Seven Cognitive Factors that Make Learning Successful in Networked Collaboration

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Abstract

This paper examines seven cognitive factors that seem to make learning successful in networked collaboration. Through our literature review, it was found that there are at least seven cognitive factors: deep thinking, more interaction, cognitive conflict resolution, adaptation over time, constructive use of technology, task coordination between media, and asynchrousness management. It is concluded that the effectiveness of learning and problem solving in networked collaboration is determined by students' use of those factors in networked collaboration.

One of the most famous collaborations in history was between Herbert Simon, Allen Newell, and J. C. Shaw who worked together over the phone. Simon was at Carnegie Institute of Technology in Pittsburgh and Newell and Shaw were at RAND in California. McCorduck (1979) wrote: "… Simon and Cliff Shaw seldom saw or spoke to each other. Newell carried out the middleman's role, mostly by long-distance telephone between Pittsburgh and Santa Monica" (p. 139). However, they were one of the most effective teams in spite of the difficulties working at a distance.

In present day, we work together with our colleagues using the help of the state-of-art technology called computer-mediated communication (CMC). Once you sit at your desk, you can see whether your partners are available, busy or even happy using an instant messenger. You can communicate through email or video-mediated conference with your colleagues who are within 10 steps or in another continent. However, the state-of-art networked collaboration technology seems not straightforward to result in better performance although barriers set by time and space have been removed. So, what factors make networked collaboration effective or ineffective for learning and problem solving? That is the topic that this review intends to investigate.

Dominant theories in CMC such as social presence theory (Short, Williams, & Christie, 1976), media richness theory (Daft & Lengel, 1986), task-media fitness theory (McGrath & Hollingshead, 1994), etc. argue that the bandwidth or capacities of transmitting information in each communication medium determine the effectiveness of networked collaboration in learning and problem solving. We call these theories the face-to-face (FTF) superiority theories since they qualify the effectiveness of networked collaboration through CMC in terms of the amount of information each CMC medium transmits. According to the FTF superiority theories, networked collaboration filters out various information such as social cues. Hence, networked collaboration cannot be as effective as FTF with possible exceptions where networked collaboration is task-oriented (Sproull & Kiesler, 1991) and where a task does not require more than a given network bandwidth (McGrath & Hollingshead, 1994). However, empirical studies tend not to find supportive evidence when the quantity and/or quality of performance instead of self-report were taken into account, and when bandwidth as an independent was manipulated (e.g. Dennis & Kinney, 1998). Also many studies show that networked collaboration is as effective as FTF (e.g. Vera, Kvan, West, & Lai, 1998). Thus, it seems that the impact of bandwidth is not a critical factor, but rather deactivated by another factor, which we assume the role of active agents in the processes of networked collaboration.

In contrast to the FTF superiority theories, cognitive perspectives try to account for learning and problem solving in networked collaboration in terms of how cognitive agents adapt and behave because "learning rests on the learning skills that the students themselves bring to bear as they learn" (Chi, Lewis, Reimann, & Glaser, 1989, p. 146). Thus, learners are expected to be involved in constructive processes where they construct knowledge, skills, and ways of working together regardless of whether they are in adverse or auspicious situations. Hence, in a low-bandwidth network, they are still expected to overcome given difficulties by maximizing the effectiveness of knowledge, strategies or skills. For example, Cho, Schunn, and Lesgold (2002) compared successful dyads with unsuccessful dyads in networked collaboration. Participants were asked to work together to understand texts while interacting with peers through a text-based generic chat interface. It was shown that in general the unsuccessful dyads tend to be involved in less effective learning processes like checking each other's answer or rephrasing, while the successful groups tended to be involved in more effective processes like explanation or elaboration. In the face of explicit errors or misunderstandings, the successful groups explored their understandings in more depth by implementing elaboration. However, the unsuccessful groups didn't explore what caused their comprehension failure and tended to keep their errors. Therefore, the prime consideration of this paper is to reveal what processes make networked collaboration successful for effective learning and problem solving.

