Knowledge Construction in Collaborative Concept Mapping: A Case Study

Hong Gao [1], Margareta Maria Thomson[2]*, E Shen[3]

[1, 3] Florida State University

[2*] North Carolina State University

[1] Hong.Gao@fldoe.org; [2*]pmm2121@gmail.com; [3] ess0086@fsu.edu

Abstract

This qualitative study examined the process of knowledge construction of a bounded case study (a group of graduate students). Participants were from the United States and were enrolled in an Educational Psychology course; they were collaboratively involved in the process of knowledge construction using concept maps as the primary data. To examine the processes and tensions during the knowledge construction activity we used the lens of the Activity Systems Theory. Study findings showed that the process of knowledge construction differed from individual to individual based on their domain expertise and concept map procedures. Also, one of the primary tools used in this activity, language, was focused upon by all participants and was identified as a source of tension as well in the group. Attempts were made by the group to establish the language used in the corresponding portion of the concept map constructed. Instructional implications for task construction and approach facilitating knowledge construction are discussed in connection with study findings.

Keywords

Cognitive Modeling; Concept Map; Activity Systems Theory; Qualitative Methodology

Introduction and Purpose

As the research findings on collaborative learning and cooperative learning are disseminated (D. W. Johnson & Johnson, 1974; R. T. Johnson & Johnson, 1979, 1988), the interests of both researchers and practitioners shifted from being mostly concerned about learning at individual level to knowledge construction at group level (Bereiter & Scardamalia, 1996, 2003; Lamon, Reeve, & Scardamalia, 2001; Scardamalia, 2002; Scardamalia & Bereiter, 1994).

Many instructional strategies that were found to be effective have been implemented or are being implemented in group setting. Concept mapping is one of such instructional strategies. Individual concept mapping has been found to be powerful in improving learning and learner attitudes (Horton, McConney,Gallo, Woods, Senn, & Hamelin, 1993; Jegede, Alaiyemola, & Okebukola, 1990; Littrell, 1999; Mason, 1992; Mukama, 2010). In addition, cognitive scientists have found that external representations assist problem solving (Zhang, 1997, 1998) and research on shared representations also point to the potential benefits of using and/or creating external artifacts to support discourse and learning in both face-to-face and online environments (Mukama, 2010; Suthers, 1999, 2001a, 2001b; Suthers, Girardeau, & Hundhausen, 2002; Suthers & Hundhausen, 2001, 2002; Woods, Senn, & Hamelin, 1993).

Concept mapping in group setting, or collaborative concept mapping, is a process where two or more individuals are engaged in coordinated and sustained efforts in the creation of one or more concept maps in order to learn and construct knowledge. However, the need for studies on collaborative concept mapping, especially focusing on particularities of language and communication styles still exists. First and foremost, most of the studies on concept mapping were conducted at individual level and our understanding of collaborative concept mapping is not adequate for effective implementation in practice. In addition, limited research studies on collaborative concept mapping have generated mixed findings across and within studies: some found that groups using concept mapping produced more interaction related to concepts and relationships between concepts (Boxtel, Linden, Roelofs, & Erkens, 2002) and groups generated verbal behaviors similar to those of scientists (Roth & Roychoudhury, 1992, 1993, 1994). In contrast, Chiu (2003) found that students devoted significant amount of time to task collaboration, procedure coordination, and team coordination rather than conducting discussions on the concepts, propositions, or relationships. Along the same line, Carter (1998) found that the concept mapping activity did not

enhance learner interaction and the student pairs had difficulty in forming relationships between different concepts and expressing ideas in hierarchical structure. Conflicting evidence is also found in the same research studies. For instance, along with the positive findings, Roth & Roychoudhury (1993) also found that some inaccurate ideas were never challenged and became ingrained.

Given the lack of research and mixed findings from the studies, this study is to take a close look at the process of knowledge construction by analyzing the types of interactions that occurred in one group during a collaborative activity. In addition, elements from the Cultural-Historical Activity Theory (CHAT) , a tool that helps researchers to fully depict both the activity and the context in which the activity occurs (Nardi, 1996), will be used to provide information on the knowledge construction process by depicting in detail what was involved in each of the elements in the activity systems and how they may have affected the way the group worked.

Cultural-Historical Activity Theory (CHAT) has its roots in the work of Lev S. Vygotsky, the sociocultural theory. Vygotsky's work and his followers, developed into different directions, one of which is activity theory (AT). The emphasis of activity theorists is on the psychological impacts of the elements of the organized social activity into the outcome of such activity. Cultural-Historical Activity Theory states that activity, not necessarily the language ("word") is the unit of analysis for social development, cultural or mental development. Engestrom (1999), sees shared activity, collaborative activity as the unit of analysis for the activity theory, and not necessarily the individual activity. The process of transformation is the focus in his research when analyzing social activity (or practice) as well as the examination of the social world structure and the conflictual nature of human interactions during the activity. The tensions and contradictions during the social practice are understood as "motive force and development" (p. 9) which trigger changes, reasons for dialogue in the group and therefore, reorganizations of the social activity. Consequently it's not only the individuals, the activity systems participants that are modified through the mediated activity, but the environment (e.g., physical, social, psychological) as well.

A model of the Cultural-Historical Activity Theory (CHAT) comprised of six elements (see Figure 1 as well), is described as follows: (1) subject, who can be an individual or a group of people involved in an activity; (2)object is what motivates the subject(s) to engage in the activity and guide the effort in certain direction; (3) instruments or tools, which refer to both the physical tools (tangible tools) and psychological tools such as sign systems that the subject(s) employ to carry out the activity and achieve the object; (4) rules, the regulations that the subjects observe, (5) community , the group to which the subject belongs, and (6) division of labor , which is related to the manner in which the task is horizontally divided among the subjects and the perceived level of expertise (Cole, 1985, 1999; Cole & Engestrom, 1993; Davydov & Radzikhovskii, 1985).

