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Developing a Grounded Theory Model on Collaboration in Learning

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ABSTRACT

The purpose of this research is to develop a grounded theory model to explain the factors influencing collaborative learning in higher education, the role of technology in facilitating collaboration, and the outcome of collaboration. We assigned 28 participants to small groups to work on course-related questions; half of the groups were face-to-face groups and the other half groups were collaborating in a simulated virtual environment with the aid of information technology. Interview data was collected and analyzed following the grounded theory approach. Congruent with distributed cognition theories, the results of our study suggest that both social and technological factors were important and interlocking. We also discussed the importance of designing learning technologies that have strong social and communications features.

Keywords

Collaboration, learning, collaboration technologies

INTRODUCTION

Collaboration allows a work group to develop an atmosphere of sharing where members can contribute their knowledge to solve the problems (Patnayakuni, Ruppel, and Rai 2006). Collaboration has become an increasingly important practice in industry. Despite the expectation that they work synergistically when they enter industry and solve problems in a team environment, students in U.S. colleges are primarily taught with individual assignments and fact-based lectures (Felder and Brent 2005).

To better accommodate the needs of future professionals, learning has been re-examined as a constructivist activity, where knowledge is actively reconstructed by learners rather than being passively transferred to learners (Rohde, Klamma, Jarke, and Wulf 2007). Learning is generated in the process of social participation in a group context (Rohde et al. 2007). Educational research has found that collaborative learning can enhance higher-order thinking, improve motivation and accountability, and enhance content learning (Springer, Stanne, and Donovan 1999). This shift of focus on learning is also reflected by changes in engineering education that add new emphasis to applying knowledge from basic science coursework, solving problems, and communicating and functioning on interdisciplinary teams (Olds, Moskal, and Miller 2005).

Information technology can provide an environment conducive to collaboration and facilitate intellectual development. Extensive research has been conducted to study the role of IT in collaboration in the learning context. However, prior research focuses on individual learning in widely dispersed asynchronous teams (e.g., Powell, Piccoli, and Ives 2004). Little research has been done to investigate the collaboration process and examine the difference between computer-supported collaborative learning and face-to-face collaboration.

The purpose of this research is to develop a grounded theory model to explain the factors influencing collaborative learning in higher education, the role of technology in facilitating collaboration, and the outcome of collaboration. This paper will review relevant literature, then describe the grounded theory procedures and the data collection. Then we will describe the categories that emerged from the interviews and analysis, and discuss the results. The research questions in this study include: 1) how do students collaborate to solve problems; 2) what are the outcomes of collaborative learning; and 3) what are the technology features that facilitate collaboration and learning.

LITERATURE REVIEW

Many information and communication technologies are used to facilitate collaboration and collaborative learning. Communication-focused technologies such as email, course-management software (Blackboard, WebCT), and forums can support the efforts of students to work together and to refer to a database of knowledge (Goodman and Darr 1998). Virtual classroom and videoconference suites (such as WebEx, Centra, and Live Meeting) allow for real-time discussion using audio, video, text chat, whiteboards, and screen sharing.

When individuals undertake collaboration that does not take place in face-to-face contexts, they form virtual (collaborative) groups and teams. Information technologies can help to bridge the discontinuities (of time, geography, and group composition) (Chudoba, Wynn, Lu, and Watson-Manheim 2005) which are experienced by members in a virtual group/team (Powell et al. 2004). The capability of information technologies to automate routine tasks, permit flexible editing, and integrate multiple communication modes makes them well suited for educational collaboration (Wegerif 2005).

Information technologies can improve the efficiency and effectiveness of collaboration, as well as the perceived learning outcomes in a group context (George, Passerini, Hiltz, Jones, and Manikopoulos 2006). Computer-supported collaborative learning may increase reflective skills, problem-solving, critical thinking, and motivation (Schellens, van Keer, Valcke, and de Wever 2007).

Factors influencing the effectiveness of collaborative learning include the development of social infrastructure (Lakkala, Ilomäki, and Palonen 2007), student learning styles, attitudes, and level of participation (Schellens et al. 2007), structuring of the discussion (Cho and Turoff 2003), and ability of the participants (Yetter, Gutkin, Saunders, Galloway, Sobansky, and Song 2006).

