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Exploring the relationship between mediating tools and student perception of interdependence in a CSCL environment. (Computer supported collaborative learning.)

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This study investigated how different tools differentially mediate the way groups interact and how the differential tool use and interactivity influence interdependence in online collaborative activity. Activity Theory is used as a framework to examine and explain computer-mediated interactions among students during group work. The findings reveal that the characteristics of tools are associated with differential communication and interaction patterns, which in turn are associated with students' perceptions of sharing the work, being socially interdependent, and the intellectual nature of the co-construction of work.

Introduction

Because of rapid advances in the capabilities of and access to technologies and the growing recognition of the importance of social construction to learning, computer mediated communication (CMC) has become a focus of educational research. CMC, as defined by Wolz, Walker, Palme, Anderson, Chen, et al. (1997), is "any form of interpersonal communication that uses some form of computer technology to transmit, store, annotate, or present information created by one or more participants" (p. 51). CMC has been promoted as a means to improve communication and collaboration in group learning (Jonassen & Kwon, 2001). The current study examines data from multiple sources in order to better understand how CMC tools mediate group work as well as how the use of those tools affects student perception of positive interdependence (Johnson, Johnson, & Holubec, 1998), an essential factor influencing cooperative work and collaborative learning. Understanding how students use CMC tools to facilitate their collaboration and how CMC tools shape the way students interact can contribute to (1) advancing knowledge about social activity in computer supported collaborative learning (CSCL), (2) developing improved instructional methods for CSCL, and (3) providing guidance for CSCL systems development. According to Bannon and Bodker (1991), tools, including means to divide work, standards, strategies, and language, are artifacts of an activity. They are made by humans and available before a certain activity takes place, and they mediate the relationships between humans and their objectives. They are also appropriated by humans to best fit their experiences and needs over the span of an activity.

Theoretical Framework
Piaget's cognition theory showed peer interaction and collaboration to be a very important source of cognitive development (Driscoll, 2000). There are three processes that contribute to one's cognitive development, they are assimilation, accommodation, and equilibrium. Piaget believed that when a problem is presented, learners use their pre-existing knowledge and information gained from interacting with their peers and environment to come to a solution. In other words, when learners experience new problems, disequilibrium sets in until they are able to assimilate and accommodate new information and attain a new degree of equilibrium (Thomson & Meggit, 1997). The equilibrations process is the backbone of cognitive development (Ginsburg & Opper, 1978).

Moreover, Vygotsky's idea of the zone of proximal development (ZPD), which is defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving in collaboration with more capable peers" (Rowlands, 2000, p. 540), identifies the essential role of having learners interact with others in their environment and in collaboration with peers. According to Vygotsky (1978), cognition is developed through social interaction, that is, students internalize the meaning and uses of mediated tools as they communicate and interact with others until they internalize the process (Lin, Lin, & Laffey, 2004). Research frequently shows that there are clear educational advantages of collaborative activity (Oliver & Omari, 1998), such as achievement enhancement (Johnson, Johnson, & Holubec, 1998; Benbunan-Fich & Hiltz, 1999), cognitive development (Bhattacharya & Chatterjee, 2000), and critical thinking (Gokhale, 1995). Along with the omnipresence of using computers and the Internet in classrooms, CSCL seems to have a promising influence on both students' learning and teachers' teaching (Oliver & Omari, 1998; Bell & Winn, 2000; Koschmann, 1996).

