



# Collaborative Information Seeking: A Literature Review

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## Abstract

Collaboration is often required for activities that are too complex or difficult to be dealt with by a single individual. Many situations requiring information-seeking activities also call for people to work together. Often the methods, systems, and tools that provide access to information assume that they are used only by individuals working on their tasks alone. This review points to the need to acknowledge the importance of collaboration in information-seeking processes, to study models, and to develop systems that are specifically designed to enable collaborative information seeking (CIS) tasks. This chapter reviews the literature from various domains including library and information science, human-computer interaction, collaborative systems, and information retrieval. Focus of the review is on the extent to which people work together on information seeking tasks and the systems and tools that are available for them to be successful. Since CIS occurs in the broader context of collaboration in general, a review of literature about collaborations is first undertaken to define it and place it into context with related terms such as cooperation and communication. A more focused review of research follows relating CIS to systems that have attempted to support such interactions. Included are identification and synthesis of a number of core issues in the field and how best to evaluate systems and collaborative tools. Key lessons learned from the review are summarized, and gaps in the literature identified to spur future research and study.

## I. Introduction

Collaboration is a useful and often necessary component of complex projects. It is in human nature to collaborate with others when the task at hand is difficult or cannot be carried out by one individual. It began when man hunted for food (Lee and DeVore, 1968) to modern office environments (Hansen and Jarvelin, 2005). Recognizing this, many libraries are undergoing renovations and expansion to provide spaces in which students and

faculty can work together, moving away from the 1950's and 1960's models using single carrels.

In many social situations, it is also common to collaborate. These situations span cultural, gender, and age differences. Large *et al.* (2002) in a study of web searching in a Canadian grade-six classroom found that participants often wanted to collaborate on search tasks. Similarly Morris' (2008) survey of knowledge workers found that the majority of them wanted to work collaboratively. Morris (2007) also proved that collaboration in many situations is vital to the success of the task at hand.

When it comes to a search for information, collaboration could be a wise choice. Twidale and Nichols (1996) pointed out a problem, however, in that "The use of library resources is often stereotyped as a solitary activity, with hardly any mention in the substantial library science and information retrieval literature of the social aspects of information systems" (p. 177). They argued that introducing support for collaboration into information retrieval (IR) systems would help users to learn and use the systems more effectively. Levy and Marshall (1994) noted that "support for communication and collaboration is . . . important for information-seeking activities, and . . . indeed, support for the former is needed to support the latter" (p. 164). On the basis of their extensive study of patent office workers, Hansen and Jarvelin (2005) concluded that the assumption that IR is a solitary one needs to be reconsidered. Twidale *et al.* (1997) showed that users often desire to collaborate on search tasks and argued that browsing is a collaborative process unlike how it is presented by a majority of search engines, that is, a single-user process. To them a truly user-centered system must acknowledge and support collaborative interactions between users. Morris (2007) proposed that four features of exploratory search experience—coverage, confidence, exposure, and productivity—could be enhanced by providing explicit support for collaborative searching and subsequent sense-making processes.

Recognizing the increasing importance of group, team and/or project, and learning environments for students and library users in general, this chapter presents a review and synthesis of related literature. The chapter is primarily divided into two parts with the first providing an overview of the concept of collaboration as studied in various fields. The second part presents a description of different aspects of collaborative computer information seeking (CIS) behavior while identifying the issues and challenges involved in building and evaluating CIS systems. In the conclusion there is a review of lessons learned from the literature and suggestions for future research.

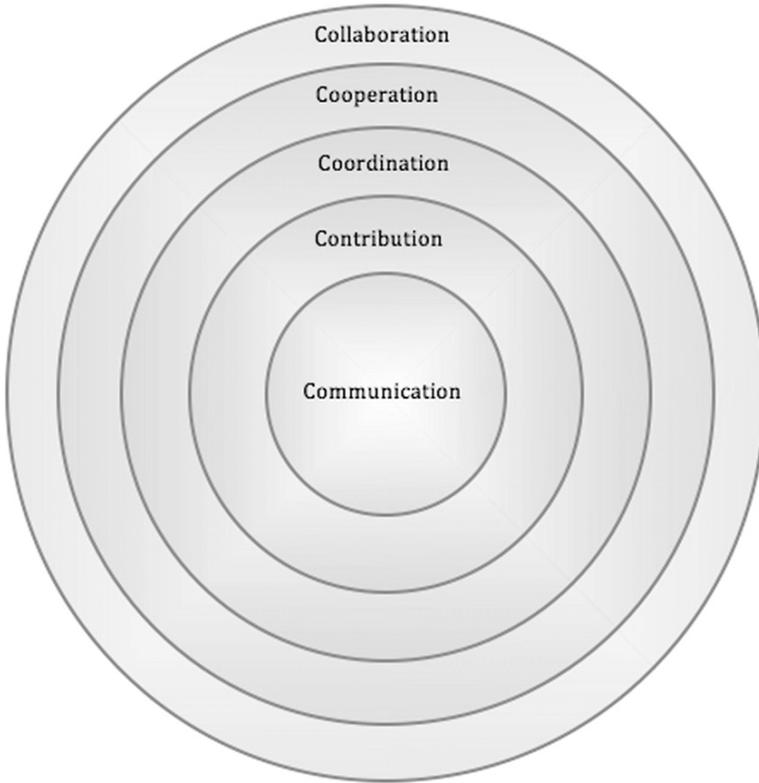
## A. Definitions and Models of Collaboration

Most people have an intuitive understanding of what it means to collaborate. As its Latin roots “com” and “laborate” suggest, *collaboration* indicates, “to work together.” London (1995) interpreted this meaning as *working together synergistically*. Gray (1989) defined collaboration as “a process of joint decision-making among key stakeholders of a problem domain about the future of that domain.” Roberts and Bradley (1991, p. 209) called collaboration “an interactive process having a shared transmutational purpose.”

People use the word collaboration in various contexts and interchangeably with terms such as coordination and cooperation. It is important therefore to define collaboration here. Denning and Yaholkovsky (2008) said that coordination and cooperation are weaker forms of working together, yet all these activities require sharing information with others. Taylor-Powell *et al.* (1998) added another component—contribution—and concluded that for effective collaboration, each member of the group has to make a contribution to the collaborative. Using communication, contribution, coordination, and cooperation as essential steps toward collaboration, they showed how a true collaboration requires a tighter form of integration, moving from simple communication to higher levels of coordination, cooperation, and collaboration.