The outcome of the collaboration may also be influenced by the environment (real or virtual, collocated or remote) in which the group interaction takes place (Alavi, Wheeler, and Valacich 1995). When virtual learning takes place, the qualities of the virtual environment are of particular importance: the “virtual” environment benefits from providing explicit and salient characteristics of the “real” environment. This improves presence and cognitive fit (Suh and Lee 2005). Cognitive fit is the match between the attributes needed for the user's task and the attributes available in the technology (Suh and Lee 2005). Many information technologies have features that can increase the focus and value of communications, making them valuable for collaboration. For example, one technology feature that enhances virtual collaboration is the ability to be able to pinpoint specific items for discussion or synopsis, highlighting key phrases and summarizing discussion in moderated discussion groups (Kienle and Ritterskamp 2007). The usefulness of the moderating technology and the enhanced communication of the group are the most influential factors in a group experience (George et al. 2006).

The existing theory of distributed cognition contributes to the idea of collaborative learning mediated by technology. Rogers and Ellis (1994) describe distributed cognition as “cognitive activities as embodied and situated within the work settings in which they occur,” especially focusing on the ways in which information is transferred or transformed. Wright, Fields, and Harrison (2000) add that the distributed cognition approach “bring[s] work on CSCW and HCI closer together by considering how technology mediates the propagation of representations between individuals,” where cognition is distributed among individuals and technological representations. Distributed cognition theory emphasizes the importance of both the social group and the tools they use to act as a group and explain how collaborative learning takes place; the affordances of the technology are part of the functional system that distributes cognitive activities (Rogers and Ellis 2001).

Virtual collaboration is a complex area for research. Despite the growing body of knowledge in this area, much remains to be learned. Much existing research concerns face-to-face collaboration or individual technology use rather than virtual groups using technologies. Other studies focus on asynchronous text-based environments, such as email or web forums. Therefore, more research needs to be done to better understand collaboration in virtual groups with real-time communication technology.

METHODOLOGY

The research methodology adopted in this study is grounded theory approach. It is a qualitative research method that uses a set of procedures to inductively develop a theory derived from data, systematically gathered and analyzed through the research process (Strauss and Corbin, 1998). Grounded theory methodologies are well-suited to developing or adding to theories about a process or population that has been little studied, or to describe “how people are experiencing a phenomenon” (Creswell, 2007, p. 62).

In grounded theory approach, data is gathered from interviews, documents, observations, and other qualitative sources. In this study, we collected one-on-one interviews from all participants. We also collected participants' background information using questionnaires and observed and recorded the group discussions.

The process of data analysis in grounded theory is systematic and follows a standard format: open coding is the “analytical process through which concepts are identified and their properties and dimensions are discovered in data” (Strauss and Corbin, 1998, p.101). Initial categories were formed by segmenting information from the raw interview data. Axial coding is the process of “relating categories to their subcategories and link[ing] categories at the level of properties and dimensions” (Strauss and Corbin, 1998, p.123). Because the linkages among categories can be very subtle and implicit, a coding paradigm involving conditions, context, action/interactions, and consequences can help to organize the connections among the categories (Strauss and Corbin, 1998, p. 128). Selective coding is the process through which the researchers identify the key category and integrate the categories around the key categories to create a storyline.

DATA COLLECTION

Participants

Participants for this study are undergraduate engineering students at a midwestern university in the U.S. Twenty-eight students participated in this study, with an average age of 22 years, nine female and nineteen male. Two were sophomores, eight were juniors, and the rest were seniors. The participants majored in various engineering disciplines but were all enrolled in the Mechanics of Materials course at the time the data was collected. The participants were volunteers who were provided extra credit for participating; they were not graded for their performance.

Research Procedures

Students were randomly assigned to groups of three members each. A total of ten groups was formed in this study. Each group was assigned the same tasks to solve some engineering related problems.

Among the ten groups, five were collaborating in a face-to-face environment using paper and pen to solve assigned problems. The other five groups were working in a simulated virtual collaboration environment using software that features interactive 3-D model and chat functionality in one interface (figure 1).

Each virtual collaboration group included two to three students who were not collocated; they were instructed to report to a specific room number and did not meet the other students in their group face to face. They were instructed to use a pseudonym (the room number) as their login name; this was intended to correct for possible contamination effects such as the reputation or appearance of the student. They could communicate through the chat room available in the software. They could also manipulate the model of the beam, bracket, or plate, but only one student could control the model at a time and had to cede control to the other students by pressing the “release tools” button.