Strijbos, Martens, and Jochems (2004) posited that there are five components of collaborative learning: participants, positive interdependence, group task, individual accountability, and a shift in the role of the teacher. Among these components, Johnson and Johnson (1992) argued that positive interdependence is the key to effective collaboration. According to Johnson, Johnson and Holubec, positive interdependence, links group members together "... so one cannot succeed unless all group members succeed. Group members have to know that they sink or swim together" (1998, p. 4). In other words, students have to clearly understand that each group member's efforts (the division of labor) are required and crucial for group success. "Each group member has a unique contribution to make to the joint effort because of his or her resources and/or role and task responsibilities" (Johnson, Johnson, & Holubec, 1998, p. 4). The major indicators of positive interdependence involve promotive interaction occurring during the group working process (Johnson & Johnson, 1992; Johnson, Johnson, & Smith, 1995) and individual accountability (Johnson, Johnson, & Smith, 1995; Slavin, 1980). Promotive interaction is defined as group members encouraging and facilitating each other's efforts to accomplish the group's objects (goals), and individual accountability refers to each participant's responsibility to accomplish the group's goals. Thus, positive interdependence impacts group members, group interaction processes, and group performance (Strijbos, Martens, Jochems, & Broers, 2004).
In sum, the review of the aforementioned aspects of collaborative learning indicates that group-based learning may be well explained through the following dimensions: individuals, a group of individuals, goals, tools and resources, regulations and rules, individual accountability, and group products. The dimensions are in line with Activity Theory, "a philosophy and cross-disciplinary framework for studying different forms of human activity" (Kuutti, 1996), which emphasizes the interactions between human subjects and the contextual environment and serves as a theoretical framework for this study.

Activity Theory emerged from Vygotsky's idea of mediation and Marx's concept of labor. Leont'ev (1981) described the mediated nature of a collaborative activity as, "only through a relation with other people does man relate to nature itself, which means that labour appears from the very beginning as a process mediated by tools (in the broad sense) and at the same time mediated socially" (Leont'ev, 1981, p. 208). In other words, analyzing a collaborative activity, the basic unit of analysis, should emphasize the relationship between human agents and objects mediated by cultural means, tools and signs. To illustrate the structure of a human collective activity, Engestrom (1987) depicted a systemic model as indicated in figure 1.

In this model, the community comprises subjects (e.g., learners) who share the same objects. The relationship between subjects and the community is mediated by rules, which refer to the explicit regulations, policies, and conventions that constrain activity as well as the implicit norms, standards, and social relations within a community (Jonassen, 2000). The division of labor mediates the relationship between the community and objects. In a collaborative activity, each group member has to contribute in order to produce group artifacts (Outcome). Instruments like signs and language, and in this case a CSCL system of communication and representation tools, are used as means by subjects to reach their objects. The research reported here examined a two-week group activity described in detail in the next section. Groups of three or four students were randomly assigned by the instructor to work together and produce a group report for knowledge sharing and course grading. Tools such as discussion boards, instant messaging (Shadow Express[TM]), and word processing applications (Shadowdoc[TM]) were used to facilitate group members' communication and collaboration.

METHODOLOGY

Context of the Study

This study investigated a two-week small group activity in a web-based graduate level course with 21 students. The graduate course was part of a program leading to a M.Ed. in educational technology. The course-related materials were delivered and most of the class interactions took place in Shadow netWorkspace[TM] (SNS). SNS is a web application system that allows a school or any type of community to establish an intranet with network workspaces for all members and classes. The members of the community have shared workspaces for collaboration; discussion boards, chat, email, and messenger systems for communication; and web-based document editors and viewers for
representation. SNS is open source software using the GNU (GNU's Not UNIX) General Public License (GPL). The software can be freely downloaded and distributed under the terms of the GPL. Shadow netWorkspace is available to anyone at http://sns.internetschools.org.

The SNS tools support students in representing, organizing, sharing, communicating, and collaborating in processes related to individual and group learning and collective activities. Most of the enrolled graduate students had at least one semester experience using SNS in prior coursework. As a consequence, they were familiar with learning, working, and using the built-in tools/applications in Shadow netWorkspace™.

In this particular activity, students were asked to work as a group to reify and organize the knowledge they had learned from investigating the history of information technology and exploring the use of technology in learning and teaching. By the end of the first week an annotated glossary for networked learning systems was produced as an artifact to demonstrate the collective knowledge of the group members. During the second week of this activity, each group had to critique and evaluate another group's first-week report using the evaluation guidelines provided by the instructor.

