

A comparison of the collaborative information retrieval behaviour of two design teams

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The goal of the collaborative information retrieval (CIR) project is to study situations where members of a work team are seeking, searching and using information collaboratively. A field study of two design teams (one at Microsoft and the other at the Boeing Company), guided by cognitive work analysis, has provided preliminary results. These show that: (a) the concept of CIR is elusive and does not easily lend itself to an operational definition; (b) work context has a strong effect on CIR behaviour; and (c) not all activities relating to CIR are carried out collaboratively.

INTRODUCTION

Many studies have been carried out to examine the information-seeking behaviour of engineers. Following Allen's classic study of research and development engineers (1), a number of studies investigated the information channels they used, the factors that affected channel selection and the social networks that supported their information-seeking activities (2, 3). Almost all of these studies aimed at results that could provide generalizations that would describe the information-seeking behaviour of *all* engineers, regardless of their specialities, or the context in which they worked. The only exception to this trend was a set of two studies that were carried out at Risø National Laboratory in Denmark (4). This paper presents preliminary results of a research project about

information seeking by engineers that is different from previous studies in three ways: (a) it examined the effect of the *context* in which the engineers worked; (b) it focused on *design engineers* only; and (c) it examined their information-seeking behaviour as a *team of engineers*, rather than as isolated individuals.

In 1999, a team of researchers from the University of Washington, Microsoft Research, the Boeing Company and Risø National Laboratory in Denmark received a research grant from the National Science Foundation to study collaborative information retrieval (CIR). The team defined CIR as any activity that is undertaken by members of a work team to collectively resolve an information problem. In this case, members of a work team are people who have been brought together to solve a problem which is the goal of the team. It was assumed that CIR behaviour might include but not be limited to: (a) two or more team members following a path together to find information for a specific problem; (b) team members using different paths to find information for a specific problem, either in parallel or sequentially; and (c) team members being guided by suggestions from other team members who had found the same or similar information earlier.

The project goal was threefold:

1. on the empirical level: to discover and analyse some manifestations of CIR as they occur in the workplace;
2. on the conceptual level: to extend an existing conceptual framework to address CIR;
3. on the technological level: to suggest technological and organizational developments that might enhance CIR.

The research plan involved the study of work teams in both Microsoft and Boeing with the intention of identifying and describing manifestations of CIR in these teams. The first work team studied was a Microsoft team designing a Web-based help and support centre. At the time of the CIR study, the Microsoft team had been working one month on a design project scheduled for completion in one year. When the observation of this team was completed, the researchers focused on another design team, but in this case a design team from Boeing. This team was one month into a three-year project aimed at designing a major aircraft system. The research team assumed that the observation of similar processes in a different setting might reveal similar information-seeking and use behaviour including manifestations of CIR.

Although this research project is still in progress, the analysis of the data collected from the first two teams is complete. This analysis reveals the challenges of defining the concept of CIR and the effect of the task and the organizational context on collaborative information seeking and use. This paper reports these preliminary results.

METHOD

Data collection

The cognitive work analysis framework guided collection and analysis of data from the CIR study. This framework, described in detail elsewhere by Fidel *et al.* (5), Pejtersen *et al.* (6) and Rasmussen *et al.* (7), was developed to help information system designers analyse and understand the complex interaction between (a) the activities and organizational relationships and constraints of work domains and (b) users' cognitive and social activities and their subjective preferences during task performance. It provided the basis for the structure and formulation of interview questions and the analysis of data collected through observations of team interactions at meetings. To collect data from each team, the researchers:

1. interviewed the team leader;
2. observed interactions between team members at meetings;
3. interviewed team members;
4. observed team members at work (for the Microsoft team only);
5. reviewed communication diagrams;
6. monitored e-mail threads (for the Microsoft team only).

Data analysis for the first team was completed before the research team started their observations of the second. This analysis suggested a revision of the data collection procedures. For observation of the second team, the researchers included the description of a critical incident (information seeking and use) as the focus for interviewing team members.