After they completed the assignments, students were interviewed regarding their experience in collaborating with each other. Interview data was transcribed and analyzed following the grounded theory approach. A questionnaire was also issued to the students. The questionnaire included an abbreviated version of the Index of Learning Styles for engineering students (Felder and Spurlin 2005) and questions about their experiences with group work.

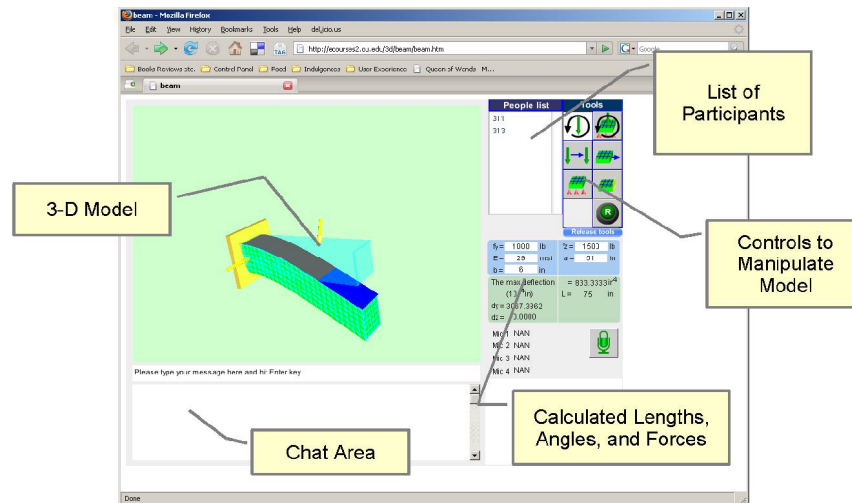


Figure 1. Screenshot of Collaboration Interface

DATA ANALYSIS AND RESULTS

Open Coding

A grounded theory approach was used to develop the concepts and categories shown in Table 1. In order to improve generalizability, the participants in both conditions were pooled to create this analysis. These six categories were discussed by individuals in both groups, although there were differences in nuance. Here we describe and elaborate on each of these categories.

1) Collaborative motivations

Students expressed the desire to identify/recognize their group members and contribute fairly to the assignment.

The students found it desirable to be able to identify and recognize group members, even *in an anonymous condition*; thus, *it relates closely to social presence but does not preclude anonymity*. One student noted that it was important to “figure out who was saying what so that in their next statement we would understand if that was a continuing statement”; this suggests that the need for identity was relative to the current social role.

Prior research suggests that the use of a regular pseudonym, or “handle,” can be a good compromise. Kilner and Hoadley (2005) found that the use of pseudonyms (i.e. consistent log-in names) was sufficient to virtually eliminate negative interactions compared with an anonymity option on a bulletin board site for military officers, and provide a sense of security that one could speak candidly in contrast to using real names.

Group members wanted everyone to contribute in a way that was representative and fair. This did not mean that everyone had equal time. Rather, each person was expected to participate in the discussion, with no person “taking over” or “being in charge.”

