# Effects of Using Multiple Forms of Support to Enhance Students' Collaboration during Concept Mapping

Anushree Bopardikar*, Dana Gnesdilow*, Sadhana Puntambekar, University of Wisconsin – Madison, 1025 West Johnson Street, Madison, WI 53706,
Email: bopardikar@wisc.edu, gnesdilow@wisc.edu, puntambekar@education.wisc.edu

**Abstract:** Collaborative learning provides opportunities to facilitate students' knowledge construction. However, students may face challenges while constructing meaning through dialogue. This study explored multiple forms of support to foster collaboration that would lead to a deeper understanding of science ideas and high-quality group concept maps. Ninety-five students from four 8th grade science classrooms participated in this study. Using a 2 x 2 experimental design, we examined the effect of teacher modeling of prompts and the effect of meaningful individual preparation prior to collaboration on the quality of students' concept maps. Statistical analyses revealed that groups that prepared individual concept maps and received teacher modeling of prompts generated the highest quality concept maps. Further, teacher modeling of prompts was only found to be effective when combined with the individual preparation of concept maps prior to collaboration. Implications for classroom practice and future research are discussed.

Research from collaborative learning in classrooms and Computer Supported Collaborative Learning settings (CSCL) has found that engaging students in collaboration provides opportunities to facilitate their knowledge construction. Students involved in collaboration may learn through generating elaborate questions, explanations, and arguments (e.g., Choi, Land, & Turgeon, 2005; Weinberger, Stegmann, & Fischer, 2006). However, other research reveals that constructing meaning through dialogue often involves challenges. Students may not always interact effectively and may have difficulty extending one another's ideas and sustaining discussions (So, 2007). Our own prior research has found that students do not always engage in elaborate science conversations in groups (Gnesdilow, Bopardikar, Sullivan, & Puntambekar, 2010). Mercer (2000) has explained that people use their past social and cultural experiences to help them to understand the ways that particular dialogic interactions unfold. Students may not be able to draw from such resources during conversations with each other if their prior school experiences have provided them with little time to talk with peers and has focused more on didactic forms of instruction and discourse.

This paper focuses on collaborative concept mapping as a specific context for researching and enhancing students' collaboration. Concept maps are graphic organizers that represent knowledge by showing relationships between concepts. A concept map includes at least two concepts connected by a linking word which explains the relationships between the concepts (Novak & Cañas, 2008). A collaborative concept map is created when students collectively generate a concept map that may reflect the understanding of the group. Collaborative concept maps may promote social thinking and metacognition among students (Roth & Roychoudhury, 1992), and engage students in elaborate science discussions to co-construct scientific meanings (van Boxtel, van der Linden, Roelofs, & Erkens, 2002; White & Gunstone, as cited in Edmondson, 2000).

To facilitate collaborative concept mapping and address the challenges involved in collaborative knowledge construction, there is a need for supporting students' collaboration. Classroom studies on collaborative learning have provided students with prompts for generating high-level science questions and explanations (Coleman, 1998; King, 1999), and instruction and training to students in various group skills, prior to collaboration (Mercer, 2000). In CSCL settings, studies have utilized software-based tools to help students construct elaborate science explanations (Vattam, Kramer, Kim, & Kolodner, 2007), provided online metacognitive support to promote students' critical discussions (Choi et al., 2005), and scripts to enhance students' online discussions (Weinberger et al., 2006). Furthermore, in classroom and CSCL settings, studies have stressed the important role of the teacher in moderating students' discussions and helping students develop collaboration skills (Mercer, 2000; Schwarz, Asterhan, & Gil, 2009).

In this study, we utilized *multiple* forms of support to facilitate students' knowledge construction during collaborative concept mapping. We examined how two supports, (i) meaningful individual preparation and (ii) teacher modeling of prompts prior to collaboration, affect the quality of students' collaborative concept maps. We will explain the forms of support in more detail in the methods section.