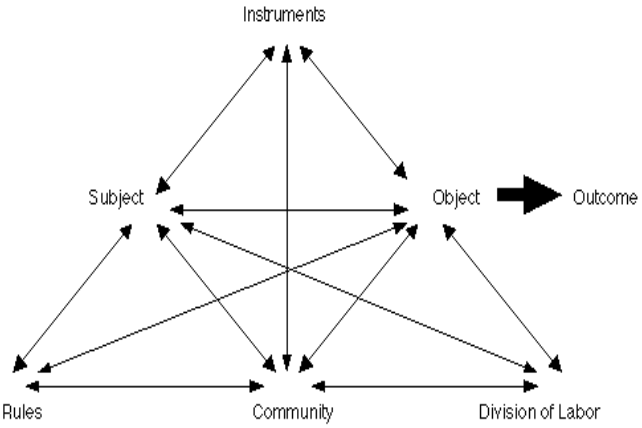

FIG.1 ELABORATED ACTIVITY SYSTEM (ENGESTROM & MIETTINEN, 1999)

Methods

Participants and context

A qualitative case study design is selected to serve the purpose of the study. One case, a group of four graduate students enrolled in a Learning and Cognition course in an Educational Psychology Department at a major university in the United States, was examined in depth. Particular attention was given to the collaborative concept mapping activity where the group worked together to create a concept map on constructivism, the topic given by the instructor for the collaborative concept mapping task.

The four participants were graduate students in different programs of study at a major southeastern U.S. university. To protect the anonymity of participants, pseudonyms are used for their names. Brenda was in her fifties at the time of the study, had a master's degree in distance education and was a doctoral student in her second year in Instructional Systems Program, in the Educational Psychology

Department. Buno, a male in his late thirties, was a second year doctoral student in Mathematics Education, in the Mathematics and Science Education Department. Tom and Bob, the other two participants, both were in their first year of their master's degree program in Instructional Systems Program in the Educational Psychology Department. Also, they shared the same career background, having military status. Tom, has been with the U.S. coast guard for twelve years, and Bob who originally came from Asia to U.S. for studies had worked as an instructional designer for the army in his home country for several years. Among the four participants, Brenda and Buno had much more exposure to the topic of constructivism than the other two participants and also they were more familiar with concept mapping technique, as revealed in the individual concept maps and their own self-evaluations of knowledge in the area in the focus group. Details regarding the procedures and data collected from activities are presented below.

Procedures and Data Sources

Data this study include the four concept maps produced individually prior to the class instruction by each participant, the concept map created by the group, the videotaped collaborative activity, the survey results, and the audio-taped focus group session which are described in detail along with study procedures.

First, participants were instructed to construct a concept map individually, after a brief training on concept mapping, on the topic of constructivism at the end of the class session prior to in-class instruction on constructivism. The concept maps collected from the individuals provided information regarding students' initial understanding of the topic. A rating scale was developed by the researcher based on previous studies (see references). The concept maps were assessed in terms of the number of concepts, links, labels, and propositions respectively that are appropriately related to the given topic (Besterfield-Sacre, Gerchak, Lyons, Shuman, & Waolfe, 2004). The total of all of the proper elements was then calculated and each individual concept map was categorized into low, medium, or high quality. The rating results then were used to form groups so that members in a group would have different levels of understanding of the topic.

This was followed by in-class instruction done by the instructor, and a collaborative concept mapping activity that lasted for about 35 minutes. Instruction for the activity was given to the students prior to the activity and each group was given a marker and an 11" by 17" dry-erase sheet to construct the concept map. The individually produced concept maps were returned to the individuals at the beginning of the collaborative concept mapping activity and the participants were told that they were allowed to use any reference materials during the activity. The groups were videotaped while they were engaged in the collaborative concept mapping activity.

A web-based survey was launched in Blackboard on the same day of collaborative concept mapping activity to gather information on individuals' experience of the collaborative concept mapping session. The students were given four days to complete the survey. The data from the survey were reviewed in preparation for the questions for the focus groups. A focus group session with the group was conducted within a week from the collaborative concept mapping session. It lasted for 1.5 hours and was audio taped. Prior to the focus groups, video of the collaborative concept mapping sessions and responses from the survey were reviewed briefly to draft questions for the focus group.

Data Analysis

Two indexes of knowledge construction were the group concept map and the interaction that occurred during the collaboration. Specifically, the first index of knowledge is referred as a) *the product*, and this is the group concept map produced in the collaborative concept mapping activity and the second index of knowledge is referred as b) *the process*, which represents the types of interaction that occurred during the activity to assess the quality of the interaction.

First, to examine the product, namely the group concept map we examined the total number of concepts, links, labels (linking words or phrases to denote the relationship between different concepts) and cross-links. Following that, to examine the process, namely the interaction that occurred during the collaborative concept mapping we analyzed the video data, after the videotape was reviewed and transcribed. This is followed by several iterations of test coding to build and revise the coding scheme (Appendix 1) by two independent coders. After a pre-determined inter-rater reliability of 85% was reached, the whole transcript was coded.

After that, the videotape of mapping sessions was reviewed to identify each of the components (subjects, tools, objects, rules, community, and division of labor) in the activity system. The primary distinction between different activity systems is the object of the subjects. That is, if there is a substantial change in the goal(s) that motivate the subject to participate and/or complete the activity, one activity system transforms to another. After the identification of the components, the videotapes reviewed for another time for major problems in the process of collaborative concept mapping session. Special attention will be given to tensions or conflicts within and between the activity systems. All the tensions or conflicted revealed in the video and confirmed by the data from the online survey and the focus group are presented below.

Results

The results of the analysis will be presented in the following order. The results of knowledge construction will be presented first. A preliminary data analysis examined the two indexes of knowledge construction: a) *the product*, this is the group concept map produced in the collaborative concept mapping activity and b) *the process*, which represents the types of interaction that occurred during the activity to assess the quality of the interaction. This is followed by a secondary data analysis, a more in-depth analysis regarding the *activity system components*, a detailed description of the elements in the activity system: the subjects, the tools, the objects, the rules and regulations that were observed by the group members both explicitly and implicitly, community, and the division of labor. Observations of the elements then will be tied back to the comments from the focus group interview to detect possible tensions that have existed and may have affected the group's decision making process.

First Index of Knowledge: a) The Product- Group Concept Map

The first index of knowledge construction is the product, in this case the group map. The group concept map (see Figure 2) consisted of three major sections: the middle section that approached constructivism from the perspective of learning communities where learners interact with their peers, more advanced learners, and mentors. The section on the right addressed constructivism as a type of learning environment and the advantages of using such environment. The section on the left depicted the elements in the process of constructivism.