Category	Concept	Dimensions	Sample Quotes
Collaboration Motivation	Identifying / Recognizing Group Members	Knowable	"I think it would've been nice if there would've been something that automatically said who was who. That way we wouldn't have to keep signifying to each other to, oh, this is me." "[One challenge was] trying to work with people you never met, never [have] been introduced to."
	Contributing	Fair Safe	"One person just dictating what you're gonna do [would be undesirable]." "I think we all shared a pretty equal part in, in putting in ideas."
Task Characteristics	Time Pressure	Efficiency	"[I disliked] having to spend the time to type it all out." "I don't know how the other groups did, if they immediately were just like buckled down, if they were all ready."
	Problem Type	Discussion vs. Calculation	"It was nice to work, in the problems that we worked it was nice to have other people helping. They were not, they weren't technical problems. If I was working with numbers and equations and the steps... someone will get it, throw the answer out there, everyone will copy it down and say let's go to the next one. I mean you don't figure out how to do it."
	Feedback Mechanisms	Technological Interpersonal	"I think [we] really got them down pat with being able to manipulate an object to see what happens with like stress and strain" "Usually when I saw something that was strange, they [the group] would reciprocate that, so I guess it was good to have the feedback."
Group Dynamics	Group Size	Small Size	"It's more effective if you have a smaller group because...if you have a group of twenty, maybe two people can give."
	Group Homogeneity	Academic Personality Social Cognitive	"From talking to this guy it seems like we're all... have about the same understanding of the material." "It was good, I mean we all talked and no one was shy and no one had a bad attitude about anything."
Technological Factors	Communication Channels	Real-Time Multiple Labeling	"I didn't know who was talking. It would've been nice to have the name next to the response there." "I liked it online because if I miss something or I didn't understand it, I could go back and re-listen to it, and I could work around my work schedule."
	Workspaces	Individual Multiple Shared Control of Tools	"[One concern was] just not being able to use the tools. If there was two sets of tools and two, two diagrams then you could even, if there was two sets on each screen then you could make comparisons." "Probably more accommodations could be discovered if all three people were able to control simultaneously; like on their own screen." "I did like the fact that only one person could have control of the picture at a time until they gave up control."
	Visualization Aids	Realistic Behavior	"I like the fact that whenever you did rotate you kind of see blue." "And the beam... if you get it at like a certain angle, then the beam is like off the page almost. And, it didn't seem very realistic that way."
Collaboration Process	Collaboration Activities	Sharing Knowledge Showing Negotiating Agreeing	"Once I figured out what was going on, I kind of put in my info." "[Consensus building was that] we're just gonna say what we were going to put down on the paper, but it wasn't too much [negotiating]. Like we were saying, making sure we [agreed]." "[If] neither one of them is wrong, you take the idea from both of them, put them together to get the correct I guess solution." "For the summarize [question]... he or she put, 'Is everyone okay with that?' And then we type okay."
	Coordination Processes	Taking Turns	"I think we took turns. [We said], I want to play with it, I want to do it now, so I gave it up and let him do it... I think that works the best."
Outcomes	Content	Improved Understanding Validating/Reassuring About Own Knowledge	"I think we did very well, we... were able to discuss the answers and give valid reasons for the description we gave." "I think I felt like we all already understood it, so it was just kind of reassuring [rather] than necessarily helping with the material."
	Interpersonal	Improved Communication	"[Text chat required us to] figure out who was saying what so that in their next statement we would understand like if that was a continuing statement."

Table 1. Results of Open Coding

2) Task Characteristics

Students expressed a sense of time pressure while working with the problems. One of them stated that *“one person at a time being able to control the object made things slower.”*

The types of problems the students are asked to solve may influence the style of collaboration. For example, one participant noted difference between the discussion questions and calculation-based problems. *“In the problems that we worked it was nice to have other people helping.... They weren't technical problems. If I was working with numbers and equations and the steps... someone will get it, throw the answer out there, everyone will copy it down and say let's go to the next one. I mean you don't figure out how to do it.”* This result is also validated by Bower (2007) in his case study of small virtual groups doing course tasks in a programming class.

Prompt feedback on performance was important to these participants. Some took an experimental approach to the task, suggesting a possible response then testing it against the model. It was also good to receive feedback from the group: *“Usually when I saw something that was strange, they would reciprocate that, so I guess it was good to have the feedback.”*

3) Group Dynamics

Group dynamics were affected by a number of factors. The groups were very short term groups, and many students noted that they were barely or not at all acquainted with their classmates. Thus, they had little social capital built up a priori. Group size was preferably small, which is supported by literature from Rohde et al. (2007), Mennecke (1995), Cho and Turoff (2003) and others who give an optimal group size of four to six.

The relative homogeneity of the group was also seen as a benefit, allowing the students to find common ground with these strangers by virtue of being enrolled in the same class. The students identified with their group members based on their academic background, personality, and social interaction. *“From talking to this guy it seems like... we all have about the same understanding of the material.”* Alavi et al. (1995) suggest that some amount of heterogeneity may create greater benefits, but believe that too much difference impedes the progress of the group.

Learning styles that may affect student interaction may include various modes of thinking (e.g. words vs. movement) as well as myriad other differences (e.g. preferring top-down vs. bottom-up approaches), and different phenotypes may emerge out of different situations (Alavi et al. 1995). Our pre-questionnaire included an abbreviated version of Felder's Index of Learning Styles (2005). The results of the questionnaire suggested that our participants were fairly typical engineering students who are detail-oriented.

4) Technological Factors

Students enjoyed the synchronous communication, but also expressed their concerns about the lack of labeling (e.g., alerts when text messages were sent) when relying on instant messages for communication in the virtual collaboration groups. The students were aware of how many others were in the group, due to a “People List” feature available on the interface, but it was preferable to connect group members to their comments.

