and advice and to share educational resources rather than as a space for importing "traditional classrooms" on-line (see Cerratto, 2001; Cerratto and Waern, 2000).

³ The problem of unequal participation is well-known and has frequently been discussed with respect to other electronic media. For example in Usenet newsgroups, discussions tend to be dominated by a few active individuals (see Whittaker, Terveen, Hill, & Cherny, 1998), and many others participate only as passive "lurkers".

⁴ The name of the project has been changed for reasons of the integrity of participants.

⁵ <http://www.abuzz.com/>.

⁶ <http://www.experts-exchange.com/>.

⁷ <http://www.sixdegrees.com/>.

⁸ A home page on the Web is the intended entry point of a logical information structure (usually called a web site) from which all other pages on the site may be reached, directly or via other pages, by hypertext links. A home page can refer to an individual, a group or an organisation. If a home page is written (partly or wholly) by and about an individual, it is called a personal home page.

⁹ @ Work was developed within our own research environment by Ovidiu Sandor and Konrad Tollmar. The design was ambitious, e.g. including links from people's personal information to the telephone switchboard, in order to be able to update information about their work hours and activities. However, the tool never reached a critical threshold of use. A possible explanation is that there were problems of usability in the Web presentation, such as long response times and lack of overview. Also, it is conceivable that people felt it was too much work to update the information, compared to the benefit they gained from it (cf. Grudin, 1988).

¹⁰ DHS was developed in a collaboration project between IPLab and CID at KTH.

¹¹ The term avatar originates from Hindu mythology, where it indicated the temporary body that a god inhabits while visiting earth.