An inspection of the group map revealed both positive and negative aspects of the map construction and process leading to this outcome. The group's attempt to be comprehensive in the content is evident in the different approaches that each section took in addressing the same topic and all of them are appropriate. This indicates that the group did have some understanding of the topic. However, an inspection of the group map revealed that there were several overall deficiencies: the linking words were repetitively used: the linking phrase "interact with" was used five times, "consists of" was used 10 times in the whole concept map. Further, the linking phrases were generic in nature and lacked the variety and accuracy in depicting the relationships between the concepts. In addition, there is a lack of cross-links that link concepts in different areas/sections of a concept map. This indicates that the learners may not be aware of the interconnections between some of the concepts and the extent of knowledge integration and synthesis was minimal at the time of the collaborative concept mapping (e.g., Canas, Coffey, Carnot, Feltovich, Hoffman, Feltovich,2003).

A closer look of the group map indicates that the sections are different in quality, which is reflected in the number of concepts, links, and linking words/phrases. As well as the amount of time used to create the sections. The middle section had 4 concepts, 6 links, a linking phrase used for six times. The section on the right had 5 concepts, 4 links, and 2 linking phrases with each used for two times. For the section on the left, it had 8 concepts, 7 links, and one linking phrase to label the links. Unlike the middle section where the possible relationships between the four concepts were exhausted (six links between four concepts), the section on the left and right had similar structures in that the links went from one concept at higher level to each one at low level without any linkages between any of the lower level concepts. The difference between the middle section and the two on both sides is also evident in the link/concept ratio: 1.5 for the middle, 0.8 and 0.8 for right and left section respectively. Evidently the ratio is substantially higher for the middle section than that for the other two sections, which in part reflects the different quality of the sections.

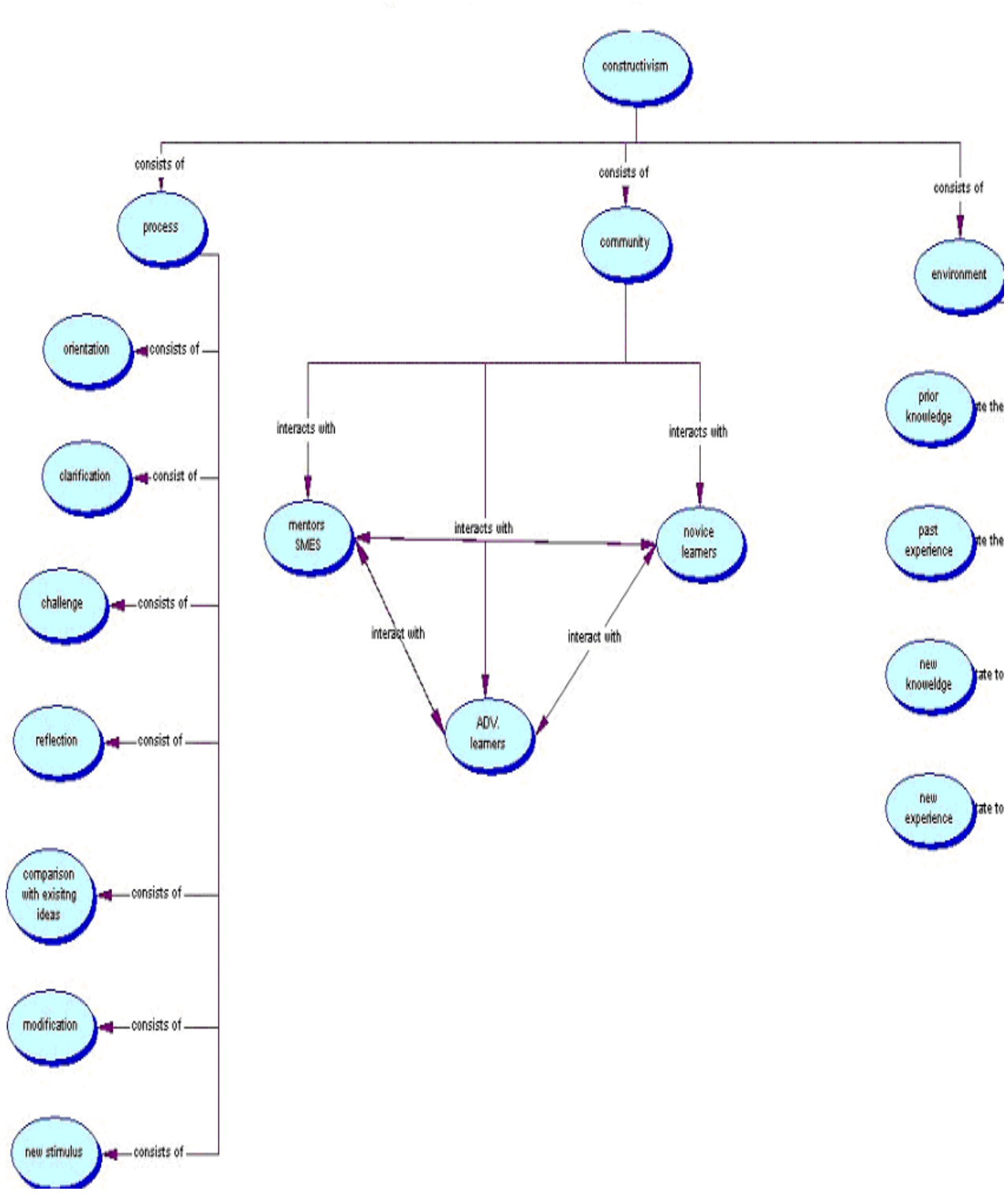

Fig.2 THE GROUP MAP

The different quality of sections is not only revealed in the links between the lower level concepts and the link/concept ratio, it is also visible in the amount of time spent by the group in construction and the number of conversational turns that occurred in each section. Videotape revealed that the amount of time to which the group devoted the sections was different: the middle section in more than 15 minutes, the right section in about 7 minutes and the left section in 3 minutes. This, in combination with the information above, revealed a trend to the three sections, as indicated in the table below: the number of concepts

was increasing while the ratio between the number of links and the time used was decreasing from more than 15 minutes for 4 concepts to 3 minutes for 8 concepts. This signals that the group was probably spending less and less time in identifying the relationships between the concepts, which is essentially the most time-consuming but the most important aspect of concept mapping. A further analysis of the collaborative concept map activity, namely the analysis of the interactions during this collaborative activity also points to similar trend: It took the group 172 conversational turns to complete the middle section, 62 turns for the section on the right, and 26 turns for the section on the left. That is, the amount of discussion devoted to each section decreased substantially over time as the link/concept ratio and the number of links decreased as showed in Table 1 below.