The workspace provided to the virtual groups received a great deal of commentary. Students were concerned about the question of who had control of the tools. Only one could control the model at a time: some thought this was a good idea, and some found it stifling. Although this attribute was hinted at in the interface (a “release tools” button), it was unclear, causing frustration. Students envisioned multiple individual workspaces, perhaps with drawing boards or tablets, and the ability to share pictures and notes. Dillenbourg and Traum (1999) note that the degree of sharedness of information, mutuality of knowledge, and persistence of information are three major factors in the ability of a group to ground their work on mutual understanding.

Visualization aids were a very popular aspect of the software. The visualizations showed a physical component and demonstrated the direction of deflection under various forces. The idea of realistic motion was an important component to the usefulness of the visualization; students wanted to see *“what would [i.e. in the physical world] happen.”* However, they did not demand photorealism; for example, one student said *“I like the fact that whenever you did rotate you kind of see blue,”* where the colors highlighted different areas as it flexed. This preference for realistic motion may also account for one participant's comment about being *“afraid to play with the rotating 3D,”* as this may not be as *“realistic.”* This may inhibit the perceived ease of use of that feature, making some individuals less likely to use the feature despite its intended usefulness.

5) Collaboration process

The collaboration process was the central category discussed by the participants. Collaboration involves several activities:

- a) Sharing. Sharing in a group context often refers to sharing knowledge, which was considered important in contributing to the group. Sharing can include information about how to interpret the questions and the visuals, and proposing solutions or partial solutions. Students found the multiple perspectives valuable even when they were not at odds: *“I... see how other people look at the problem, the same problem I do, and that gives me... more ideas to look at this one problem in different directions, different ways.”*
- b) Showing. Students mentioned showing or demonstrating various points with their hands (in the face-to-face setting) or by manipulating the 3-D models in the virtual workspace. One of the face-to-face students described it in this way: *“I was showing... the diagram [of] what was happening and... where... the diagram mentioned the stresses and the bending the forces. I imagined those and how it reacts to the beam that was showing in the module.”* Because spatial manipulations can be difficult to describe in words, it is important that students can show each other their individual understanding of the task questions and the technology.
- c) Negotiating. Participants said that they resolved disagreements by argumentation and demonstration, naturally extending sharing and showing into a brief negotiation process. Two students who disagreed would each give their reasons, so that one of the students would change his or her mind, or the group would identify a compromise position. When *“neither one of them is wrong you take the idea from both of them, put 'em together to get the correct solution.”*
- d) Agreeing. Many students believed it was easy to come to an agreement because they had a similar background and saw the same pictures. A commonly cited way to come to agreement was a call-response conversation, where one person would propose a response and the others would accept or modify it.

6) Collaboration outcome

The students often alluded to the achievement of correct solutions, but when asked to judge their overall experience, they also cited the achievement of correct understanding of the tasks (including the software features and the discussion questions) as well as social interactions among group members.

One individual stated that *“I think we did very well; we all contributed our fair share and were able to discuss the answers and give valid reasons for the description we gave.”* Another participant mentioned the outcome of providing desirable feedback or corroboration, which helped to validate his/her knowledge: *“I think I felt like we all already understood it, so it was just kind of reassuring [rather] than necessarily helping with the material.”*

Axial Coding and Selective Coding

Once the categories have been abstracted from the interview data, the categories can be related to each other and a model depicting the relationships among the categories is developed. Strauss and Corbin (1998) describe a method that models the categories as conditions, actions/interactions, and consequences. In this study, the central phenomenon is collaboration in learning. We propose that the causal conditions which promote collaboration are social and performance motivations, and that these are moderated by contextual conditions including technological and group characteristics. The participants then pursue various collaboration activities to reach outcomes that would result in improved understanding of the content, and enhanced interpersonal interaction experience. These interactions are summarized in figure 2.