## Methods

### Participants and Instructional Context

We conducted this study in four eighth grade science classes taught by the same teacher in a public school near a mid-sized US Midwestern city. Twenty-five groups, with a total of 95 students, participated in this study. These students had worked in collaborative groups in their science class for about three months prior to this study. Students then engaged in a seven week design-based science curriculum, called CoMPASS, to learn about work and energy in simple machines through completing a set of five design challenges (Puntambekar, Stylianou, & Goldstein, 2007). Students collaborated in the same small groups of three or four during the CoMPASS unit to generate predictions and questions, to explore information on a hypertext system, and to perform physical and computer-based experiments. Students also constructed several individual and collaborative concept maps during this unit, which were used for both instructional and assessment purposes.

### Study Treatment and Comparison Groups

Our study focused on supporting collaborative knowledge building during group concept mapping by investigating the effects of *multiple* forms of support for students' collaboration. Based on previous research, we designed two forms of support to enable students to engage in collaborative knowledge building through concept mapping. The first form of support was teacher modeling of prompts to involve students in more elaborate science discourse. This was grounded in sociocultural approaches to learning which emphasize cultural tools and practices, such as discourse, during collaborative activities (Vygotsky, 1978). Consistent with studies on the teacher's role in facilitating students' collaboration, we included teacher modeling of these prompts for a constructive student dialogue (Mercer, 2000; Schwarz et al., 2009). This support aimed to facilitate students' *discussion* of science concepts when working in peer groups and to provide them with social and cultural experiences prior to collaboration as models of how elaborate science conversations may unfold through the teacher's expert enactment of the prompts (Mercer, 2000). As in prior research by Coleman (1998) and King (1999), our prompts reminded students to question, elaborate, and justify their ideas during dialogue with their peers. We provided students with written prompts and the teacher demonstrated constructive science discussions using these prompts. Specifically, the teacher read each prompt to the class and explained its meaning in her own words. Then she modeled a scenario to elicit students' thinking about how to use the prompts to help their peers elaborate and improve their science ideas to make deeper connections on the map. The prompts were designed to support students on both individual and collaborative levels. One of the individual level prompts was, "justify your thinking about why the concepts or relationships between concepts you contribute are important," and one of the group level prompts was, "ask other group members to justify, give evidence, or support their ideas."

The second form of support explored an individual preparation activity related to the science *content* prior to the collaborative concept mapping activity. This support was intended to help students generate and reflect on the scientific concepts to productively contribute to their collaborative activity. This is similar to the individual use of the Design Diaries to help students plan their ideas before meeting in their groups, so that they could engage more productively during their collaborations (Puntambekar & Kolodner, 2005). We used individual concept mapping as the meaningful preparation activity prior to collaboration. This choice was based on the work of Novak and Cañas (2008) who explain that concept mapping provides a *scaffold* or *template* to help students organize and structure their knowledge. They further associate concept mapping with a constructive process of learning or knowledge creation, which they describe as being different from more rote forms of learning. This choice was also based on a study by van Boxtel, van der Linden, and Kanselaar (2000), who asked students to individually prepare either a concept map or a poster for five minutes before engaging in a collaborative activity. Their findings, though not statistically significant possibly due to the brief time period allotted, showed greater conceptual understanding for students who had time for individual preparation. In our study, we offered students greater time for individual preparation to examine the effect of the nature of individual preparation on the quality of students' collaborative concept maps. We included an individual lists condition to control for time on task between the different conditions. Students had approximately 12 minutes to individually prepare for their collaboration using any classroom resource. We believe that constructing a concept map is a meaningful activity because it requires students to consider different concepts and to represent the relations between these concepts, helping them reflect on and thus be metacognitive about their prior ideas. This metacognitive engagement may help students contribute their ideas towards an elaborate science discourse, which is consistent with research highlighting the role of metacognitive activities in science classrooms (Gunstone, 1994; Hennessey, 2003).