Methods

Scope This review deals with networked collaboration for learning and problem solving between peers in unstructured situations, which by itself covers many situations. Therefore, the long history of collaborative learning and problem solving at a distance using surface mail, fax, phones, TVs, and satellites are not taken as being included in the main issue. Non-peer interactions like student-teacher interactions in teaching, tutoring, or otherwise are not dealt with, either.

Cases To find papers to be analyzed, ERIC (1982 - 2002/06), ISA (Information Science Abstract; 1966 - 2002/09), LLBA (Linguistics & Language Behavior Abstracts; 1973 -2002/09), PsychInfo (1978-2002/09), Sociological Abstracts (1986-2002/09), ACM (American Computing Machinery) were searched with keywords. In total, 676 studies were located with abstracts, but many studies were excluded if they were beyond the scope of this review as defined above. Finally, 102 studies were left for the analysis.

Results

Networked collaboration may produce positive performance in learning and problem solving depending on some cognitive and adaptive processes. In this section, the processes that make networked collaboration effective are critically addressed.

Think in More Depth

Deep thinking has been considered one of the most important processes for learning and problem solving. Researchers have argued that networked collaboration especially through text-based CMC could be successful if participants incubate deep thinking activities such as articulation, reflection, or critical thinking (Hammond, 1999; Lotman, 1988; McNeil, Robin, & Miller, 2000; Warschauer, 1997).

Collaborators interacting through a synchronous text-based interface such as the chat could benefit from the speech-like, real-time interactions as well as the time available for reflection and preparation, although perhaps at the expense of organized utterances due to the delay time between utterances (Kroonenberg, 1994/1995). Warschauer (1997) argued that "the historical divide between speech and writing has been overcome with the interactional and reflective aspects of language merged in a single medium: CMC" (p.472). Therefore, compared to FTF, participants in networked collaboration could use more deep thinking strategies like exchanging more ideas, proposals and perspectives. Conversational analyses showed that students felt freer to have reflective time and to take issue with different perspectives (Cho et al, 2002; Dubrovsky, Kiesler, & Sethna, 1991). Therefore, participants in networked collaboration tend to become involved in more desirable conversational processes and patterns like scientific inquiry and more task-relevant conversations (Barile & Durso, 2002; Jonassen & Kwon, 2001).

Asynchronous channels like emails or electronic bulletin boards could fortify deep thinking activities because those channels could also furnish participants with learner-centered time to think and external, permanent long-term memory aids. Thus, along with the self-regulated time, CMC allows people to think more about issues or assignments. Therefore, asynchronous communications could be very effective for interpretation and reflection (Warschauer, 1997). Therefore, participants in asynchronous interaction generate more discussions and more complete reports than FTF, for instance (Benbunan-Fich, Hiltz, & Turoff, 2002). In addition, Jonassen and Kwon (2001) analyzed conversations collected from undergraduate engineering students who solved ill-structured and well-structured business tasks through either FTF or an asynchronized text-based conferencing medium. The students in the networked collaboration condition had significantly fewer off-task interactions and raised significantly more disagreements than FTF students. A more interesting result was that the students in networked collaboration showed iterative scientific inquiry patterns of problem definition, orientation, and solution development during problem solving, while those in FTF stopped after a single cycle of the sequence. In other words, once FTF students developed their problem solutions their interaction was terminated. Reid, Malinek, Stott, and Evans (1996) also found that FTF groups were considerably more involved in process loss such as off-task behaviors than networked collaboration groups.

As in text-based channels, deep thinking could be implemented in non-text CMC channels. For example, Alavi, Wheeler, and Valacich (1995) carried out a longitudinal field study of comparing the effectiveness of computer-mediated groups between a local campus, computer-mediated distributed groups from different campuses, and FTF groups. It was found that although there were no significant differences in outcomes between the comparison conditions, a significant difference was found in higher-level critical thinking, which appeared only in the computer-mediated distributed groups.

Also, it seems that students are willing to reflect upon thinking to compensate for the difficulties posed by networked collaboration (Galegher & Kraut, 1994).Vera et al. (1998) found that, compared to video-mediated collaboration (VMC), the conversational process in text-based CMC involved more abstracted conversation, sacrificing other features like elaboration.