Data Collection

The Group Work Evaluation (GWE) questionnaire was given to all students after they completed this two-week collective activity. This questionnaire was modified from Johnson and Johnson's (1992) Group Process Survey that measured participants' perceptions of positive interdependence among their group members. In order to thoroughly capture group interaction, the investigators acted as non-participant-observers in each group during the course of the activity. Extensive observation notes of observed activities, social interactions, and group work processes and strategies were documented. Furthermore, students' reflections of their group collaboration and actions and about their group artifacts were collected. Through examining these data resources, we hoped to build knowledge of how groups use different tools to meet group goals and produce group artifacts and how the characteristics of mediation influence individual perception toward interdependence.

Interaction Mapping

Because the structure of the interaction patterns among students and the nature of the interaction itself were very complex, a visual mapping of inter-message referencing, or an interaction map for short, was done to represent the actions and interactions during each group's learning activity. Since we wanted to identify the interaction patterns in each group, we chose to use the message as our unit of analysis. According to Rourke, Anderson, Garrison, and Archer (2001), this type of unit has several advantages: 1) it is objectively identifiable; and 2) the unit's parameters are completely determined by the contributor instead of researchers.
Similar to the technique of concept mapping, interaction maps show the connections and relationships between messages. Each node in an interaction map represents a message posted to the group discussion board. A link between messages indicates how one message refers to another. For example, Node 1__Node 2 means Node 2 is a direct response to Node 1. An isolated node indicates an attempted thread with no further discussion. After analyzing these visual maps, two unique patterns of the interaction among small groups emerged: interactive and monologue.

FINDINGS

Interaction Patterns and Use of Tools

Notes from observing students' tool/application usage and review of students' logs (self-reports of tool use) depict that among the six groups, five (Teams 1, 2, 4, 5, & 6) used group discussion boards as the major tool to mediate group work. As students progressed through the activity, a general discussion pattern emerged from each group's discussion board. In the beginning, a large portion of the discussions were related to the division of labor and each group member's responsibility. After identifying each member's task responsibilities, the use of group discussion boards shifted to posting individual's accomplishments, checking work progress, and providing feedback to others' work.

The interaction patterns carried out by the five groups using discussion boards were categorized into two different types: interactive (Teams 1 & 5) and monologue (Teams 2, 4, & 6). A discussion board showing an interactive pattern indicates that an original message was followed by many ongoing group discussions (Figure 2). To the contrary, a discussion board carrying out a monologue pattern is one in which each participant makes contributions, but not much interaction occurs (Figure 3). By the end of this activity, all groups had created a document using the built-in word processing tool in SNS to collect and organize the work before submitting the group report to the class dropbox. Unlike the other groups, Team 3 did not create a group discussion board, rather, all members contributed to a single document directly. Having multiple authors of a document is possible in SNS because the documents are web-based and multiple authors can contribute text or other media objects to the online document.

Group Work Evaluation Items

Exploratory factor analysis (EFA) with a varimax rotation was used to detect the structure in the relationships among the eighteen statements in the Group Work Evaluation (GWE) questionnaire. Three factors were generated after running EFA and had Eigenvalues greater than 1. Based on Johnson and Johnson's (1992) taxonomy the factors have been labeled: individual accountability, pro-motive interaction, and intellectual nature of co-construction. These three factors explained 73.34% of total variance with a Cronbach's coefficient alpha of 0.90. The internal consistency reliabilities of each of the three composite factors included in the analyses are presented in Table 1. The measures which aggregate to each composite score are also listed. The reliability estimates for each of the factors were computed using item level data. The reliabilities
were within an acceptable range (.85, .86, and .77, respectively). At this point, it is important to note that the investigation only had 21 subjects. It is known that small sample sizes in EFA are unlikely to yield strong results; thus, replications of these findings in a larger sample size may lend more support to the factors. To compensate for the limitation imposed by the sample size, multiple sources including both qualitative (observation notes, group artifacts, and students reflections) and quantitative data (descriptive statistics, ANOVA, and Post Hoc analysis results) are analyzed. Regardless of the limitations imposed by the sample size, several important findings have emerged from our analysis.