On the basis of these two works, a model of collaboration is synthesized and presented in Fig. 1. This model has five components: communication (information exchange), contribution, coordination, cooperation, and collaboration. It shows which activities support others. For example, coordination is a subset of collaboration, which indicates that for a meaningful collaboration, there has to be coordination of people and events. These five sets are described below in more detail with examples.

1. *Communication*. This is a process of sending or exchanging information, which is one of the core requirements for carrying out collaboration, or maintaining any kind of productive relationship. For example, a message on a public library bulletin board about a book sale is a way for the library to communicate with visitors.
2. *Contribution*. This is an informal relationship by which individuals help each other to achieve their individual goals. For example, Mark has some old books that he no longer needs, and he asks the library if they would take them. Upon the library’s approval (communication), Mark donates the books.
3. *Coordination*. This is a process of connecting different agents together for a harmonious action. This often involves bringing people or systems under one umbrella at the same time and place. For example, a secretary setting up a meeting of computer, library, and university administrators to plan for future technology enhancements is undertaking a task of coordination.



**Fig. 1** A set-based model of collaboration. An inner set is essential to or supports the outer set.

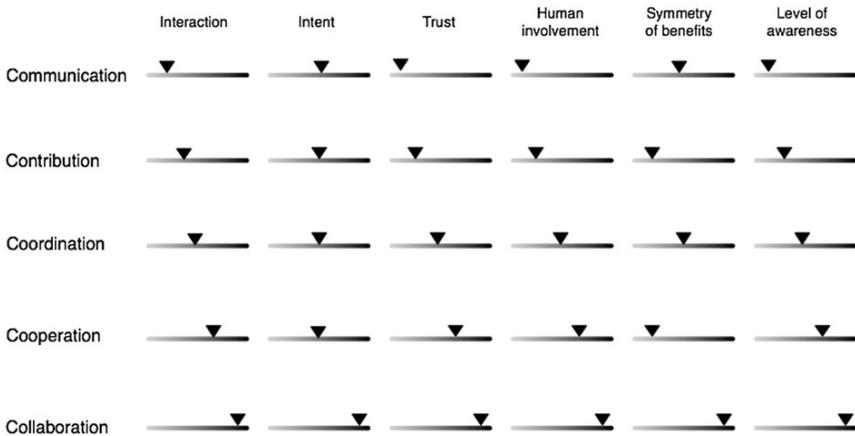
4. *Cooperation.* This is a relationship in which different people with similar interests take part in planning activities, negotiating roles, and sharing resources to achieve joint goals. In addition to coordination, cooperation involves following some rules of interaction. An example in a library setting might be a reference librarian working with a cataloger to develop finding guides for a donation of personal papers.
5. *Collaboration.* This is a process involving various individuals who may see different aspect of a problem. They engage in a process that goes beyond their own individual expertise and vision to complete a task or project. In contrast to cooperation, collaboration involves creating a solution or a product that is more than the sum of each participant's contribution. Authority is vested in the collaborative rather than in an individual entity or organization. For example, in the library world, consortia and networks such as OCLC are built collaboratively by member libraries to provide broader and deeper access to information.

A collaborative solution tends to be better than one made by one individual. (Surowiecki, 2004). Chrislip and Larson (1994) defined

collaboration as a “mutually beneficial relationship between two or more parties [agents] who work toward common goals by sharing responsibility, authority, and accountability for achieving results” (p. 5). Similarly, according to Gray (1989), collaboration is “a process through which parties [agents] who see different aspects of a problem can constructively explore their differences and search for solutions that go beyond their own limited vision of what is possible” (p. 5).

The difference among these five activities can be summarized using the variables, which are depicted in Fig. 2.

1. *Interaction*. While communication is at the center of other activities, it is possible to have little/ no interaction while communicating. For example, a system administrator sending an email to a user may not require any further interaction. Collaboration, however, requires high levels of interactions among the participants.
2. *Intent*. Similar to interaction, a collaborative project requires much stronger intent compared to those tasks that merely need coordination of events or one entity cooperating with another.
3. *Trust*. To have an effective and mutually beneficial collaboration, participants need to establish trust, which is not required for coordinating or cooperating.
4. *Human involvement*. Communication may not require much human involvement. For instance, posting a message on a notice board is an act of communication, but seldom requires interactive communication or involvement. Collaboration, on the contrary, requires participants to be actively engaged with one another.
5. *Symmetry of benefits*. The kind of collaboration considered here is, by definition, mutually beneficial. Thus, it benefits everyone involved in the process. The amount of benefit may vary depending on participants’ roles and responsibilities. For example, a person gathering literature



**Fig. 2** Distinguishing communication, contribution, coordination, cooperation, and collaboration using different variables. A variable is represented with a bar going minimum to maximum from left to right.

for someone is performing an act of contributing to (cooperating) another's task such as writing a report. Co-authorship, on the contrary, is an act of collaboration, benefiting all the participants.

6. *Level of awareness.* For an interactive, intentional, and mutually beneficial collaboration to be successful, it is imperative that all the participants be aware of each other's actions and contributions. This also helps to establish trust among participants. Such awareness may not be a requirement for coordination or cooperation.

## B. Principles

Let us now look at the principles or conditions for an effective collaboration. Most researchers agree that an effective collaboration must be *democratic* and *inclusive*, that is, it must be free of hierarchies of any kind, and it must include all of the stakeholders (London, 1995).

Regarding democracy in collaboration, Flora *et al.* (2004) pointed out that “without community empowerment and broad participation in agenda setting, the decision-making process of discussion, debate, and compromise is relatively meaningless” (p. 273). Osborne and Gaebler (1992) also expressed their views against hierarchies by noting that centralized and hierarchical associations tend to be divided up into many layers and boxes. This makes communication across units and between layers difficult, thus inhibiting the real potential of collaboration.

There is also a general agreement about the inclusiveness in collaboration. Theobald (1987) argued that all leadership in a community must be involved, whether participants fit traditional definitions of leaders or not. Chrislip and Larson (1994) concurred, reporting that all the successful collaborations that they studied involved participants from affected sectors, such as government, business, and community groups. Gray (1989) also claimed that collaboration could only be meaningful if the stakeholders were interdependent, stating that “collaboration establishes a give and take among the stakeholders that is designed to produce solutions that none of them working independently could achieve” (p. 11).