More Equal and/or More Interaction

Because networked collaboration tends to obscure social status cues, participants in networked collaboration do have more equal interaction and more learner-centered interactions (Hammond, 1999; Warschauer, 1997), which may create more opportunities for learner-based activities.

In a sense, the lack of social cues may encourage to be more interactive non-dominant students who are less vocal or less able to communicate in FTF. Therefore, non-dominant students may actively participate in online discussions more than in FTF (Dubrovsky et al., 1991; Eveland & Bikson, 1988; Sproull & Kiesler, 1991). A dramatic example is from research on English as Second Language (ESL) students. Sullivan and Pratt (1996) observed that in FTF discussion about the half of the ESL students participated. In contrast, in online discussion 100 % of the ESL students participated. Also, Eveland and Bikson

(1988) observed that participants in networked collaboration tend to like changing leaders, but not in FTF. Yet, there are still people who are silent in online environments (Hammond, 1999).

Cognitive Conflict and Management

Cognitive conflict is defined as awareness of differences in perspectives and opinions on the group's task and solutions. Learning could be advanced by cognitive conflict between peers. Just as students are most productive in FTF when both strategy and judgment are different, teams performing complex cognitive tasks in networked collaboration also benefit from differences of opinion about the work being done (Jehn, Northcraft, & Neale, 1999). However, merely detecting these differences does not appear to be enough for cognitive growth. Once a difference is found, participants must try to resolve the difference through explaining and elaborating the conflict (Cho et al., 2002) through argumentation processes (Ravenscroft & Matheson, 2002) in order for positive outcomes to result.

Therefore, it could be argued that participants in networked collaboration could maximally benefit from resolving conflicts. However, it is still an open question that they really could reach a consensus through conflict resolution or negotiation process. Studies showed a mixed result on conflict management between networked collaboration and FTF: Some studies showed that participants in networked collaboration have more difficulties in managing conflicts than in FTF (Galegher & Kraut, 1996; Hollingshead, 1993), some studies did not find this problem (Barile & Durso, 2002, Fjermestad & Hiltz, 1999) and other studies showed that participants in networked collaboration are more constructive in resolving conflict (e.g. Chidambaram, 1996; Whitworth, Gallupe, & McQueen, 2001), while FTF is destructive to the process of managing conflict.

Although learners may not reach an agreed upon solution, they could nonetheless benefit from actively participating in argumentation that occurs more frequently in networked collaboration. Because of various characteristics in networked collaboration, participants may actively explore their tasks with more critical and reflective perspectives than those in FTF where equivocal advice rather than critical one is accepted (Edward & Bello, 2001) and where they are forced to agree with group or authorities (McGrath & Hollingshead, 1994; Whitworth et al., 2001).

Adaptation over Time

When time is set free instead of being constrained, the impact of negative factors that run against networked collaboration tends to be ameliorated.

Participants in networked collaboration tend to master basic skills and literacy concerning their environment. One example is computer literacy which plays a barrier to good collaboration, especially in the beginning stages, and which affects learning and problem solving, such as when participants are distracted from their tasks (Feenberg, 1989; Orvis, Wisher, Bonk, & Olson, 2002; Pilkington, Bennett, & Vaughan, 2000). However, this roadblock seems to diminish over time (Pilkington et al., 2000). Also, Orvis et al. (2002) found that shifting patterns of interactions appeared over a six month period of networked collaboration. At the start, technological concerns reached a peak. However, the technological concerns gradually reduced over time.

Therefore, changes of collaboration processes over time appear to lead to different outcomes. For example, Hollingshead, McGrath, and O'Connor (1993) used a series of thirteen tasks over thirteen weeks. Until the time the first two tasks were performed, FTF groups outperformed networked collaboration groups. However, after that, networked collaboration groups' performances improved over time and then were not different from FTF groups'. Thus, groups in networked collaboration can adjust over time to constraints on their communication as members interact more, which leads to the performance level of FTF groups (Walther, 2002). For this, Hollingshead, et al. (1993) wrote: "Surprisingly, the relationship between technology and task performance appeared to be more dependent on experience with the technology and with group membership than the type of task on which the group was working" (p. 324).