Perceptions Toward Positive Interdependence

Individual Accountability

The nine statements that contribute to the first factor asked students to reflect on their experiences in sharing the work (i.e., the division of labor) and developing the product. Students used a 5-level Likert scale to rank these statements, where 1 was strongly disagree and 5 was strongly agree. The higher the rating for the nine statements, the more positive feedback was given toward the group work and the contributions of the members. As shown in Table 1, for Factor 1, Team 3, the team that did not use a discussion board to collaborate, had the lowest mean scores in almost every item across the six groups with the exception of item A5. In contrast, Team 5 had the highest mean scores in the first eight items listed in Table 1 for the individual accountability factor. Analysis of variance (ANOVA) indicates that a statistically significant difference was found to exist among the six groups for students' responses to items A3 (F= 3.771, p= .022) and A4 (F=3.441, p= .029). To determine which specific pair/pairs groups were differentially expressed, Post Hoc tests were applied. The results of Scheffe's Post Hoc comparison reveal that the means of students' perceptions of their collaboration (A3 and A4) in Team 5 were significantly higher than the means of Team 3 students. In addition, as was shown in Figure 2 members in Team 5 actively participated in group discussions and frequently interacted with each other.

The most obvious difference between these two groups was the tool selected to mediate group collaboration. Team 5 used the group discussion board, while Team 3 only created a single-shared document to articulate their ideas and responsibilities. The current word-processing tool of SNS has limited capabilities for tracking changes made by individual users during the course of collaboration; for that reason, individuals' efforts were not easily identified. In contrast to the word processing tool, the discussion board automatically documents all of the interactions and notes the contributor for each message posted. The members of Team 3 had less awareness of what other members were doing because the word processing tool did not provide information about the social aspects (who contributed what) of the work tasks. Essentially members were invisible in the word processing document. Another interesting finding shown in the data was that Team 2, 4, & 6 having a monologue interaction pattern in group discussions had lower Factor 1 mean scores than did the groups having an interactive pattern (Team 1 & 5).
This finding shows the relationship between the ways of using a tool to mediate group work and the students' perceptions of sharing the work (division of labor).

**Promotive Interaction**

The second composite factor measured students' promotive interaction and included six 5-level Likert scale statements with 1 being strongly disagree and 5 being strongly agree. Consistent with findings in Factor 1, students in Team 5, who used the discussion boards interactively, gave higher scores for helping, sharing, and encouraging efforts to complete individual's responsibilities. Team 6 students, who used the discussion board for monologues and gave relatively low scores to items for Factor 1, had the lowest mean scores for the first five statements and a relatively low score for the last item contributing to Factor 2 across the six groups. On the other hand, unlike findings for Factor 1, students in Team 3, who used the online document editor, gave relatively higher ratings of their perceptions of promotive interaction. However, there was no statistically significant mean difference among students' perceptions toward promotive interaction across the six teams.

Content analysis with the message as the unit of analysis shows that even though the discussion board served as the primary tool mediating conversations and collaboration in Team 6, there were only eleven off-task messages generated during the process of group work. For this group, the discussion board was principally used as a bulletin board, for the purpose of making announcements as shown by these illustrative messages sent by Team 6 members:

- Because I will be out of town next Thursday (Feb.27th) and not come back until Monday (March 3rd). I plan to write 15 definitions for our group (total 60, we have 4 people) in advance and submit to the folder in our team 6 (message #1).

- I have posted these 8 with definitions and explanations to the data for review. I will post 7 more tomorrow. I will be gone from the 26th to the 4th, but I can be reached by email or the board (I'll take my laptop) (message #3).

- My dear team members: I will be out of town tomorrow. Could you please combine them and submit it to our team member in the Act4 folder. I am very appreciated what you did (message #8).