To spell out what situations could create a meaningful collaboration, Surowiecki (2004) presented four conditions for a successful collaboration.

1. *Diversity of opinion.* Each person should have some private information, even if it is just an eccentric interpretation of known facts.
2. *Independence.* People's opinions are not determined by the opinions of those around them.
3. *Decentralization.* People are able to specialize and draw on local knowledge.
4. *Aggregation.* Some mechanism exists for turning private judgments into a collective decision.

Collaboration, in many situations, is a process that ties people of varying opinions and abilities together. However, the process may not necessarily

lead to agreement on all issues. Gray (1989) acknowledged that not all collaborations lead to consensus, but added that when agreements for action are reached, they are always done so through consensus. Denning and Yaholkovsky (2008) also noted that it is solidarity, not software, which generates collaboration.

### C. Process

Following are questions compiled by London (1995) that need to be considered before starting a collaborative process.

1. What are the structural relationships between the parties and the possible power issues inherent in the collaborative arrangement?
2. Is there a clear understanding among all the parties of the respective goals of the other participants?
3. What form of leadership is required to facilitate the process?
4. Does the project have some form of integrating structure, such as a cross-section of steering committees, to facilitate and coordinate decision making and implementation?
5. Will the project be more effective with a neutral, third party mediator?
6. Should the media be involved?
7. Does the project have enough time, money, and staff support?

Such questions are important to answer since collaboration may incur costs and since the problem and circumstances may not call for collaboration.

Collaboration is typically a complex process involving a number of phases, various interactions, and other sub-processes. Gray (1989, pp. 57–74) identified three major phases of collaboration.

1. *Pre-negotiation or problem-setting phase.* This phase is often the most difficult, and involves six issues.
  - a. The parties must arrive at a shared definition of the problem, including how it relates to the interdependence of the various stakeholders.
  - b. The parties must make a commitment to collaborate.
  - c. Other stakeholders must be identified whose involvement may be necessary for the success of the endeavor.
  - d. The parties must acknowledge and accept the legitimacy of the other participants.
  - e. The parties must decide what type of convener or leader can bring the parties together.
  - f. The parties must determine what resources are needed for the collaboration to proceed.
2. *Direction-setting phase.* During this phase, the parties need to identify the interests that brought them together, determine how they differ from the interests of the others, set directions, and establish shared goals. This phase is characterized by six steps.
  - a. Establishing ground rules.
  - b. Setting the agenda.
  - c. Organizing subgroups (especially if the number of issues to be discussed is large or the number of stakeholders exceeds the 12–15 member limit for effective group functioning).

- d. Undertaking a joint information search to establish and consider the essential facts of the issue involved.
  - e. Exploring the pros and cons of various alternatives.
  - f. Reaching agreement and settling for a course of action.
3. *Implementation phase.* During this final phase, the participants go through the following steps.
- a. Participating groups or organizations deal with their constituencies.
  - b. Parties garner the support of those who will be charged with implementing the agreement.
  - c. Structures for implementation are established.
  - d. The agreement is monitored and compliance is ensured.

Similar to these three phases defined by Gray (1989), Denning and Yaholkovsky (2008) provided three main stages of solving a complex problem: design, collaboration, and follow-through. They defined five specific stages of collaboration: (1) declare, (2) connect, (3) listen to and learn all perspectives, (4) allow a “we” to develop, and (5) create together.

#### D. Limitations

As was noted earlier in many situations collaboration is a natural choice, especially for solving complex problems (Denning, 2007). However, the costs and benefits associated with a collaborative process must be understood to evaluate the usefulness and the effectiveness of a particular collaboration.

London (1995, p. 9) identified the following limitations of a collaborative process.

1. Collaboration is a notoriously time-consuming process and is not suitable for problems that require quick and decisive action.
2. Power inequalities among the parties can derail the process.
3. The norms of consensus and joint decision-making sometimes require that the common good take precedence over the interests of a few.
4. Collaboration works best in small groups and often breaks down in groups that are too large.
5. Collaboration is meaningless without the power to implement final decisions.

Gray (1989) listed four circumstances under which it is best *not* to collaborate: (1) when one party has unchallenged power to influence the final outcome; (2) when conflict is rooted in deep-seated ideological differences; (3) when power is unevenly distributed; and (4) when constitutional issues are involved or legal precedents are sought, and when a legitimate convener cannot be found.

Sometimes collaboration is forced upon a group of people. Such examples might include the merger of two companies or an instructor using forced groupings in a class. In these situations, collaboration may start with acts of cooperation, in which participants merely follow a set of rules for

working together. Later, it may or may not result in collaboration depending on responses to the previously mentioned factors and questions.

Disparity of workload and benefits is another limitation. Having diversity in collaboration could lead to success (Surowiecki, 2004), but as Aneiros and Estivill-Castro (2003) point out, roles according to positions (manager vs. knowledge workers) can create constraints in collaborative information seeking (CIS). They advised against a master/slave model of collaboration and proposed instead to have unconstrained co-browsing with asymmetric roles. Grudin (1994) also talked about disparities in benefits and responsibilities among participants. He claimed that it is almost impossible to have a groupware system in which every participant does the same amount of work and/or benefits the same. Owing to such inequality, a groupware application may become less useful over time and may even stop being used.

The kind of collaboration that is considered here (intentional and mutually beneficial) is slightly different than Grudin's notion of groupware, and CIS systems are considerably different than the groupware systems Grudin discussed. However, several of the issues he identified are relevant, and several are explored further in Shah (2009).

Grudin's recommendation for a system developer was to ensure that the system benefits all participants. At the same time, he pointed out difficulties in so doing because, while managers or higher authorities gain more benefits, they are the decision makers and pleasing them is equally, if not more important, than pleasing participants who have to do more of the work.

## **E. Collaboration in the Context of LIS**

To understand the model of collaboration presented earlier (Fig. 2) in the context of information science, the five sets from that figure are enlisted in Table 1 with examples. Sending an email or instant messaging (IM) is a form of communication, but these communications may or may not be part of a collaborative project. Morris (2008) in fact established that email is one of the most frequently used methods of communication in a collaborative project. While communication tools to exchange contributions, there are specialized tools and places for so doing. Popular ones include, online support groups and social Q and A sites, such as Yahoo! Answers. The askers and answerers (contributor) on these sites are not truly collaborating however. One user is merely helping the other with his/her information need. To make such a process more effective and explicit, people use traditional/video conference calls or net meetings, which require coordinating agents (people as well as systems). Once again, such a coordinated event might/might not be a part of a collaborative project.