TABLE 1. STATISTICS ON EACH SECTION OF THE GROUP CONCEPT MAP

Sections	Content of the section	# of concepts	# of links	Link and concept ratio	Time spent	# of conversational turns
Middle	Constructivism as a community of practice	4	6	1.5	15 min.	172
Right	Advantages of constructivist learning environments	5	4	0.8	7 min.	62
Left	Processes of constructivism	8	7	0.8	3 min	26

The sections also differ in the uniqueness of the expressed ideas. The middle section centered on the idea of "communities of practice", although it contained only 4 concepts, the ideas expressed in the section transcended any of the ideas from the individual concept maps, the in-class instruction, or the ideas presented in the textbook. It was not seen in any of the other groups' concept maps in this class.

Second Index of Knowledge: b) The Process- Quality and Types of Interactions

The second index used to measure knowledge construction is the types of interaction that occurred during the collaborative concept mapping activity. The coding scheme was developed after three iterations of test coding by two coders and scheme building and revision. One page of transcripts was randomly selected for testing coding each time. Initial coding scheme was developed after the first testing coding which was then revised based on the second test coding. The revised coding scheme was then further modified with attention on those where the two coders differed. The coding scheme was finalized after the third time test coding when the inter-rater reliability reached 85%.

When transcribing the video, we also included non-verbal communication such as the recorder refined the map, added elements to the map to signal his agreement with the proposal or the revisions. Thus the number of interaction coded here will be larger than the number of conversational turns which only count the verbal interaction between the group members. Table 2 below presents the frequency and percentage of interaction for each of the category.

TABLE 2 ANALYSIS OF INTERACTION: PERCENTAGE AND FREQUENCY OF EACH CATEGORY

Category	Brief Description	Level	Frequency	Percentage
Propose	New elements (concepts, links, labeling words, propositions) for the group concept map are proposed		28	11%
Refine	Changes or revisions are proposed to any elements in the concept map	high	8	3%
Task collaboration	Procedure related discussions		48	18%
Elicitation	Elicitation of content-related elements for the group map		13	5%
Agree	Express agreement by explicitly say "yes" or recording ideas on the board without revisions		37	14%
Elaboration/Clarification	Elaborate on what was meant to other group members	high	56	22%

Answer without elaboration	Simple answer to a question or an elicitation without providing explanation or justification		9	3%
Ask to confirm	Ask to ensure accurate understanding of what has been proposed		26	10%
Disagree	Express disagreement with what has been proposed		10	4%
Evaluation	Evaluate the quality of proposals or suggested revisions	high	17	6%
Social	Social acts; interaction not related to either content or procedure		10	4%

Data analysis indicates that the group was on task with 96% of interaction devoted to the task and only 4% for social acts. Among the on-task interaction, 18% of interaction was process-oriented. Three categories (refine, elaboration/clarification, evaluation) were considered to be high level interaction as they required the speaker to evaluate and/or make revisions to proposed ideas or elaborate on his/her own point of view or provide explanations for certain proposals or revisions. They accounted for 31% of the interaction. It seems that the interaction in which the group engaged did challenge each other's thoughts and stimulate ideas in this activity.

Activity System Components

Given that multiple elements are involved in this complex task, we used the activity theory to depict the process in which each section was created. The six elements of the activity theory, also the elements of our secondary data analysis are : the subject (an individual or a group of people involved in the activity); the object (what motivates the subject(s) to engage in the activity); the instruments or tools, that the subject(s) use; the rules; the community(the group to which the subject belongs) and the division of labor (tasks divided among the subjects and the perceived level of expertise).

Two different activity systems were identified during the activity in the review of the videotape and the data from both the survey and the focus group. In the two activity systems, the subject was the same: the same group of the four graduate students, namely Brenda, Buno, Tom and Bob. What differentiated the activity systems were the two distinct objects operating in the two systems: the initial object being to create a group map that was comprehensive enough to incorporate different perspectives of the group members, high in quality, and reflect the understanding of the topic from the group. This object motivated the group particularly effectively while they were working on the middle section. On one hand, the group did attempt to maintain the object till the end of the activity as the diversity of perspectives that the group adopted in interpreting the complicate concept of "constructivism". However, the object shifted to creating a map that was complete in structure to finish the task on time especially at later stage of the concept mapping task when the group realized that there was a possibility that they may not complete the task on time. The employment of this object was apparent the creation of the left part where the elements were literally moved from the PowerPoint slides to the group map without much discussion.

In addition, the changes of the objects lead to the use of different tools, rules, communities, division of labor, and the manner in which the tools were used. For the first object, the group used individual concept maps, particularly two concept maps from Brenda and Buno, to start their work. The individual concept maps were artifacts important to the construction of the group map for they served as cognitive tools for the group members to record previous understanding and stimuli for recall of previous information related to the topic. This actually off-loads the cognition needed to recollect what has been constructed prior to the construction of the group concept map. As one of the group members briefed in the focus group session on the personal concept map stimulated her recall of the product and the thought processes that lead to the product:

> Brenda: I could quickly refer back to how I thought through the subject and I did not have to re-established the mental picture since it's already there… it is a good starting point to continue building my picture of what I thought about constructivism. It certainly was not finished when I completed it at the end.

In addition to the advantage of easy recall at individual level, the concept maps became medium of communication themselves. On one hand, the group members used the individual maps as a point of reference in their discussion by pointing to certain

parts of the map or making revisions to the original maps. The individual concept maps became an efficient communication tool for each other to share perspectives and exchange ideas. The feature of graphical representation made the maps self-explanatory and verbal communication, in some cases, became redundant. Similar use of external representations has been found by other researchers (Roth, & Roychoudhury, 1992; Suthers, 2001a) and it was found that such use assisted the group in their communication. More importantly, it became a tool that helped the group members to easily "see" and appreciate their peers' perspectives, as this use of concept maps was discussed by different members of the group:

> Brenda: (we fit together as a team extremely well), because when we saw each other's product, it didn't require much explanation for anyone else to understand what others has done; we merged quite well and saw the possibilities there; and I think that's unusual in a classroom situation, we come together and can instantly relate to in terms of what their thoughts are no matter how different it is from my perspective I can understand it, appreciate it, and value it.
>
> Tom: …for me, the concept maps are essentially just on top of the stuff; so it was easy for us to look at each other's concept maps and Buno and Brenda's map look pretty good and their maps just became our focal point of discussion. Because their maps seem to be adequate starts to build upon. But because the maps are easily available to us, in fact we've got maps that are pretty good and they provide us excellent starting points.