Data analysis

The interviews, think-aloud protocols from observations and meetings were taped and transcribed. These data were then analysed by the research team using the cognitive work analysis framework. The framework provided a template for developing detailed descriptions of the work tasks, decisions, communication and collaboration, and information needs, and the strategies, tactics and heuristics that team members use for obtaining information. It also guided an analysis of the organizational goals, structure and culture of each workplace. The researchers prepared a report

on these observations, which was shown to the team leader and some team members for comment and correction.

RESULTS

Information seeking and use: the Microsoft team

The first team that the researchers observed was a design team at Microsoft. The team consisted of a team leader or project manager, a program co-coordinator (who left shortly after the start of the study), two senior product designers, two junior designers, one visual designer and two usability engineers. The team was charged with designing an online help and support centre. The basic idea for the help centre service was to provide a unified portal for a wide variety of help information, much of which already existed in separate systems: for example, local application help, Windows updates and product support. In addition, the system had to be extensible so that original equipment manufacturers could add and integrate their own help content and present it to users in a unified form.

It should be noted that the project was just beginning as the research team started its observations, so the data collected reflect a team in the initial stages of a new design project. As the project was aimed at providing a Web-based service, the lifetime of the project was short, and iterations on the system were expected. Many of the team's information needs, therefore, involved creating detailed specifications and designs for the new service rather than looking up information from external sources.

Information needs

The information needs of the help centre design team were concerned with issues of content, design, management, scheduling and users. Essentially, the team was responsible for designing access to existing content. This required a thorough understanding of both the content and its structure. An example of this type of need was manifest when the designers of the taxonomy decided to explain the taxonomies through pop-up screens. In this case, they needed to know the average length of the explanations that would appear on these screens. Most often, the team's information needs related directly to design issues. Design-related needs were often brought before the team by individual members who needed information before continuing their work. Administrative issues also had a direct effect on the team's work. The views and perceptions of management were vital information for the team's work because these determined the focus, pace and scale of the team's project. A common management question for the team was who to contact for help in figuring out a certain issue that was relevant to the design. While managers were in a good position to answer

such questions, other team members were also active in helping to answer them. Lastly, some of the team's information needs involved questions about user behaviour, such as how customers behave in certain instances. Ideas about answers to these questions were often discussed but not completely resolved in meetings.

Information seeking

Team members used a variety of strategies for getting the information they needed. This could be information they needed as individuals or information needed by the team as a whole. The most common strategy team members used was to get information from another person. This often took the form of simply asking another team member, but it also included asking people outside the team. Team members also used personal networks to link with colleagues whom they had worked with on other tasks for organizations outside Microsoft.

The use of meetings, either formal or informal, was the most common method for getting information from people, particularly for information problems that were shared by several members of the team. Meetings were often directed at a specific information-gathering purpose: for example, the design manager needed to share information with the team that had been passed to her by the product manager; the product manager needed to alert the team about an issue related to the design of the help centre; the usability engineer wanted to provide feedback to the group; the product designer wanted to demonstrate a particular feature so that he could obtain feedback from other team members that would allow him to proceed to the next stages of design. Less formal meetings, such as corridor meetings, or *ad hoc* meetings in the form of corridor conversations were also used for information gathering.

Although information about design specifications was of paramount importance to this design team, in this highly dynamic context of software design direct questioning about design specifications was not common. Newer team members explained that it was difficult to pin people down about specifications. For this reason, members of the team had developed a method to obtain this sort of information, which involved developing a tentative proposal that included specifications and asking the responsible person to give them feedback. Thus, by giving information to the person who was authorized to give specifications, team members received the information they needed when that person reacted to their proposal.

Some members of the team used information sources in the form of books, research reports or Web sites but this was uncommon. Similarly, a few of the team members reported that they used the Microsoft library to obtain the information that they needed. It was commonly assumed that the best way (perhaps the only way) to obtain information was to ask the right person or to know someone who knew the right person.