**Table 1**  
Various Group Activities and Examples

Activity	Definition	Examples
Communication	Exchanging information between two agents	Email, chat
Contribution	Offering of an individual agent to others	Online support groups, social Q&A
Coordination	Connection different agents in a harmonious action	Conference call, net meeting
Cooperation	Agents following some rules of interaction	Wikipedia, second life
Collaboration	Working together synergistically to achieve a common goal	Brainstorming, co-authorship

As stated before, coordinated contribution needs a set of rules that the participating agents need to follow, and Wikipedia is a good example of cooperation. Its participants not only contribute in a coordinated fashion, but are governed by rules that need to be followed. For example, in cases of a disagreement, there are guidelines for how to make interactions work.

Let us look back to the terms coordination and cooperation and see how they fit around this understanding of collaboration expressed in Table 1. Austin and Baldwin (1991) noted that while there are obvious similarities between cooperation and collaboration, with the former involving pre-established interests, while the latter involves collectively defined goals. Malone (1988) defined coordination as “the additional information processing performed when multiple, connected actors pursue goals that a single actor pursuing the same goals would not perform” (p. 5). While this definition is close to the one given previously, it could be argued that it still fits in the model described in Fig. 2 since it says nothing about creating solutions.

From the definitions and models described earlier, we can synthesize that to have a successful collaboration while seeking information, we need to create a supportive environment where:

1. The participants of a team come with different backgrounds and expertise;
2. The participants have opportunities to explore information on their own without being influenced by the others, at least during a portion of the whole information seeking process;

3. The participants should be able to evaluate the discovered information without always consulting others in the group; and
4. There has to be a way to aggregate individual contributions to arrive at the collective goal.

One important requirement for successful collaboration is the kind of tasks being undertaken, but this has not been mentioned in the literature. As Morris and Horvitz (2007b) hypothesized, it is tasks that are exploratory in nature, which are most likely to benefit from collaboration.

## F. Lessons for Collaborative Information Seeking

On the basis of the lessons learned from the general notion of collaboration, this subsection proposes (1) a set of conditions under which collaborative information seeking is useful and (2) a set of guidelines for building a successful CIS environment. The conditions under which collaboratively seeking information is useful are given below. They are not very different from those of any other kind of collaborative process.

1. *Common goal and/or mutual benefits.* For the most part, this is not a function of a system. A system can provide support for people with a common information goal who want to collaborate but does not typically initiate the collaboration. People do. A few systems can connect visitors to the same web sites in order for them to potentially collaborate, such as the one described by Donath and Robertson (1994). These systems are based on the assumption that the people browsing the same web sites may have the same information needs.
2. *Complex task.* Denning and Yaholkovsky (2008) recognized the benefit of collaborating while solving “messy” or “wicked” problems. While listing the conditions under which it is not useful to collaborate, London (1995) argued that if a task is simple enough, there is no point in collaborating.
3. *High benefits to overload ratio.* Often, a simple divide and conquer strategy could make collaboration successful. However, such a process may carry overhead due to phases preceding and following the process of information seeking. London (1995) noted that collaboration is only useful if such overhead is acceptable for a given situation. Fidel *et al.* (2004) showed that collaboration induces an additional cognitive load, which they referred to as collaborative load. For the collaboration to be viable, it has to meet or exceed benefit expectations with the cognitive load that it brings.
4. *Insufficient knowledge or skills.* A common reason to collaborate is that one individual has insufficient knowledge or skills to solve a complex problem.

The guidelines for building successful CIS systems are as follows:

1. They should provide effective ways for the participants to communicate with each other;
2. They should allow, and encourage, each participant to make an individual contribution to the collaborative information search;

3. They should coordinate participant actions, information requests, and responses to have an active and interactive collaboration either synchronously or asynchronously whether co-located or remote;
4. They should ask participants to agree and follow a set of rules. For example, if participants disagree on the relevancy of an information object, they should have a way in the system in which to discuss and negotiate a mutually agreeable solution; and
5. They should provide mechanisms to let participants not only to explore their individual differences but also to negotiate roles and responsibilities.

## II. Collaborative Information Seeking

While this author uses CIS, readers should be aware that there are many related and interchangeable terms in use such as collaborative information retrieval (CIR) (Fidel *et al.*, 2000), social searching (Evans and Chi, 2008), concurrent search (Baecker, 1995), collaborative exploratory search (Pickens and Golovchinsky, 2007), co-browsing (Gerosa *et al.*, 2004), collaborative information behavior (Reddy and Jansen, 2008; Talja and Hansen, 2006), and collaborative information synthesis (Blake and Pratt, 2006).

Despite the lack of agreement on terminology, following is an attempt to examine CIS in the context of space-time and user-source-time.

Foster (2006) defined collaborative IR as “the study of the systems and practices that enable individuals to collaborate during the seeking, searching, and retrieval of information” (p. 329). Shah (2008) referred to CIS as a process of information seeking “that is defined explicitly among the participants, interactive, and mutually beneficial” (p. 1). There is still lack of a universally accepted definition. Focus here is not only on retrieving or browsing but also on performing information seeking in collaboration. As we saw earlier, information seeking goes beyond searching and retrieving information.

### A. Space and Time

The classic way to organize collaborative activities is based on two factors: location and time (Rodden, 1991; Hansen and Jarvelin, 2005; Golovchinsky *et al.*, 2008). Fig. 3, inspired by Twidale and Nichols (1996) depiction, shows various activities, methods, and environments on these two dimensions.