As the understanding of the topic by each individual in the group was apparent in the individual concept map, the concept maps became a tool with which the group members could easily assess individual expertise on the topic in the group. That is, the graphical representations of the ideas prompted the group members to conduct self-assessment of understanding and at the same time to assess expertise in the group. This in turn helped the division of labor afterwards. Two members, Tom and Buno, discussed this in great detail in the focus group from their view:

> Buno: I compared Brenda's map with mine and I realized that Brenda's picture is a lot bigger than mine. My concept map is somewhere in her map, a detailed structure, a node in her map. I realized that we needed to follow a structure and we all agreed to that. That sometimes I tried to put something in it because I believe those things are related.
>
> Tom: I was kind of in awe, because like I said, my map was, hardly had anything on it, I did not know anything about it; we got there, and then I do not remember looking at Buno's that much, look at it, I do not remember whose it is, I was like, "wow, he's got a lot of stuff on there" he must know this topic, and by the way, could discuss the topic within the group. I right away felt like that I knew less than both of them, and I kind of felt that Buno had a better handle on it than I did, although I knew he did not have any real world experience with it than I did; like myself, maybe he had read the chapter, maybe more closely; so I kind of felt like, like I was writing down the code tails a little because here are the pretty good maps, the conversation went, and that I kind of recognized some expertise in the area, at least perceived expertise, and so… you know if something was said, it made sense to me, therefore it must be true, I guess.

The reasons for their frequent reference in the collaborative concept mapping were revealed in the focus group discussion: (1) they were easily accessible as they were given to each individual right before the activity and placed on the top of the reference materials; (2) the maps were in the target format of the final group product; The similarity in the structure and the easy availability are the primary reasons why the group started with the individual concept maps, as the group members were asked in the focus group why they started with the individual concept maps.

The choice of the tools and the manner in which the tools were used changed in latter part of the activity. In the creation of the section on the right, only one primary concept map was used and the discussion focused on a portion of the individual map on which the section was based. Review of the group map and the reference individual map revealed that the concepts were the same and minor revisions were made to the linking phrases. The situation deteriorated for the last section where the elements were literally copied from the PowerPoint slides to the group map without much discussion after the group decided on the focus of the area and where the materials should be from. Once that decision was made, the recorder filled in the details. Evidently, the PowerPoint slides were

not used in a constructive fashion in that they were treated as an authoritative source where no revisions or refinements would be necessary for the group map.

Along with the change of tools and the manner in which the tools were used, *language*, as a psychological tool (Davydov & Radzikhovskii, 1985; Nardi, 1996), was used intensively and there were multiple instances of evaluation of individual concept maps, proposals, and elaborations. The group enjoyed this part of the work as they expressed in the focus group:

> Brenda: that to me was the richest part of it, because we all had a tremendous map to contribute individual perspectives; as Bob said earlier, it was wonderful to be able to see the different perspectives; had we been able to merge them all instead of just picking something here and there, I think we could have come up with something really challenging to our thought processes as well as a useful product.

In contrast, the amount of high quality interaction such as refinement, evaluation, and elaborations diminished as the group was constructing the left section. The *community* in which the group worked changed as the task progressed in each of the groups in class and the progress of the peer groups also influenced the way the group approached to their task. The group was working at the end of the classroom, with the dry-erase sheet on the wall and the individual concept maps lying on the table for the whole group to review and analyze. It has another group of four who engaged in the same task 5 feet apart and each group could easily see what the other group was creating. At the beginning of the task, all of the groups were engaged in the same tasks with similar tools, and started with a blank dry-erase sheet with no concepts on it. It was a community where the group did not feel itself different from the others and thus could proceed rather comfortably at its own pace. The environment changed later as the peer group seemed to have put more concepts on the sheet, which created a peer pressure into the activity. When asked in the focus group, Tom said the following:

> Tom: I was worried because the group working beside us had more on their chart than we did; and that the activity is at the tail end of the class; if it is at the beginning of the class; we may not be quite as aware that there will be discrete ending point.

The negative impact of the changed environment and the resultant peer pressure were also reflected in the different rules adopted by the group. In each of the activity systems, two types of rules were involved: one is the rules that were imposed by the instructor and the researcher and the other being the ones implicitly abide by the group members. The imposed rules included using the format of a concept map to express their ideas, using the marker and dry-erase sheet provided, having to work in groups, seek consensus before adding new elements or making revisions to the group map, and complete the group map within the time limits. The implicit rule was that everybody should contribute to the group work according to the division of labor decided by the group. The rules observed from the outset of the activity were not diligently observed by the group. In latter part of the activity in the creation of the left section of the group concept map, the group changed the rules as the recorder pulled ideas directly from the Powerpoint slides without discussion onto the group map. The rule that was implicitly observed by the group at that point was that it was acceptable to put up ideas or details without discussion when the priority was to complete the map and there were time constraints. This was in direct conflict with the external rule of "seeking consensus before adding or making revisions to the group map" by the instructor. It seems that the group, at that point, considered this approach appropriate and it is the easiest way to complete the map on time. On the other hand, the enactment of different rules reflected the different attitudes towards the tools and the epistemological beliefs of the group members: they were fairly critical about each other's map and conducted serious discussions when using the information from the individual concept maps. The criticality was lost in the use of the information from the slides provided by the instructor in part due to time constraints and more importantly, the authoritative nature that they implicitly assigned to the materials from parties they deemed as experts.

The division of labor also changed during the activity. At the start of the activity, the division of labor was not clear until the group reviewed the individual concept maps and decided on which ones were of higher quality and who possessed more expertise in the topic area. On that point, there was a brief discussion on the division of labor, particularly who was going to record the ideas and draw the map for the group.

> Tom: Do we have a blank sheet?

All looking around….yes, here….

Tom: Yes, we just use this one…

Brenda: We can use the board because we can erase then. Who wants to be the artist?

Bob: Ok…I will.