According to Johnson, Johnson, and Holubec (1998), promotive interaction can be done by sharing resources and helping, supporting, encouraging, and praising each other's efforts. Promotive interaction contributes to an affective and cohesive relationship among group members. The observations that sharing, helping, and supporting were not prominent in the way Team 6 operated is consistent with the lower ratings for promotive interaction of Team 6 members for their group work.

**Intellectual Nature of Co-Construction**
Factor 3 measures students' perceptions of the intellectual nature of co-construction during collaborative learning. Johnson and Johnson (1989) believed that challenging each other's reasoning among students promoted higher quality decision making and greater insight into the problems being considered (Johnson, Johnson, & Smith, 1995). Two 5-level Likert scale statements from GWE were identified as representing the intellectual nature of co-construction through EFA. The results among the groups were consistent with what was found for Factors 1 and 2: Team 5 had higher mean scores while Team 3 and 6 received lower mean scores. However, use of ANOVA showed that the differences for these two items were not statistically significant across the six teams.

CONCLUSION

This study investigated how tools mediate the way groups interact and how the tool use and interactivity influence interdependence in collective activity. Shadow netWorkspace™ made a variety of CMC tools available but five of the six groups chose the discussion board as the primary means to facilitate their group work. These findings are consistent with many CMC studies that identify discussion board, or computer conferencing (CC) in general, as the primary means for communication and collaboration in online environments [Jonassen & Kwon, 2001; Berge & Collins, 1995; Harasim, 1990; Hiltz, 1990]. Content analysis reveals that group members discussed the division of labor and rules of their group work in the beginning of the assignment period, and shifted their focus to task-oriented communication after identifying each member's responsibilities. The results emphasize the importance of and expectation for individual accountability that students have during collaborative activity. That some groups did not reach a high level of interactivity and interdependence may indicate that effective collaboration may take more time to develop in an online environment. Benbunan-Fich and Hiltz (1999) found that students identify difficulties working collaboratively in an asynchronous situation, and therefore, it is suggested that some pre-composed structure, such as rules or procedures for group interaction, may facilitate the effectiveness of collaborative work and the development of collaborative skills (Strijbos, Martens, & Jochems, 2004; Hiltz, Dufner, Fjermestad, Kim, Ocker, et al., 1996).

Our factor analysis of the GWE indicates that interdependence has several dimensions including individual accountability, promotive interaction, and the intellectual nature of the co-construction. This finding needs replication and confirmation but it may prove valuable for making sense of interaction in CSCL environments. Although the sample size was small our findings of how the teams worked (interactions and tool use) confirm the first factor and provide some evidence for the second and third factors. Team 3, the only group that did not use discussion boards to support collaboration, perceived the lowest degree of interdependence. We attribute the lack of interdependence to the lack of awareness and visibility of its participants' actions and contributions. In addition, when only comparing the five teams that used discussion boards the data show that students who carried out an interactive discussion pattern rated higher in each dimension than those in the monologue-pattern groups. Since positive interdependence is a measure of members' unique contributions (i.e., resources, responsibilities, and feedback) to the joint effort in a collaborative activity, it is likely that participants in less-interactive groups...
perceive lower positive interdependence. Furthermore, our results also suggest that the characteristics and capacities of a CMC tool and the ways it is used to mediate group interaction impact learners’ perceptions. We believe that a CMC tool that helps participants see other's actions in online environments will support better collaboration through promoting positive interdependence and affect.

The dimensions used to explain collaborative learning in this study are aligned with the constructs of Activity Theory, which helps explain the interactions among participants by showing relations among mediated tools, rules and regulations, community, division of labor, and objectives. While further study is needed to support and refine the ways that tool use influences interdependence, the results of this study suggest that characteristics of CMC tools may be a significant mediator of positive interdependence. While Activity Theory offers a powerful framework for understanding how tools are used for collaborative learning, our findings suggest that Activity Theory may need elaboration for use with CMC. Our findings suggest that tools may not only be seen as mediating the subject to object relationship, but perhaps also directly mediating the subject to community relationship. Further exploration of this issue seems warranted. Additionally, since outcome is another aspect in Activity Theory, further studies could examine the relationship between tool use, positive interdependence and the quality of group work.