As we can see from this figure, the majority of collaborative activities in conventional libraries are co-located and synchronous (e.g., face-to-face meetings, reference interviews), whereas collaborative activities relating to digital libraries are more often remote and synchronous (e.g., digital referencing, virtual meetings). Social information filtering, or collaborative filtering, a process benefiting from other users’ actions, is asynchronous and

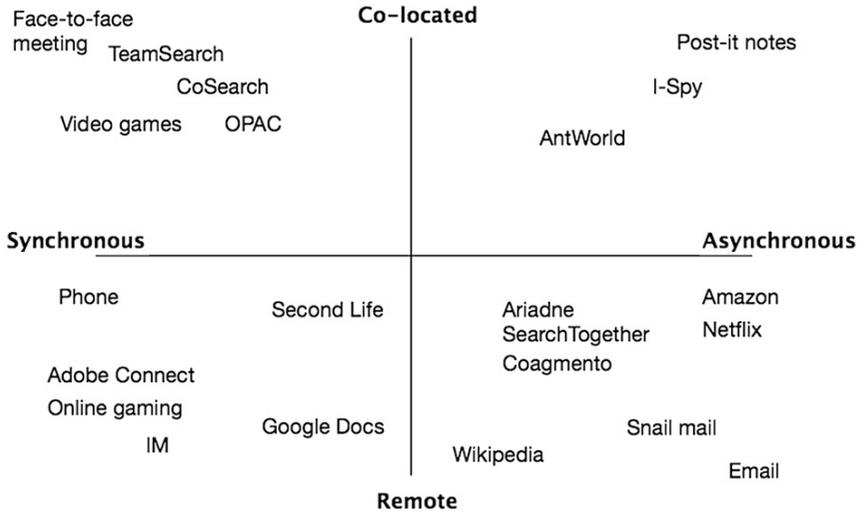


Fig. 3 Looking at collaboration with space and time dimensions.

mostly remote. Email also serves as a tool for doing asynchronous collaboration among users who are not co-located. Chat or IM (represented as “internet” in the figure) enables synchronous and remote collaboration.

Adobe Connect<sup>1</sup> facilitates online meetings in which the participants can share and discuss information and falls under synchronous-remote collaboration in Fig. 3. This environment needs (1) a way to connect remote participants, (2) a shared space for exchanging information, and (3) a communication channel to provide real-time message passing among the participants.

### B. User-Source-Time Configurations

Another way of looking at how different systems fit into a broad spectrum of collaboration is to consider user(s), source(s), and time as shown in Table 2.

- *Single-user mode search.* This is a typical search. A user issues a query to a search engine and receives a ranked list. Relevance is found by considering various factors about individual documents, the whole collection, and links (Brin and Page, 1998; Kleinberg, 1999). Relevance feedback (Buckley *et al.*, 1994) and personalization (Teevan *et al.*, 2005) are common ways to improve searches in this mode.
- *Multisource search.* No search engine has full coverage of the web (Sullivan, 2005) so issuing the same query to different search engines typically yields different sets of results.

<sup>1</sup><http://www.adobe.com/products/acrobatconnect/>

**Table 2**  
Different Scenarios of Collaborative Information Processing

User	Source	Time	Examples
Single	Single	–	Typical search
Single	Multiple	Asynchronous	Multisource search
Single	Multiple	Synchronous	Meta-search
Multiple	Single	Asynchronous	Collaborative filtering, collaborative navigation, collaborative IR
Multiple	Single	Synchronous	Collaborative navigation, collaborative IR
Multiple	Multiple	Asynchronous	Collaborative filtering, collaborative IR
Multiple	Multiple	Synchronous	Collaborative navigation, collaborative IR

- *Meta-searching*. Instead of a user issuing a query to different search engines, a system can do so simultaneously by combining results obtained from a set of search engines, re-ranking them, and presenting a single ranked list to the user (Aslam and Montague, 2001). Examples are *Dogpile* and *Clusty*.
- *Collaborative filtering or recommender systems*. If multiple users are using the same source for information, the source can keep track of what users are looking for and what they find. On the basis of tracking statistics, the source can make recommendations to other users who are looking for the same or similar information. *Amazon.com* is an example of such a system.

Two other systems to consider are CIR and collaborative navigation, both of which are discussed later.

### C. Control, Communication, and Awareness

Three components specific to group-work or collaboration that are highly predominant in the literature are control, communication, and awareness. Understanding these factors are helpful in various design stages of CIS systems.

#### 1. Control

Rodden (1991) identified the value of control in computer-supported cooperative work (CSCW) systems and listed a number of projects for implementing control. For example, the COSMOS project (Wilbur and Young, 1988) had a formal structure to represent control in the system. They used roles to represent people or automatons and rules to represent flow and

processes. Roles of people could be supervisor, processor, or analyst. Rules could be a condition that a process needs to satisfy to start or finish. Rodden classified these control systems as procedural-based systems.

To express control in a collaborative environment, early CSCW systems used various mechanisms to pass around messages. These messages were often referred to as structured definition language (SDL) messages. In the most basic sense, these were email messages sent back and forth among participants. SDL provided support for collaborative projects by imposing a structure to messages, incorporating additional fields of information that were used to filter and distribute messages appropriately. For example, Malone *et al.* (1987) proposed an *Information Lens* framework, in which messages carried additional information (some of which was automatically generated), which could be used to filter and classify the messages to suit individual needs within a group.

Later Malone extended this framework to *Object Lens* (Malone and Lai, 1988), in which the participants could create not only messages to pass information around but also any kinds of objects. Each objects had a similar structure imposed on it to guide control and distribution processes. Object Lens also allowed people create links among the objects formed. Malone pointed out that this was similar to hypertexts on the world wide web.

## 2. Communication

Communication is one of the most critical components in any form of collaboration. In fact, Rodden (1991) identified message or communication systems as the class of systems in CSCW that are most mature and most widely used. Donath and Robertson (1994) presented a system that allowed users to know that others were viewing the same webpage and to communicate with them to initiate a possible collaboration or at least a co-browsing experience.

Using four multidisciplinary design situations in the USA and Europe, Sonnenwald (1996) identified 13 communication roles. He explained how these roles can support collaboration, among other aspects of information seeking process, such as knowledge exploration and integration, and task and project completion, by filtering and providing information and negotiating differences across organizational, task, discipline, and personal boundaries.

## 3. Awareness

Several related terms and definitions are used in the literature to refer to awareness in collaborative projects. For example, Dourish and Bellotti (1992,

p. 107) defined awareness as “an understanding of the activities of others, which provides a context for your own activity” (p. 107). Dourish and Bly (1992) provided the following definition for awareness:

Awareness involves knowing who is “around,” what activities are occurring, who is talking with whom; it provides a view of one another in the daily work environments. Awareness may lead to informal interactions, spontaneous connections, and the development of shared cultures—all important aspects of maintaining working relationships which are denied to groups distributed across multiple sites. (p. 541)

A set of theories and models for understanding and providing awareness emerged in the early literature. Gaver (1991) asserted that an intense sharing of awareness characterizes focused collaboration in which people work closely together on a shared goal. He further claimed that less awareness is needed for division of labor and that more casual awareness can lead to serendipitous communication, which can turn into collaboration. He proposed a *general awareness* model that incorporates and supports all such activities. Bly *et al.* (1993) also identified the importance of general awareness saying, “When groups are geographically distributed, it is particularly important not to neglect the need for informal interactions, spontaneous conversations, and even general awareness of people and events at other sites” (p. 29).