Tom: Bob, you're good at it.

Bob: All right (testing the markers on the board)

Buno: Put a concept somewhere in the center.

From that point on, Bob took the job of recorder and faithfully recorded the ideas from the other group members. Although later Tom and Brenda took turns to work with Bob, the basic division of labor that Bob as the recorder and the others as idea suppliers stayed the same in the construction of the middle and right section. At this stage, he did not have the time to verbalize his thoughts while he was processing information supplied by the other group members, as he later recalled in the focus group session:

Bob: yes. … (unclear) the only problem was that trying to share with the three of them, I did not have time to review my own paper. I had to share with the other three; I tried to capture them all. I tried to analyze and synthesize in my mind. The whole process, the way that the concept map was for me, the basic… how it fit the ... I try to see how it fit the map, I try to see how it fits in the picture…when I saw the map on the wall, I try to see what was covered and what was not; that was the purpose of my concept map.

It is evident from the above statements that Bob was trying to analyze, synthesize, and reflect the multiple perspectives in the discussion as much as possible as he recorded the ideas onto the dry-erase sheet. The division of labor did not change much until they came to the construction of the left section of the map when there was little time left. Once the group decided that the section on processes related to constructivism should be included, it was up to the recorder who went back to the PowerPoint slides and obtained information directly from the source rather than took formed ideas from the other members. Unlike before, the information was neither processed by the other group members nor by recorder himself.

The above analysis indicates that there are many differences between the two different activity systems from objects to the other elements except subject. However, there are several tensions that persisted in mediating the group activity throughout. Each of the tensions is described below.

1) Object vs. Community

The participants were asked to start the group work right after the class instruction and each individual did not have the chance to reflect on what had been presented and form own understanding while concept mapping is the type of task that involves high cognitive processes such as analysis, synthesis, and evaluation. When the group set the goal of creating high quality group map that captures both perspectives of the group members as well as multiple aspects of the complex topic, the successful accomplishment of the object requires more reflection on the part of the learners before and during the task. This conflict in turn could have negatively affected the effectiveness of the interaction, as one group member reflected in the focus group session:

Tom: I was going to say I would have felt better prepared for the group activity if I had done that individual exercise that we had done in last class. First it would give me another opportunity to rustle with some of the concepts myself; when I went to the group, I would have felt, you know, more prepared, kind of, fresher, be able to have something more to contribute, because I have already, have thought this about my current knowledge, a little bit, kind like that, rustle with this first, then I felt I am more prepared for the activity.

2) Object vs. Time Constraints

The tension between these two was constant till the end of the activity. At the end of the discussion, everybody felt they rushed through and the need for more time. What exacerbated the situation is that the group's lack of familiarity with the concept mapping technique, no chance for individual reflection on the topic prior to the group activity, and time-consuming high cognitive processes needed to produce a quality concept map. In the focus group, the group revealed that they did not like the group map they produced and the constant tension between the two may have contributed to this dissatisfaction. Although the tension persisted throughout the activity, the group members did not change their object until peer pressure and

instructor's warning of time limits made the tension of object and time constraints more salient to the group. That is, it seems that the existence of certain tension will not necessarily affect the group in the activity unless they are perceived as so by the group.

3) Subjects vs. Objects

To produce a quality concept map, the subjects need two types of knowledge: knowledge in the topic area and knowledge of concept mapping technique. The facts that the group placed the central topic in the center of the dry-erase sheet and the discussion to make a choice between a tree-shape and a network concept map speak to the fact that the group did not possess the level of familiarity with concept mapping technique. As for the content area, although all of them had extensive exposure to the topic prior to the collaborative concept mapping activity, it usually takes learners much longer to form a coherent understanding of a complex topic. Thus the lack of adequate training and knowledge in the two areas obviously placed the group in a disadvantageous position to achieve the object they set. In addition, the division of labor was not efficient in that the one who was recording the ideas was a non-native speaker who had strong accent and did not have much exposure to the topic other than that in this class. All of these slowed the communication and made the object less accessible after time went by.

Overall, all the above tensions point to the tension between process and product: the use of concept map format to express ideas inherently requires long time for the group to process, integrates, and synthesize information before an idea can take its shape. On the other hand, the time given to the group did not allow adequate time. When the group relaxed the rule of time constraints (while they did not pay much attention to the time constraint), the group members focused more on the discussion and ideas rather than the artifact of the group concept map. However, when the signals of time constraints came from several different sources (the instructor's warning, the completed map of other groups), the group had to change their object and attend more to the product rather than the discussion and ideas. Such tensions existed throughout the activity and played out differently at different stages of the activity. The group members were fully aware of the changes in the processes (italics added).

> Bob: we were pushed to come up with a product, and it is something just good enough to be put up, but not something that we wanted, you can see right now there were things that were not really hooked up, things are messy, there is… we should go there, we should go there, but there is no questions like why we should go there, could we put it here, could we change it, could we link it, *the questions were very prevalent in the first part of the discussion, but not carried forward in the last few minutes, in the last five minutes*, actually.

Conclusion

Although the collaborative concept mapping activity has the potential of facilitating knowledge construction, the activity itself does not automatically generate high quality interaction or products. It is evident that in the two activity systems, the amount of interaction that took place and the products were distinct from each other in quality. In this instance, the group did produce some "new" knowledge in the sense that the group was able to work collectively to produce a section that was beyond what each individual could have created. In addition, the types of interaction that occurred during the activity seem to be substantial and deepen on each other's understanding. Similar research show that collaborative concept map activities might enhance learning, but it's highly dependent on the learning context, learners' abilities and level of expertise in that particular content area, as well as in constructing concept maps (Haugwitz, Nesbit, Sandman, 2010; Mukama, 2010; Chiu,Huang, Chang, 2000).

Overall, most research in this area (e.g., Suthers, Girardeau, & Hundhausen, 2002; Suthers & Hundhausen, 2001, 2002; Woods, Senn, & Hamelin, 1993; Mukama, 2010) found that constructing concepts maps as well as studying concept maps proved to be beneficial learning activities, allowing learners' to process more in-depth information and in different ways, therefore resulting in more profound, meaningful learning and long-term retention. However, other research in this area (i.e., Kotsopoulos, 2010; Nesbit & Adesope, 2006) reported that concept mapping activities have slight instructional benefits comparing to other instructional methods more engaging (e.g., reflective activities, journals,

discussion board) when different instructional strategies were compared. Additionally, same research showed that concept maps tend to be advantageous tools of learning for students with lower verbal abilities compared with students possessing more developed, higher verbal abilities, partly because concept mapping "unlike natural language are restricted to a simple, non-recursive syntax in which propositions are represented by regular subject-verb-object structures." (Haugwitz, Nesbit, Sandman, 2010, pg 538).