CIR

When analysing the data for this first team the CIR researchers were seeking an operational definition that would distinguish individual and collaborative information retrieval. As a working definition, the researchers designated CIR as the act of seeking and using information from outside the team to solve an information problem that affects more than one team member. Employing this definition the researchers observed that team members collaborated a great deal when they defined information problems and developed the strategies for information retrieval. The act of retrieval itself, however, was generally carried out by individuals.

Information seeking and use: the Boeing team

The second team that the researchers observed for the CIR study was a team of engineers and technicians at Boeing. This team was designing the structural and spatial properties of all the components associated with a particular aircraft system. It is a complex system involving many components and the Boeing team was responsible for designing the spatial configuration and the installation and removal procedures for all of these components. These component designs were then transmitted to a supplier in the form of specification control drawings. The supplier then produced and delivered the components.

The team comprised a team leader, seven engineers and two technicians. Each engineer is responsible for one or more of the components that make up the system design. Such a person is called a 'focal'. For example, there is a focal for the fire detection system, and another focal for the anti-ice duct. A focal is also responsible for the information the team needs about his system. When defining his system, each engineer in the team has to communicate with many other engineers, some inside the team and some outside it, in order to coordinate the design but also to secure the quality of the design from various perspectives, such as how much stress the part can take or how much it might weigh.

The researchers observed that the Boeing team used a number of well-defined procedures for CIR. First, the team's weekly meetings were often

set up to receive information from people outside the team, who might or might not be members of the Boeing organization. Secondly, each team member was responsible for gathering needed information in his focal area and would do so on behalf of the team. Nevertheless, the team was flexible in its approach and *ad hoc* resolution of information problems was not uncommon.

Information needs

The engineers in the Boeing team have several categories of information needs. The most important needs related to the scheduling of the design process, when design components had to be completed. Team members also needed to know the procedures they should follow, including requests for instruction about how to perform a task, and about the format for delivering information. In this highly structured team, with each team member having particular responsibilities for the system design, issues related to the interfaces between parts were normally resolved privately. There were, however, some design specifications that were relevant to the whole team. These information needs related to issues such as the cost of hardware and the setting of standards for specific parts or components. In their daily work, team members also needed information about the activities of other members. This information was needed so that team members could coordinate their actions. The engineers found that being informed about the context of the system design was as important to them as the details that directly related to their work. They needed to know the reasons for particular design requirements and the company's vision for the product.

Although a number of information needs were not resolved during the observation period, it was possible to identify the type of information that was needed for most of the design challenges the team was facing. The information sought included dates, cost figures, data elements, design drawings, oral explanations or comprehensive presentations about vision and priorities, oral explanations about the reasons for design requirements and the data that others need and written and oral descriptions and agreements about procedures.

The Boeing team members did their best to get as much information as they could before they actually started their design but it was impossible to anticipate all the constraints ahead of time (partly because it was impossible to think about all of them). The team had a number of goals they were trying to achieve, including cost and weight reduction. In exploring ways of changing the system design to meet these goals, they

needed information about limitations of materials, such as strength and heat resistance. In some cases, the team members did not know they needed particular pieces of information until they had talked to other people. These negotiations started in various formats, and generally generated e-mail messages, phone calls, telephone conference calls and face-to-face meetings.

The information that team members sought related to various aspects of their design work. Because many of the information problems arose from design work, the information itself affected the way team members designed certain parts. However, various other facets of their work life were affected. Although the researchers did not observe directly how the information was used, the nature of the information sought indicated that finding the needed information could have affected decisions about issues such as:

- the pace at which they had to do their design;
- the time it would take to complete the design of a part;
- the procedure they would follow;
- the cost estimation of a certain part which might have possibly determined whether to continue with the current design, or whether a new design was required;
- the format of the forms team members had to fill in;
- their reporting of laboratory tests;
- their ability to make final design decisions.