#### 4. Importance of control, communication, and awareness

Empirical observations and other studies of usability testing relating to control, communication, and awareness indicate that an effective collaborative system should have the following attributes:

1. A flexible mechanism to incorporate structured message passing;
2. A way of facilitating control among the participants as well as with automaton components; and
3. Facilities to present awareness of various objects, processes, and people at any given time to everyone in the group.

Several systems such as *SearchTogether* (Morris and Horvitz, 2007b) and *Coagmento* (Shah, 2010) incorporate support for chat or IM. Some works have also tried to provide other sorts of communication channels in collaborative workspaces, such as audio chat, video conferencing, and bulletin board support. While chat is an obvious choice for synchronous communication, email still prevails when it comes to providing asynchronous communication (Morris’ (2008). Given the importance of email, and the level of familiarity and comfort that most people have with it, an effective collaborative search system should provide support for passing such messages among the participants. In addition, there needs to be some kind of structure imposed

on messages such as time stamps, tags, and associated processes. This can be helpful in distributing the messages with some sort of filtering and/or following rules and roles of a system. Pickens *et al.* (2008) demonstrated a collaborative video search system where one of the participants was responsible for issuing queries (prospector), and the other participant was responsible for going through the results looking for relevant information (miner).

Since users of a collaborative search system work with different sources, documents, queries, snippets, and annotations, everyone in the group should be aware of all such objects as they are collected and modified. In addition to this, it is important to show attributes associated with an object, for example, that a document has already been viewed.

Several systems supporting collaboration have identified control, communication, and awareness as critical to their design. For example Farooq *et al.* (2009) used such a collaborative design for *CiteSeer*, a search engine in computer and information science disciplines. On the basis of a user survey, they identified four mandates for redesigning the *CiteSeer* collaboratory: (1) visualize query-based social networks to identify scholarly communities of interest, (2) provide online collaborative tool support for upstream stages of scientific collaboration, (3) support activity awareness for staying cognizant of online scientific activities, and (4) use notification systems to convey scientific activity awareness.

#### **D. Co-browsing or Collaborative Navigation**

Co-browsing or collaborative navigation is a process that allows participants to navigate or browse, and share information with a possible intermediate interface. Root (1988) introduced the idea of social browsing to support distributed cooperative work with unplanned and informal social interaction. He described a “social interface,” which provided direct, low-cost access to other people through the use of multimedia communications channels. The design of his conceptual system, called *CRUISER*, incorporated three basic concepts: social browsing, a virtual workspace, and interaction protocols. His premise was that by integrating all digital media into a richly interconnected workspace, the context of workgroup activities would be significantly extended and enriched. Root’s idea of facilitating informal and effortless interaction among a group of people was continued by Donath and Robertson (1994) with *The Social Web*. This allowed a user to know what others were concurrently viewing and to communicate with them. They worked on the assumption that users accessing the same page are likely to share similar interests.

Cabri *et al.* (1999) unveiled a system for synchronous cooperative browsing that permitted users within a workgroup to share information and work toward a common goal. This was done using a proxy without changing browsers on the user's end. Gerosa *et al.* (2004) had a similar idea with proxy-based co-browsing in e-learning. They called this *Symmetric Synchronous Collaborative Navigation*, a form of social navigation, in which users shared a virtual web browser. They provided a symmetric, proxy-based architecture that did not need a special browser. This allowed users to merge into a collaborative environment with as little effort as possible. Esenther (2002), with his collaborative web browsing (CWB) system, targeted casual (nontechnical) users allowing them remotely to synchronize pointing, scrolling and browsing of uploaded content in their web browsers.

Another example of a collaborative browsing application is *AntWorld* by Menkov *et al.* (2000). This tool was developed to make it easier for the members of a common-interest user group to collaborate in searching the web. *AntWorld* harnesses the expertise of members of a common interest group as displayed by their evaluation of documents encountered while searching. It stores users' judgments about documents they found and uses this information to guide other users to pages that might be useful.

Sometimes it is not just the web pages that people want to browse and share, but other objects such as bookmarks. Keller *et al.* (1997) provided *WebTagger*, a social bookmarking service similar to *del.icio.us*, which allowed a group of users to tag and share webpages. *WebTagger* enables users to supply feedback on the utility of resources that they bookmarked relative to their information needs, and provides dynamically updated rankings of resources based on incremental user feedback.

Several other systems used their own interfaces rather than relying on a web browser. For instance, *GroupWeb* (Greenberg and Roseman, 1996) is a browser that allows group members to share and navigate world wide web pages visually in real time. Its groupware features include document and view slaving for synchronizing information sharing, telepointers for enacting gestures, and "what you see is what I see" views to handle display differences. *GroupWeb* also incorporated a groupware text editor that lets groups create and attach annotations to pages. Similar is *GroupScape* (Graham, 1997), which was a multiuser HTML browser to support synchronous groupware applications and browsing of HTML documents on the web. Yet another architecture to support multiuser browsing is *CoVitesse* (Laurillau and Nigay, 2002), a groupware interface that enabled collaborative navigation of the web based on a collaborative task model. This system represented users navigating collaboratively in an information space made of the results of a query submitted to a search engine. In contrast to these systems, which are

primarily designed for remotely located participants, *CoSearch* (Amershi and Morris, 2008) provides multidevice support for collaborative browsing among co-located participants.

## E. Collaborative IR

As discussed earlier, if and when a problem in IR is difficult to solve, a carefully executed collaboration can help. Smyth *et al.* (2003) argued that one way would be to connect users to information that is difficult to find by collaboration in the search phase of an information-seeking process. They showed how collaborative searches could act as a front-end for existing search engines and could re-rank results based on the learned preferences of a community of users. Smyth *et al.* attempted to demonstrate this concept by implementing the *I-Spy* system (Freyne *et al.*, 2004).<sup>2</sup> *I-Spy* captures queries and related results for a given workgroup and uses that information to provide filtered, and presumably more relevant, information to users. Thus, *I-Spy* acts more as a collaborative filtering process than as synchronous collaborative searching.