It should be noted that in our study the new knowledge was generated when certain tensions were not salient in the environment and thus not perceived by the group members. That is, the knowledge construction took place when the group did not feel time constraints or peer pressure. When the tensions became more intense and salient in the environment at later stage of the activity, the group was forced to focus more on the product itself than the quality of the product. The group was aware of the change in the object and the activity system, which contributed to their dissatisfaction with the group product. Similar findings from research in line with our study's results reported that collaborative learning occurs when learners interact harmoniously to construct knowledge and create a sense of community facilitating shared knowledge (e.g., Ciani, Summers, Easter, & Sheldon, 2008; Dillenbourg, 1999). Other studies (e.g., Kotsopoulos, 2010; Andrejevic, 2005) reported that tensions encountered during the collaborative learning activities and disruptions in the student's normalized patters of learning created greater opportunities for students to demonstrate critical thinking and problem solving skills, as well as improvement in individual student learning and participation. Therefore, it is important to consider possible tensions inherent in a design of a task. While external constraints could be imposed, others mechanisms should be built in to assist the group to alleviate the tension such as setting a goal/object that is appropriate and reachable with the time allowed and resources available.

APPENDIX 1

CODING SCHEME

Functions/Category		Examples
1. Propose	Propose concepts, links, labels, hierarchies that have not been proposed before	
	1.1Propose a new concept	139: How about self-regulation?
	1.2 Propose a new link	
	1.3 Propose a new label	
	1.4 Propose a new hierarchy	
	1.5 Propose a new proposition (a meaningful statement)	154: can we say constructivism promotes higher-order thinking?
2. Refine	Make revisions to concepts, links, labels, hierarchies, or rephrase a whole proposition previously proposed	
	2.1 Propose change to a concept	
	2.2 Propose change to a link	
	2.3 Propose change to a label	133: maybe two columns here.
	2.4 Propose change to a hierarchy (physical placement of a concept, link, or label)	148: we can take it to the other side. I don't mind.
	2.5 rephrase a whole proposition previously proposed	
3. Task collaboration	3.1 propose new process (statements related to the sequence of the task, what's to follow)	128: (I see). So, we have to rewrite.
	3.2 ask for help on aspects irrelevant to content of the map	e.g., can you pass me the marker?
	3.3 offer help on aspects irrelevant to content of the map	e.g., here it is.
	3.4 check notes/references for information	151: Learning goals …(looking through notes)
	3.5 negotiate/discuss how to go about doing something (or when questions are asked or doubts on certain processes/procedures are presented)	129: but we can have it all up there.
	3.6 Inform others of shared understanding	131: yes, I see what you are saying.
	3.7 elicit process-related responses	e.g., what shall we do next?

4. Elicitation	4.1 elicit content-related responses by asking questions	139: … Is self-regulation a characteristic? And learner centered a strategy? 150: what kind of learning goals we get out of constructivism?
5. Agree	Agree with what has been said about content	144: well, yes… critical thinking...
	Confirm another's interpretations of a proposal/modification	143: right.
6.Elaborate/ Clarify	6.1 One person elaborates on the meaning of the content-related statements he/she previously made	155: … for me constructivism promotes higher order thinking kind of critical thinking, reasoning… as think really deeply on some problems.
	6.2 Provide clarifications on what one meant without elaboration on the content(more related to the physical structure of the map)	130: we can have one here (shows on map), and one here (shows on map) and draw links
7. Answer without elaboration	Provide a simple answer to a question without elaboration (content related)	
8. Ask to confirm	Ask to confirm a proposal made before	123: linking it together? 147: so we don't want it to be a characteristic?
9. Disagree	9. One has doubts about the proposal (content)	
10. Evaluate	10. place judgment on what was presented or the quality of artifacts (concept maps)	13: T: that's pretty good. 21: L: …but you're all talking about something related to the function
11. Social	Statements that are not related to content or process of the task	

REFERENCES

Andrejevic, M. (2005). The work of watching one another: lateral surveillance, risk, and governance. *Surveillance & Society, 2(4),* 479-497.

Bereiter, C., & Scardamalia, M. (1996). Rethinking learning. In D. Olson & N. Torrance (Eds.), *Handbook of education and human development: New models of learning, teaching and schooling* (pp. 485-513). Cambridge, MA: Basil Blackwell.

Bereiter, C., & Scardamalia, M. (2003). Learning to work creatively with knowledge. In E. D. Corte, L. Verschaffel, N. Entwistle & J. V. Merrienboer (Eds.), *Unraveling basic components and dimensions of powerful learning environments*. Oxford, UK: Elsevier Science.

Besterfield-Sacre, M., Gerchak, J., Lyons, M., Shuman, L. J., & Waolfe, H. (2004). Scoring concept maps: an integrated rubric for assessing engineering education. *Journal of Engineering Education, April 2004*.

Boxtel, C. v., Linden, J. v. d., Roelofs, E., & Erkens, G. (2002). Collaborative concept mapping: provoking and supporting meaningful discourse. *Theory into Practice, 41*(1), 40.

Canas, A. J., Coffey, J. W., Carnot, M. J., Feltovich, P., Hoffman, R. R., Feltovich, J.(2003). *A summary of literature pertaining to the use of concept mapping techniques and technologies for education and performance support* (technical report submitted to the Chief of Naval Education and Training). Pensacola, FL: The Institute for Human and Machine Cognition, The University of West Florida.

Carter, C. W. (1998). *A case study of meaningful learning in a collaborative concept mapping strategy as a preparation for a college biology laboratory.* Unpublished Doctoral Dissertation, Georgia State University.

Ciani, K.D., Summers, J.J., Easter, M.A., & Sheldon, K.M.(2008). Collaborative learning and positive experiences: Does letting students choose their own groups matter? *Educational Psychology, 28*, 627-641.

Chiu, C.H. (2003). Exploring how primary school students function in computer supported collaborative learning. *International Journal of Contemporary Engineering and Lifelong Learning, 13*(3/4), 258-267.