In addition, other collaboration processes could change over time. Hobman, Bordia, Irmer, & Chang (2002) noticed that on the first day, people in networked collaboration showed more emotional conflicts than those in FTF. However, these emotional conflicts disappeared over time. Zornoza, Ripoll, & Peiro (2002) observed that constructive resolution of conflicts in networked collaboration groups changed over time. Meanwhile, Chidambaram (1996) showed that although in the beginning, FTF groups showed more constructive conflict management than CMC groups, over time this pattern reversed direction, at which point the networked collaboration groups were more constructive.

Constructive Use of Technology

The ways of working together in networked collaboration are different from those in FTF. The differences could provide participants with disadvantages as well as unique advantages. Sometimes the disadvantages lead to ineffective learning in networked collaboration. Other times, people try to overcome given advantages in the process of appropriating technologies into their tasks (Andreassen, 2000; Arnseth & Ludvigsen, 2001; Scott, Fowler, & Gibson, 1993; Vera, Kvan, West, & Lai, 1998).

Most frequently, people devise strategies for *linguistic compression* based on discourse routines when frequent information exchanges are difficult. For example, Condon and Cech (1996) found that participants in networked collaboration decimate unnecessary elaborations and repetitions in order to increase the efficiency of communications because of the typing requirements. Therefore, networked collaboration groups focus more on orientation and management, while FTF groups rely on discourse markers and short orienting phrases. Vera et al.

(1998) found a similar pattern. Participants worked on an architectural design task through either a text-based chat interface or a high quality VMC. It was found that the two media did not generate significant differences in performances and general collaboration patterns. However, very interestingly the participants in the chat condition had significantly higher levels of design process communications, while sacrificing other features like elaboration. Thus, networked collaboration could be task-oriented by decreasing the number of disambiguating sub-dialogues (McGrath & Hollingshead, 1994) at the expense of less important activities which might retard the development of social relations focused on fewer social/emotional interactions (Scott et al., 1993). Therefore, the cost of interaction in networked collaboration could foster argumentation processes in networked collaboration.

Sometimes participants devise strategies to use technology in ways that were not originally intended by the technology. For example, people have developed *emoticons* in text-based CMC for expressing emotions such as :) as happy, :-(as sad and :-e as disappointed. In addition, Arnseth et al. (2001) reported another interesting case that shows how a technology tool is meshed with collaboration processes. In their study, participants in networked collaboration used the chat and Post-Its interfaces that functioned as their names imply. The participants had very general difficulties with the chat interface such as wrong positioning of utterances, disparity between writings and feedback, and delays between writing and posting. Then, some of them found a way around these problems by using the Post-Its as a chat which was not intended by the technology. The authors stated: "when they needed to co-ordinate some activity, recall, and discuss earlier work that had been done, and plan future activities.… they created a chatroom by placing Post-Its beside each other and by putting their names as headings." People also use CMC functionally depending on their work. In a collaborative writing task, the communication tools were most used in the planning and revision phase, but not in the drafting phase (Galegher & Kraut, 1992).

Task Coordination between Media

Learning and problem solving could be improved when available media resources are taken advantage of to the fullest. There appeared three coordination patterns between media. First, FTF and networked collaboration may serve better for different processes since each medium does have unique advantages. For example, Newman, Johnson, Webb, and Cochrane (1997) found that students in FTF were better at creative problem solving while those in networked collaboration were better at further elaboration and integration in an information management task. Also it was found that FTF is better for interdependent tasks such as negotiation and consensus, while networked collaboration through emails could be better for independent tasks (Galegher & Kraut, 1994; Vera et al., 1998), especially in the early stages of a project (Galegher & Kraut, 1994). In addition, Neuwirth, Kaufer, Chandhok, and Morris (1996) used a system that helped comments on documents. Reviewers could comment in either voice mode or written text mode. Interestingly, they found that voice mode reviewers tended to produce more comments about purpose and audience issues, while text mode reviewers tended to focus on more substantial issues like substance or content