While *I-Spy* attempts to extend content-based filtering techniques by incorporating communities, several collaborative systems have been developed by extending a traditional IR model to incorporate multiple users. However, such extension is often ineffective or nontrivial. For instance, Hyldegard (2006), in studies of information seeking and retrieval in a group-based educational setting, found that people in a collaborative group to some extent demonstrated cognitive experiences similar to individuals in Kuhlthau's information search process (ISP) model (Kuhlthau, 2005). However, these experiences did not result only from information-seeking activities but also from work-task activities and intragroup interactions. Her later work also indicated (Hyldegard, 2009) that group-based problem solving is a dynamic process that shifts between a group perspective and an individual perspective. Such a finding calls for a thorough investigation into CIS that is not simply an extension of a traditional IR system. As stated by Olson *et al.* (1992) "The development of schemes to support group work, whether behavioral methods or new technologies like groupware, should be based on detailed knowledge about how groups work, what they do well, and what they have trouble with" (p. 347).

Unlike co-browsing, where the applications are aimed toward web browsing, works on collaborative IR are often focused on specialized domains

<sup>2</sup>This has been transposed to HeyStaks (<http://www.heystaks.com/>).

for searching. For example, Twidale and Nichols (1996) provided the *Ariadne* system, which allowed users to collaborate with an information search expert remotely and synchronously over a library catalogue. The authors saw the importance of supporting social aspects of searching for information and showed how it can be addressed. *Ariadne*, however, did not support asynchronous collaboration.

Morris and Horvitz (2007b) introduced *SearchTogether* that allowed a group of remote users to collaborate synchronously or asynchronously. It focused on supporting awareness, division of labor, and persistence in collaboration. Awareness was provided using per-user query histories, page-specific metadata, and annotations. Division of labor was implemented using integrated IM as well as a recommendation mechanism, by which a participant could recommend a page to another participant. *SearchTogether* also provided “Split Search” and “Multi-Engine Search” options for automatic division of labor. Finally, persistence was implemented by storing not only information about all sessions, but automatically creating a shared artifact that summarized the results of a collaborative search.

*MUSE* (Krishnappa, 2005) supports synchronous, remote collaboration between two people who are searching a medical database. *MUSE* lets its users perform standard single-user searches, with a provision of chat and the ability to share metadata about the current database results with the other user. Another example is  $S^3$  (Morris and Horvitz, 2007a) which is not so much a CIS system, but it does enable sharing of retrieved results asynchronously among a set of users.

Research produced by the CIR group at University of Washington, studied situations where members of a work-team were seeking, searching, and using information collaboratively and showed how such processes can be realized in a multiteam setting. This started with Fidel *et al.* (1999), who defined collaborative IR (CIR) “as any activity that collectively resolves an information problem taken by members of a work-team regardless of the nature of the actual retrieval of information” (p. 2). They used a cognitive work analysis framework in a field study that examined social, organizational, cognitive, and individual characteristics of information seekers, and then focused on collaborative situations (Fidel *et al.*, 2000). From their studies involving two design teams working in collaboration, they found (Bruce *et al.*, 2003) 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 behavior. Later Poltrock *et al.* (2003) found that any IR activity may be performed by an individual on behalf of a team, by an ad-hoc group, or by the team working together in a meeting. They also concluded that technologies intended to support teamwork could be more

effective by recognizing and supporting collaboration in the activities that comprise IR and their coordination.

## F. Realization of a Collaborative Environment

There are several ways in which a collaborative environment can be realized. People are familiar with using tools such as telephones and email for collaborating with remotely located users, both asynchronously and synchronously. These tools, however, are not specifically designed to handle collaboration. Effective collaboration may require a different set of tools. To understand the issues in implementing a collaborative system, three important aspects can be identified: processes, content, and devices. Following is a brief description of each of these aspects along with related works.

### 1. Processes

Several realizations of a collaborative environment have focused primarily on systems. These typically present algorithmic ways of combining multiple instances of search requests, result lists, or other interactions from different users to perform implicit “collaboration.” For example, a good deal of work in implementing a collaborative search system has focused on reformulating search requests of a user based on other users’ search requests on the same/similar search goals. Fu *et al.* (2007) showed how different queries from a set of users for the same information goal can be combined for better retrieval performance.

### 2. Content

A simple way of taking advantage of collaboration is dividing the content among the users for viewing, judging, or manipulating. With *WebSplitter*, Han *et al.* (2000) demonstrated how a unified XML framework could support multidevice and multiuser web browsing. Similarly, Maekawa *et al.* (2006) developed a page partitioning method for collaborative browsing, which divides a web page into multiple components. They also designed and implemented a collaborative web browsing system in which users can search and browse their target information by discussing and watching partial pages displayed on multiple devices.

### 3. Devices

Typically, in a CIS environment, by system, we are referring to computers, but several works have tried to extend information access and distribution to other forms of devices to enable collaboration among users in various work places. For instance, Maekawa *et al.* (2006) presented a collaborative web browsing system in a mobile computing environment. Their motivation for using collaboration in the mobile device environment was to overcome the issue of low functionality that restricts the services provided for mobile users. Amershi and Morris (2008) presented *CoSearch*—a collaborative browsing interface to be used on computers, and introduced *CoSearchMobile*, designed to provide similar functionalities on mobile devices. The *CoSearch* system leverages readily available devices such as mobile telephones.

Blackwell *et al.* (2004) described a tangible interface for collaborative IR. The purpose of this interface was to allow multiple users to interact simultaneously to refine a query. Morris *et al.* (2006) presented *TeamSearch* system, which used an interactive table for a small group of co-located participants in searching for digital images to use in a report. Mitsubishi Electric Research Lab (MERL) has developed *DiamondTouch* (Smeaton *et al.*, 2006b), an interface device that supports direct user collaboration on a tabletop. Such an interactive tabletop is ideal for multimedia searches done collaboratively. Smeaton *et al.* (2006a, c) reported video searching in collaboration using *DiamondTouch* interactive tabletop devices. Among other things, the authors found about a 10% increase in the level of user-interaction as the users moved from their first search to the last one.

### G. Evaluation

Evaluating a collaborative information searching environment can be a huge challenge due to its complex design involving users, integrated systems, and a variety of interactions. While a CIS system can be measured using typical measures of IR as did Smyth *et al.* (2005) additional measures for evaluating collaborative information search systems are needed. To date, evaluating various factors in CIS behaviors and results can be summarized as measuring (1) retrieval performance of the system, (2) effectiveness of the interface in facilitating collaboration, and (3) user satisfaction and involvement.