Information seeking

To obtain the information they needed, the engineers on the Boeing team used a range of strategies, tactics and heuristics. Since the team was modifying an existing aircraft system design, much of the information that the team members needed could be found in Boeing information systems and databases. The engineers searched these systems or delegated the searching of these systems to others (other engineers or technical designers), when the need for information arose. Some of these systems were hard to use and took time to learn. Engineers who had been working at Boeing for some time and had been contributing information to these systems searched for the information they needed using part numbers, model numbers and serial numbers.

The observed information behaviour of the team was compatible with the social constructionist view of information seeking and use described by Tuominen and Savolainen (8). Because information gathering was so tied

to communication behaviour, engineers in the team did not regard their information gathering as research behaviour (information seeking and searching). Gathering information was seen as information generation, sharing and transmission. Circulation of information between and among team members was regarded as the dominant information-gathering strategy. Team members did this to identify and to fill gaps or needs. The identification of needs for information arose incidentally out of these discussions, in which case the strategy for finding information was to ask questions. This strategy then led to more questioning.

For members of the Boeing team, the most common strategy for getting information was, therefore, to ask other people. Team members asked one another for information. In some cases, this meant asking the engineer sitting near them in the work area. It might be an informal 'brain dump' or a spontaneous exchange. There were some people whom the engineers asked for information and others to whom they supplied information. A great deal of communication was required to bring together all the knowledge that was needed to design the aircraft system. Engineers in the team, therefore, tried to ensure that they had good relationships with the key people from whom they sought information.

The cycle of gathering information sometimes began with the team leader delegating information-gathering tasks to particular members of the design team. He took his concerns about needed information to members of the team who he thought would know the answer or to team members who had responsibility for that particular aspect of the design. This took the form of keeping the lead up to date or educating him on the process that was being followed by the focal engineer.

Gathering information from people also took the form of seeking validation or verification of the information a team member had retrieved from another engineer on the team or a related Boeing manager. It involved an assessment of the credibility of the people being asked for information. If the person providing the information was authoritative then the engineer in this case was certain that the information was accurate and reliable.

The most common place for generating and resolving shared information needs was the team's weekly meetings. One team member was responsible for the agenda for these meetings, which usually included some items that were information needs. During the meeting, the engineers discussed the needed information and either got answers at the meeting or devised a plan for finding what they needed to know. The team then collectively decided whether to keep the item on the agenda for the next meeting. This was

achieved in a systematic manner. It was not unusual for an information item to be on the agenda for several consecutive meetings.

One way the team resolved information needs that were brought to a meeting was by inviting a person known to have the needed information to participate in a meeting. This approach was quite common and, in fact, in one of the meetings that the researchers observed it was decided that a certain person would be invited to all subsequent team meetings so the team could receive weekly updates from him. Managers highly placed in Boeing were sometimes invited to team meetings when the engineers needed the big picture and wanted to make sure they understood it.

Another method that the team used for resolving information needs in a meeting was to formulate the need through a discussion, and then to delegate the task of finding the information to one team member. This always created a new item for the next week's meeting agenda. Selecting the person to look for the needed information was usually a straightforward process. Team members had explicit responsibilities which designated who would get the information that was needed. The team, however, did not blindly follow this distribution of responsibility. If the focal engineer had difficulties finding the needed information, other team members volunteered to approach information sources that were more accessible to them than to the focal person. If the information needed did not fall neatly into one of the designated focal categories, a team member would volunteer to get it. Some team members were also proactive in resolving information needs even before they arose. These individuals anticipated what information other team members would need and found it before the issues were defined as an information problem by the team.