Second, networked collaboration could be used to support the weakness of FTF. It seems that task arrangement and brainstorming tasks could be better achieved in networked collaboration (Diehl & Stroebe, 1987). Therefore, emails or other such media are used for coordinating FTF meetings (Finholt, Sproull, & Kiesler, 2002) for collecting multiple diverse sources. Also, networked collaboration could be used for preparing FTF. According to Diehl and Stroebe (1987), FTF meetings are not good at brainstorming tasks because participants listen to each other and censor their own ideas, instead of freely brainstorming. Therefore, before FTF meetings, networked collaboration could be used to gather various ideas and thoughts. Then these ideas could be used as resources for FTF meetings. Likewise, networked collaboration could then extend FTF by having communications after FTF meetings (Sproull & Kiesler, 1991).

Third, FTF meetings could increase the probability of success in networked collaboration because FTF can temper networked collaboration. Therefore, FTF meetings could be a predictor for the success of a networked collaboration team (Schunn, Crowley, & Okada, 2002). For example, Maznevski and Chudoba (2000) observed global virtual teams that use considerably more technology-supported communications than FTF teams because team members work and live in different countries. It was found that the most successful teams were those that engaged in very regular transitions between virtual meetings and FTF meetings with deliberate rhythms based on time. Therefore, the researchers argued: "conducting regular meetings in person is essential to global virtual team effectiveness to the extent that the task requires a high degree of interdependence and there are geographic, organizational, and cultural boundaries that must be spanned" (p. 488).

Asynchronousness Management

Asynchronous interaction is accompanied by the costs to maintain the delay between messages. Compared to FTF, even synchronous networked collaboration is not likely to ameliorate this cost, and asynchronous CMC could become disastrous if the time delay is too problematic. However, the very nature of asynchronous communication in networked collaboration seems to provide important benefits like reflective thinking for learning and problem solving. Compared to synchronous interactions, asynchronous interactions are even freer from time and space constraints, and are more easily integrated into current practice because synchronous networked collaborations need scheduled times to meet and places to access and use computers. This appears to explain why emails are frequently exchanged between people whose offices are right next to each other. Many a study reported that asynchronous collaboration is effective or sometimes better in improving classroom learning than synchronous or FTF collaborations, as measured by the qualities of writings and solutions (Benbunan-Fich & Hiltz, 1999).

Discussion

As specified in the FTF superiority theories, networked collaboration could have various disadvantages in part because of the lower bandwidth of collaboration channels and in part because the participants apply their conventions learned from FTF collaboration to networked collaboration. Nevertheless, learning in networked collaboration could be successful if learners could develop and implement strategies to overcome given difficulties.

In this review, we take cognitive perspectives which emphasize the active role of cognitive agents in constructing their learning. Although in this research area the role of cognition in networked collaboration was not seriously taken into account in contrast to the FTF superiority theories, cognitive perspective seem very relevant to understand what mechanisms underlie learning and problem solving in networked collaboration. Based on the findings, it seems that the effectiveness of learning and problem solving in networked collaboration depends on what knowledge, skills or strategies active agents devise and implement in networked collaboration because learners can think and make conscious decisions about their learning processes.

Also, it seems that networked collaboration involves its own unique cognitive processes different from those in FTF. For example, FTF groups and networked collaboration groups use different coordination strategies (Benbunan-Fich, Hiltz, & Turoff, 2002; Vera et al., 1998). Instead of enforcing high fidelity coordination, networked collaboration groups adopted loosely coupled interaction models with lower level of interdependence compared to FTF (Benbunan-Fich, Hiltz, & Turoff, 2002). Also, people in networked collaboration could reduce perceived ambiguity or uncertainty by using explicit request strategy and by more interactive questions and answers as well as more self-disclosure strategies (Tidwell & Walther, 2002). Therefore, for successful learning and problem solving students in networked collaboration need be equipped with skills or strategies that fit well in networked collaboration.

The paucity of studies that directly focus on the role of cognition in networked collaboration made much of the findings inferred from existing analyses from the literature. Although the findings of this review are still informative, it seems necessary to examine with empirical data how the seven factors play roles and what strategies students use with the factors between networked collaboration and FTF.

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