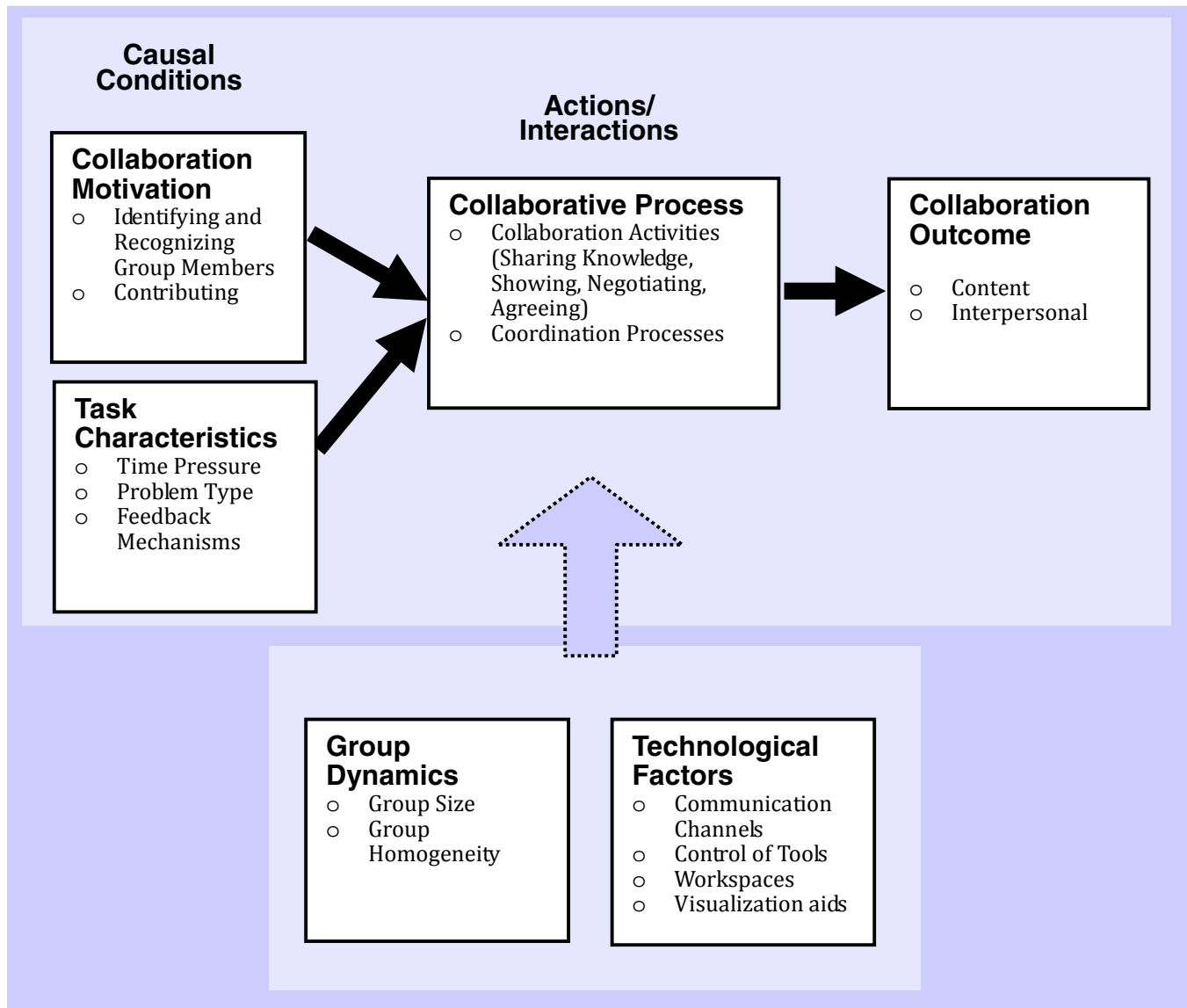


Figure 2. A Model on Collaboration in Learning

As this study comprises results from both face-to-face groups and virtual collaboration groups, we also compared the two types of collaboration and analyzed the differences between the two types of groups following the grounded theory model. This comparison suggests dimensions and properties that may be especially relevant to virtual groups. Table 2 summarizes the main differences in the face-to-face group and virtual collaboration group.