Not all the information needs of the team were well formulated and then systematically resolved, however. At times, team members just 'surfing around' to bring useful information to their attention. Team members accomplished this in various ways. For example, a small part of most weekly meetings was taken up with informal conversation in which people tried to find out the latest information. Usually, this information came from someone who was not on the team, but team members could also contribute information in this way. At times the team understood who among them had recently talked with a source person. This team member was then asked at a meeting if there was any update on this or that. On other occasions, a team member who happened to have talked to the right person informed the team that he had the information that was needed. Another form of team members 'surfing around' was observed in

information exchanges. In this case, instead of launching inquiries with a well-formulated need, engineers on the team simply entered into a conversation with a supplier and asked generally how things stood. The engineers tended to obtain the information they needed from the conversation that followed.

CIR

The operational definition the researchers developed for CIR faced a challenge when they analysed the data collected from the Boeing design team. Of particular concern was the designation of team membership. In this design situation, engineers in the team have fixed and intense communication with individuals who support their design work. Thus, for example, there are certain stress analysts who work with the team, and similarly certain vendors. Should they be included in the team when one defines CIR? This dilemma highlights the challenge of finding an operational definition for CIR.

Even with this more flexible definition of team membership, the CIR researchers observed that, like the Microsoft team, engineers at Boeing worked collaboratively to define information problems and to identify search strategies, but the act of retrieving information was performed by individuals on their own.

COMPARISON OF THE TWO DESIGN TEAMS

The work context for the two teams observed in the CIR study to date is very different. This difference has various facets. It is most important, however, to examine the nature of the product that each team designed. The Microsoft team worked on a Web-based software product. Such a product required a relatively short time to develop, and included some tolerance for failure because it is unlikely that major harm will be caused by a mistake, and because a new version would be developed in a relatively short time, without major investment. The Boeing team, on the other hand, was involved in designing an aircraft system. This product requires a relatively long time to develop, the involvement of many more professionals of all sorts is needed and there is no tolerance for failure. As a result, the design process required a lot of systematic interaction between various experts and representatives of official bodies, and checking against in-house, as well as national and international, standards, to guarantee not only the quality of the product but also its safety. In addition, for the Microsoft team, the product requirements were less clear because the designers were trying to anticipate what the user might need. In fact, for this type of product, the Microsoft designers may not discover the uses that

people apply it to until the service is actually installed. The team at Microsoft was creating something new, so external dependencies were less of an issue. At Boeing the design team had to be concerned with the way their system would fit into many requirements of various kinds.

Nevertheless, the information behaviour of the design teams was similar in a number of ways. Because both teams were engaged with the processes of design, the tasks and decisions of their members were prescribed by design specifications and timetables. The design sequence and schedule were, therefore, paramount for both teams. Both teams also worked within an organizational culture that based itself on direct communication between people. Therefore, for both teams, the most effective way to find the information for the design process was to identify and communicate with another person. The information provider could be another employee of the company, a specialist in a particular area, a manager authorized to make particular types of decisions, a supplier from outside the organization or an informal contact that a team member had made while working at another company.

For both teams, the designing process was iterative and highly interactive. The process required continuous cycles of information giving, information sharing, requests for feedback, confirmation and validation. In both teams, design elements became information-bearing objects that could be transferred and exchanged and, most importantly, become the focus for information-generating discourses. For both teams, the design became the information query. The preliminary design was offered to the information source (another person). The information requested was a reformulation, amendment, validation or answer. In each case the individual or group of people who were the information source provided the information relative to the team's query (the design component). The approach to information exchanging, however, was characterized differently by the teams. At Microsoft individuals put forth a design query in the form of 'Would that be a cool feature?', whereas at Boeing the primary key for information seeking is 'Can I assemble that, can I put these things together?'

In terms of information seeking and use, both teams used weekly meetings to identify information needs and the strategies that could be used for finding information. In fact, one of the primary activities for these meetings was to discuss needed information, to invite guests who could provide information for the whole team and to delegate information gathering to particular members of the group. If an information need arose that could not be resolved by internal team resources, the strategy that

both teams most commonly used was to invite a person to the next meeting who could answer this question. In most other cases, the teams selected a team member to be responsible for getting the information. The teams also identified appropriate external sources for a delegated team member to search for information. It was common at Boeing, for example, to have a pre-meeting of team members with the aim of clarifying information needs prior to sending someone out to meet a vendor.