References


YI-MEI LIN
### Table 1: Reliabilities of Variables and Group Mean Scores

<table>
<thead>
<tr>
<th>Measure and variable</th>
<th>Cronbach's Alpha</th>
<th>Unstandardized factor loading</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FACTOR 1 -- Individual</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accountability</td>
<td>.85</td>
<td></td>
</tr>
<tr>
<td>We each share a portion of the group work (B7)</td>
<td>.94</td>
<td>4.33</td>
</tr>
<tr>
<td>We participate equally in this group project (B6)</td>
<td>.92</td>
<td>4.33</td>
</tr>
<tr>
<td>We contribute equally to this group project (B8)</td>
<td>.89</td>
<td>4.33</td>
</tr>
<tr>
<td>How effective was your group in working together (C1)?</td>
<td>.80</td>
<td>4.00</td>
</tr>
<tr>
<td>I feel my group members are responsible for this group project (A1).</td>
<td>.77</td>
<td>4.33</td>
</tr>
<tr>
<td>I feel I can accomplish this group project alone (A3 reversed).</td>
<td>.76</td>
<td>3.33</td>
</tr>
<tr>
<td>I feel overall our group cooperates well in this project (A5).</td>
<td>.65</td>
<td>4.00</td>
</tr>
<tr>
<td>I feel that I must work collaboratively with my group members to complete this group project (A4).</td>
<td>.62</td>
<td>4.00</td>
</tr>
<tr>
<td>I feel less anxiety and stress working with the group on this project (A6).</td>
<td>.59</td>
<td>4.00</td>
</tr>
<tr>
<td><strong>FACTOR 2 -- Promotive Interaction</strong></td>
<td>.86</td>
<td></td>
</tr>
<tr>
<td>We are committed to the group project (B9).</td>
<td>.84</td>
<td>4.33</td>
</tr>
<tr>
<td>We share necessary materials and information with each other (B2).</td>
<td>.71</td>
<td>4.00</td>
</tr>
<tr>
<td>We act in a trusting manner (B3).</td>
<td>.68</td>
<td>4.00</td>
</tr>
<tr>
<td>We help each other out whenever necessary while working on the project (B1).</td>
<td>.60</td>
<td>4.00</td>
</tr>
<tr>
<td>I feel that we depend on each other while working on this group project (A2).</td>
<td>.59</td>
<td>4.67</td>
</tr>
<tr>
<td>Our group members' actions/</td>
<td>.45</td>
<td>4.33</td>
</tr>
</tbody>
</table>
behaviors have an impact on my work (A8).

FACTOR 3 -- Intellectual Nature of Co-Construction
We challenge each other's ideas or reasoning, so as to come up with better solutions (B4).
We are not afraid of challenging each other’s opinions and raising different ideas (B5).

Measure and variable                      Group

FACTOR 1 -- Individual Accountability
We each share a portion of the group work (B7)
We participate equally in this group project (B6)
We contribute equally to this group project (B8).
How effective was your group in working together (C1)?
I feel my group members are responsible for this group project (A1).
I feel I can accomplish this group project alone (A3 reversed).
I feel overall our group cooperates well in this project (A5).
I feel that I must work collaboratively with my group members to complete this group project (A4).
I feel less anxiety and stress working with the group on this project (A6).

FACTOR 2 -- Promotive Interaction
We are committed to the group project (B9).
We share necessary materials and information with each other (B2).
We act in a trusting manner (B3).
We help each other out whenever necessary while working on the project (B1).
I feel that we depend on each other while working on this group project (A2).
Our group members' actions/behaviors have an impact on my work (A8).
FACTOR 3 -- Intellectual Nature of Co-Construction

We challenge each other's ideas or reasoning, so as to come up with better solutions (B4).

We are not afraid of challenging each other's opinions and raising different ideas (B5).

Note. Scores for A3 have been reversed to match the direction of the other items.


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