	Face To Face Collaboration	Virtual Collaboration
Collaboration Motivation	More detailed identity for other group members was desired. "Comfort levels" and "friendliness" were cited more often. There was more focus on egalitarian groups.	Most desired richer communication, although anonymity was also desirable. Social roles focused more on "helping" the person manipulating the visualization.
Task Characteristics	The group found it difficult to tackle this type of problem without aids and depended upon each other for feedback.	Visualization aids important for feedback and experimentation; thus, reliability of aids was a concern. Rich media feedback was requested. This group emphasized the usefulness of collaboration on complex problems.
Group Dynamics	Emphasized "comfort levels" with other people; more interested in personal details of other students.	Problem complexity improves discussion but also requires more technological scaffolding
Technological Factors	General requests for technologies that were "responsive" and "interactive." Ease of use, comparing notes, and videoconferencing with other attributes mentioned.	Specific requests for small improvements in technology: larger display, pseudonym labeling, improved scrolling.
Collaboration Process	Perceived roles emphasized "seeing" and showing, deciding how to visualize in absence of strong visualization aids.	Control of visualization changed perceived roles to emphasize negotiation and agreeing.

Table 2. Differences Between Groups

DISCUSSION

The results of this study identify factors influencing collaboration in learning. When working in groups, students want to be able to identify and recognize the other members of their group so that they have a sense of knowing who the other members are. They also hope that everyone will be represented and that they will feel safe to contribute. With respect to the task, they also are concerned about the time pressure they may feel and whether they will be able to complete the task efficiently. The type of problem they are collaborating on will also affect how they expect to behave in the collaboration; problems that are more open-ended are more likely to encourage a useful collaborative process. They are eager for feedback, whether from other people or from technological sources.

Other factors in their context affect how their collaborative process actually works out. These include the size of the group, with a small group encouraging more collaboration, and the homogeneity of the group, which can include academic or content-area background as well as individual factors such as personality, social norms, and cognitive biases such as learning style. A certain degree of homogeneity is likely to engender a sense of common ground, although it may limit the creativity with which the group approaches the problem.

Meanwhile, the technological context also affects the collaboration. The use of information technology offers convenience and flexibility, allowing more group members to participate, but this is counterbalanced by the desire for real-time discussion. Multiple communication channels may then be appropriate, and it is important that the technology support social goals by labeling who is communicating and who is "listening" at any given time. The coordination of control of any specialized tools should be as user-friendly as possible. Workspaces should be flexible, allowing for shared notes and demonstrations as well as individual spaces for experimentation. Any visualization aids need not be photorealistic, but they should show accurate behavior to scaffold thinking about the discussion. Visualization aids are very useful in discussing situations that involve spatial relations.

The collaboration process is expected to include a number of collaborative activities. These are likely to include sharing knowledge, showing or demonstrating, negotiating disagreements, and settling on an agreed upon answer. Coordination processes that help to organize the collaboration are also likely. These may vary from ordinary cultural-linguistic cues in face-to-face groups to newer chat conventions and explicit turn-taking requests in technologies to perhaps more formal mechanisms when needed. The group will expect to find a reasonable, satisfying response to the scenario in the group, but they also will expect the collaboration to be interpersonally satisfying.

IMPLICATIONS AND CONCLUSION

This study develops a model to explain collaboration in learning using the grounded theory approach; future research can provide further validation and extension of the model and use the model as a springboard of concepts. The results of this study suggest that collaborative technologies must be designed to accord with the group and task characteristics in which they

are likely to be used. Technology tools should include specialized, task-specific feedback and visualization where appropriate. Collaboration technologies should attempt to integrate synchronous and asynchronous communication channels and provide a range of medium options, including text, audio, and video, and allow group members to review previous communications. They should also provide workspaces for working privately and publicly, as well as clear indications of who controls any special areas.

The technology should facilitate the recognition of group members, whether by pseudonyms, color coding, profiles, icons, or other methods. Similarly, technologies to support coordination processes are appropriate, ranging from queues for turn-taking in an audio-video conversation, checklists, shared calendars, “sticky notes” and whiteboards, to customized technologies such as interactive procedural manuals. Technology designers should consider implementing status markers, color coding, tags, or other features that allow one to identify negotiations in progress and finalized agreements. In short, a clear vision of the possible task processes and sociability issues should be build into information technologies.

When designing group educational experiences, educators must weigh carefully what questions and informational technologies will be used. The attention paid by the students to both the social and the technological aspects of the activity suggests the importance of structuring these aspects to improve the learning outcome. For example, assigned questions should leverage the unique capabilities of the technology. Group assignments should promote concepts, procedures, and discussion rather than the result of a calculation or rote answer. These concerns may discourage some educators from attempting to use group assignments and technology, perceiving this attention as overhead that detracts from the mastery of the material. However, it is possible that instead these aspects increase engagement with the material and provide opportunities for students to learn it at a higher level.

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