Despite these similarities, the teams had very different relationships with their external sources of information. CIR is easier or at least more efficient when there is strong support for information exchange between the team and outside teams or vendors. At Microsoft, a friction when working with external teams was observed. Team members acknowledged that there was little cooperative work between people in different teams. This was attributed to lack of communication, the fact that "lots of people in all these different groups don't necessarily talk to each other". At Boeing, on the other hand, there was a clear structure for information exchanging between the team and outside sources.

Both teams had a distinct division of labour. The teams themselves were an assemblage of expertise relative to a particular design task. In both cases, the aim was to exploit the collective expertise that comes with managed, highly interactive collaborations. At first glance, the division of labour that was apparent for each team appears to be contradictory to the notion of collaboration because division of labour should disconnect collaborative work. In fact, the observations of these teams revealed the opposite. For both teams, division of labour was used to facilitate more effective collaborations. Well-defined work roles helped to identify the range of responsibilities and tasks of a team member relative to other members of the team. These distinctions facilitated more effective information seeking outside the team. Definition of role gave each team member a heightened sense of responsibility because individuals could identify their particular part of the information problems that were engaging the team at any point in time.

While the division of labour was similar for the two teams, the designation of roles was achieved very differently. At Boeing, the team was assembled according to the roles and expertise required to design an aircraft system. The Boeing team had a hard division of labour in terms of the functionality of the team. There was more emphasis on individual work on individual components of the system design. At Microsoft, the definition of the team member's role was more flexible and often self-defined. As a Microsoft

team member stated, "people just kick in and do what they can do when it needs doing". Each team member found ways to define his or her role in the designing process. To some extent, this approach is common in the Microsoft organizational culture: "you just kind of have to insert yourself into the process...The ones who are not successful are the ones who sit and wait to be told what to do. That won't work".

Another difference between the two teams was the use of local and personal databases. Generally speaking, the Boeing designers relied very heavily on documents including text, drawings and images, while the software designers used very little documentation. In addition to the in-house databases that the Boeing engineers searched, they had access to volumes of standards and other printed materials, and also developed their own 'libraries' or databases. Most of the software designers in Microsoft did not use these types of resources. In addition, the physical environment at Boeing was more conducive to collaboration because most team members had their workstations in the same open area, while the designers at Microsoft were located in individual offices that were not adjacent to one another.

CONCLUSION

This paper reports on very preliminary results from a study of CIR. The few findings presented here reflect the challenges of studying the collaborative behaviours of teams seeking and using information in the workplace. First and foremost, the concept of CIR became increasingly elusive as the researchers gained more knowledge about it. It is possible that creating a stable and inclusive definition for the concept will require the study of several diverse teams located in various organizations and performing a range of tasks. It is clear, however, that more research is required to develop a definition that is sufficiently inclusive to encompass the complexities of team behaviour in relation to CIR.

The results presented in this paper also show that the nature of the task and the structure and the culture of the organization in which tasks are performed are important factors that determine CIR behaviour. In this paper we do not describe the structure and culture of the relative organizations, but their effect on collaboration is clear. Here, we explained the distinction between the two teams through the products they design. The attributes of these products, however, require certain organizational structures and cultures for their production, and these affect the designers' work directly. Other organizational factors play a role as well and will be analysed in future publications of the CIR study.

Lastly, the findings from these two teams indicate that not all information behaviour takes place collaboratively even in teams that carry out CIR. For the design teams we studied, collaboration took place when identifying, analysing and defining the information need, as well as in devising strategies for information seeking. The act of retrieval, however, was carried out by individuals.

The study of these two teams is only a first step in the study of CIR. Analysis of data from additional teams will shed new light on the concept itself, will reveal new patterns of behaviour and will make it possible to identify the behaviour common to CIR across teams.

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