Baeza-Yates and Pino (1997) presented work on a measure that could extend evaluation of a single-user IR system to a collaborative environment based on retrieval performance. Aneiros and Estivill-Castro (2005) proposed evaluating the “goodness” of a collaborative system through its usability. Baeza-Yates and Pino (1997) treated the performance of a group as the

summation of the performances of the individuals in the group. In short, the majority of the work on evaluation has addressed the usability of the collaborative interfaces. For example, Morris and Horvitz (2007b) tested their *SearchTogether* system with a user study to evaluate how users used various tools offered in its interface and how those tools affected the act of collaboration. While they showed the effectiveness of their interface in letting people search together, there was no evaluation of the learning that took place in the group due to collaboration. Laurillau and Nigay (2002) for their *CoVitesse* system, did evaluations for the user interface as well as various network-related parameters, but not on its effects on retrieval performance.

Some of the application designers also let “real” users use their systems and evaluated the effectiveness of their system based on users’ feedback and/or their success in solving their “real” problems with it. For instance, Twidale *et al.* (1995) invited volunteers to bring an existing problem to solve. Students from a wide range of academic backgrounds (including Psychology, Computing, Women’s Studies, Chemistry, Religious studies, and Environmental Science) used their *Ariadne* system. The typical case was that they were about to write an extended essay, dissertation or group project and needed to do a literature search. The testing informed the iterative development of the system. Smyth *et al.* (2003) tested their I-Spy system with leave-one-out evaluation methodology. From 20 users, they left one user as a *testing user* and used the other 19 users as the *training users*.

Prekop (2002) presented a qualitative way of evaluating CIS studies. He proposed this by measuring *information-seeking patterns*. These patterns describe prototypical actions, interactions, and behaviors performed by participants in a collaborative endeavor. The three patterns that the author described were information seeking by recommendation, direct questioning, and advertising information paths. Along similar lines, Olson *et al.* (1992) analyzed behavior and patterns of users by studying 10 design meetings from four projects in two organizations. The meetings were videotaped, transcribed, and then analyzed using a coding scheme that looked at participants’ problem solving and the activities they used to coordinate and manage themselves. The authors also analyzed the structure of their design arguments. The authors claimed that the coding schemes developed might be useful for a wide range of problem-solving meetings other than design.

Wilson and Schraefel (2008) analyzed an evaluation framework for information seeking interfaces in terms of its applicability to collaborative search software. Extending Bates’ tactics model (Bates, 1979) and Belkin’s model of users (Belkin *et al.*, 1993), they showed that the framework can be just as easily applied to collaborative search interactions as individual information seeking software, but pointed out that there are additional

considerations about the individual's involvement within a group that must be maintained as the assessment is carried out.

### III. Conclusion

While exploring the notion of collaboration in general, and the motivations behind it, it was discovered that there are a variety of definitions of collaboration in the literature, and that the term is often used interchangeably with coordination and cooperation. For purposes of this review, a working definition of collaboration was deemed to be a "group of participants intentionally working together in an interactive manner for a common goal." The second part of the review was devoted specifically to research, literature, and products in the fields of library and information science and related domains. Several key issues for designing and implementing collaborative information search systems, user behavior, and evaluation in these environments were identified and synthesized.

To summarize, the following key points were derived from the review of the literature.

1. Collaboration involves people working together for a common goal or solution; simply working together or interacting is not enough.
2. Collaboration is intentional and interactive.
3. The value of collaboration in information seeking depends on the kind of task involved, that is, people may not find it useful to collaborate in simple known-item, fact-finding tasks.
4. Collaboration may help an individual participant to achieve what he could not accomplish working in solitude.
5. A careful collaboration can help a team produce something that is more than the sum of individual participants' contributions.
6. Collaboration involves certain overhead and an additional cognitive load. These factors need to be considered when evaluating CIS environments.
7. Information exchange and filtering may be necessary conditions for collaboration, but they are not sufficient conditions of and by themselves.
8. Collaboration among the users can occur at various levels during information-seeking processes: (1) while formulating an information request, (2) while obtaining results, and (3) while organizing and using the results. All these levels should be supported to create an effective collaboration environment.
9. A successful collaborative system needs to have support for control, communication, and awareness to help participants be more efficient and be actively engaged in the collaboration.
10. A deeper understanding of how collaboration as well as information seeking works is required to accommodate multiuser environment, going beyond the single-user IR systems and environments.
11. A holistic approach is needed, along with models that can measure and evaluate collaborative information systems and environments which beyond traditional single-user IR paradigms.

From a review of relevant literature, it is clear that there are still several missing pieces in the field of CIS systems and environments as follows:

- While there is a fairly good understanding of why people collaborate, motivations are not always identified in the context of situations in which collaborative information searches occur.
- The literature provides a list of tools and methods that are used in collaboration, but the relative merits of these tools and methods are not clear. Too often, tools not specifically designed for collaboration are being used for carrying out collaborative tasks.
- The literature about computer-supported collaboration identifies three major issues in information seeking/searching systems and environments: control, communication, and awareness. Control is domain specific, and communication is system specific. Awareness, however, may depend on a number of factors, including task, distribution of responsibilities among the collaborators, roles of the collaborators, nature of the final product, need for privacy versus sharing among the collaborators, and the nature of their collaboration (synchronous vs. asynchronous, co-located vs. remote). Since the issue of awareness is highly understudied in the literature a better understanding of how to support for awareness in a collaborative search system would add considerable value to them in both theory and practice.
- Several suggestions are made for evaluating a collaborative information systems as well as users' performance while working with such systems. However, it remains unclear what factors should be measured and how. Therefore, a taxonomy of evaluation metrics for information seeking in different collaborative environments is indicated.
- The literature to date includes a number of works that try to understand people working with collaborative systems and their behavior in both online communities and social networking sites. A link that connects these two is missing. A better understanding is needed of how to leverage people's engagement in social networking sites to promote collaboration and to support various social activities within collaborative systems.
- Finally, there is need to develop models that extend or augment single-person information-seeking systems and information-seeking behaviors into collaborative environments.

The above issues are at the core of the CIS domain. Given the shift to teamwork and group-driven projects and information gathering, further study and research would enable development of better and more supportive collaborative information systems.

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