Chiu,C.H., Huang,C.C., & Chang,W.T. (2000). The evaluation and influence of interaction in network supported collaborative concept mapping. *Computers & Education, 34*, 17-25.

Cole, M. (1985). The zone of proximal development: where culture and cognition create each other. In J. V. Wertsch (Ed.), *Culture, Communication, and Cognition: Vygotskian Perspectives*. Cambridge: Cambridge University Press.

Cole, M. (1999). Cultural psychology: some general principles and a concrete example. In Y. Engestrom, R. Miettinen & R.-L. Punamaki (Eds.), *Perspectives on Activity Theory* (pp. 87-106). Cambridge: Cambridge University Press.

Cole, M., & Engestrom, Y. (1993). A cultural-historical approach to distributed cognition. In G. Salomon (Ed.), *Distributed Cognitions: Psychological and Educational Considerations* (pp. 1-46). Cambridge: Cambridge University Press.

Davydov, V. V., & Radzikhovskii, L. A. (1985). Vygotsky's theory and the activity-oriented approach in psychology. In J. V. Wertsch (Ed.), *Culture, Communication, and Cognition: Vygotskian Perspectives* (pp. 35-65). Cambridge: Cambridge University Press.

Dillenbourg, P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed.), *Collaborative-learning: Cognitive and computational approaches* (p.1-19). Oxford: Elsevier

Engestrom,Y. (1999). Innovative learning in work teams: Analyzing cycles of knowledge creation in practice. In Y. Engestrom, R. Miettinen, & L.Punamki (Eds.), *Perspectives on activity theory* (p. 377-406). Cambridge, UK: Cambridge University Press.

Engestrom, Y., & Miettinen, R. (1999). Introduction. In Y. Engestrom (Ed.), *Perspectives on Activity Theory* (pp. 1-18). Cambridge: Cambridge University Press.

Haugwitz, M., Nesbit, C.J., & Sandman, A. (2010). Cognitive ability and the instructional efficacy of collaborative concept mapping. *Learning and Individual Differences, 20*, 536-543.

Horton, P. B., McConney, A. A., Gallo, M., Woods, A. L., Senn, G. J., & Hamelin, D. (1993). An investigation of the effectiveness of concept mapping as an instructional tool. *Science Education, 77*(1), 95-111.

Jegede, O. J., Alaiyemola, F. F., & Okebukola, P. A. O. (1990). The effect of concept mapping on students' anxiety and achievement in biology. *Journal of Research in Science Teaching, 27*(10), 951-960.

Johnson, D. W., & Johnson, R. T. (1974). Instructional goal structures: cooperative, competitive, or individualistic. *Review of Educational Research, 44*(2), 213-240.

Johnson, R. T., & Johnson, D. W. (1979). Type of task and student achievement and attitudes in interpersonal cooperation, competition, and individualization. *The Journal of Social Psychology, 108*, 37-48.

Johnson, R. T., & Johnson, D. W. (1988). Cooperative learning: two heads better than one. *Transforming education, Winter*, 34.

Kotsopoulos, D. (2010). When collaborative is not collaborative: supporting student learning through self-surveillance. *International Journal of Educational Research, 49*, 129-140.

Lamon, M., Reeve, R., & Scardamalia, M. (2001). *Mapping the growth of deeply principled understandings in a knowledge building community.* Paper presented at the Annual Meeting of the American Educational Research Association, Seattle, WA.

Littrell, R. L. (1999). *Concept mapping: an instructional tool for learning economics and a research tool for determining students' understanding of economics.* Unpublished Doctoral Dissertation, the University of Kansas.

Mason, C. L. (1992). Concept mapping: a tool to develop reflective science instruction. *Science Education, 76*(1), 51-63.

Mukama, E. (2010). Strategizing computer-supported collaborative learning toward knowledge building. *International Journal of Educational Research, 49*, 1-9.

Nardi, B. A. (1996). Studying context: a comparison of activity theory, situated action models, and distributed cognition. In B. A. Nardi (Ed.), *Context and consciousness: activity theory and human-computer interaction* (pp. 69-102). Cambridge, MA: The MIT Press.

Nesbit, J.C.,& Adesope, A. (2006). Learning with concept and knowledge maps: a meta-analysis. *Review of Educational Research, 76*, 413-448.

Roth, W.-M., & Roychoudhury, A. (1992). The social construction of scientific concepts or the concept map as conscription device and tool for social thinking in high school science. *Science Education, 76*(5), 531-557.

Roth, W.-M., & Roychoudhury, A. (1993). The concept map as a tool for the collaborative construction of knowledge: a microanalysis of high school physics students. *Journal of Research in Science Teaching, 30*(5), 503-534.

Roth, W. M., & Roychoudhury, A. (1994). Science discourse through collaborative concept mapping: new perspectives for the teacher. *International Journal of Science Education, 16*(4), 437-455.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67-98). Chicago: Open Court.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences, 3*(3), 265-283.

Suthers, D. D. (1999). *Representational support for collaborative inquiry.* Paper presented at the IEEE, Maui, Hawai'i.

Suthers, D. D. (2001a). *Collaborative representations: supporting face to face and online knowledge building discourse.* Paper presented at the the 34th Hawaii International Conference on the System Sciences (HICSS-34), Maui, Hawaii.

Suthers, D. D. (2001b). Towards a systematic study of representational guidance for collaborative learning outcomes. *Journal of Universal Computer Science, 7*(3).

Suthers, D. D., Girardeau, L. E., & Hundhausen, C. D. (2002). *The roles of representations in online collaborations.* Paper presented at the annual conference for American Educational Research Association, New Orleans, LA.

Suthers, D. D., & Hundhausen, C. D. (2001). *Learning by constructing collaborative representations: an empirical comparison of three alternatives.* Paper presented at the Computer-supported Collaborative Learning, Universiteit Maastricht, Maastrict, the Netherlands.

Suthers, D. D., & Hundhausen, C. D. (2002). *The effects of representation on students' elaborations in collaborative inquiry.* Paper presented at the CSCL (computer-support collaborative learning).

Zhang, J. (1997). The nature of external representations in problem solving. *Cognitive Science, 21*(2), 179-217.

Zhang, J. (1998). A distributed representation approach to group problem solving. *Journal of American Society of Information Science, 49*(9), 801-809.