The study involved a 2 x 2 experimental design to examine the effects of teacher modeling of prompts and meaningful individual preparation on the quality of group concept maps. The four conditions were: i) individual map + teacher modeling of prompts; ii) individual map only; iii) individual list + teacher modeling of prompts; and iv) individual list only (see Table 1). We randomly assigned the four classes to the four conditions.

All students in all conditions received the same directions. The teacher emphasized deep connections between concepts and offered suggestions for focal concepts and linking words. Students could use resources from previous class activities for their collaborative concept map. Students worked face-to-face in their small groups for 20 minutes to construct these paper and pencil group concept maps.

Table 1: 2 X 2 study design of teacher modeling of prompts and type of individual preparation activity.

| Factors | Teacher Modeling of Prompts | No Teacher Modeling of Prompts |
|---|---|---|
| Individual Map | Individual Map + Teacher Modeling of Prompts (6 groups) | Individual Map Only (5 groups) |
| List | Individual List + Teacher Modeling of Prompts (6 groups) | Individual List Only (8 groups) |

To investigate the two forms of support across the four conditions discussed above, we formulated three research questions: 1) Do groups that receive teacher modeling of prompts generate more deep level, elaborate connections, on their group concept maps than groups that do not receive teacher modeling of prompts? 2) Do groups that engage in individual map preparation generate more deep level, elaborate connections on their group concept maps than groups that engage in individual list preparation? 3) Do groups that engage in individual concept maps and receive teacher modeling of prompts generate more deep level, elaborate connections on their group concept maps than groups in all other conditions?

For our first question, we hypothesized that groups that received teacher modeling of prompts would generate more deep level, elaborate connections on their group concept maps than groups that did not receive teacher modeling of prompts. For question two, we hypothesized that groups that engaged in individual concept map preparation would generate more deep level, elaborate connections on their group concept maps than groups that engaged in individual list preparation. Finally, for our third question, we hypothesized that the individual concept maps + teacher modeling of prompts groups would generate more deep level, elaborate connections on their group concept maps than groups in all other conditions.

### Data Sources and Analysis

We analyzed 25 collaborative concept maps across the four conditions that students drew at the end of the work and energy unit. We focused on the quality of the propositions, or connections, on the maps. A proposition is two concepts connected by a linking word to form a semantic unit. Each proposition was scored based on a three level coding scheme modified from prior work (Gnesdilow et al., 2010; Puntambekar et al., 2007) (see Table 2). A Level 2 proposition score shows a more elaborate understanding of science concepts than proposition scores assigned a Level 1. The first two authors independently coded 15% of all maps with about a 92% inter-rater reliability. The remaining maps were then scored.

Table 2: Concept maps scoring rubric.

| Level | Description | Example |
|---|---|---|
| 0 | Incorrect, ambiguous, or no connection | levers are inclined planes |
| 1 | Simple fact, example, definitions, formula, overgeneralization, unelaborated connections, (e.g. increases, decreases, reduces), everyday language acceptable | third class lever is one of three kinds of lever |
| 2 | Scientific language, elaborate explanations, specifying conditions for increase or decrease | levers increase MA when the fulcrum is closer to the load than applied force |

## Results

We examined the effects of the four conditions on the quality of students' collaborative concept maps as follows. First, we performed a Kruskal Wallis test to identify if there were pre-existing differences among the four classes in students' content knowledge. This preliminary analysis was important to establish equivalence among the conditions. Next, we performed tests of equality of proportions to compare the quality of connections on the concept maps in the four conditions by examining the proportion of Level 2 connections on the maps.

### Kruskal Wallis Analysis

We performed a Kruskal Wallis test to determine if the four classes (conditions) differed in their content knowledge prior to the final collaborative concept mapping activity. All students individually took an online test of physics knowledge contextualized in the pulley unit. This test consisted of 19 multiple choice and 11 openended items. The total score on this test ranged from zero to 45 points. We chose the Kruskal Wallis test for this preliminary analysis because of the small sample size of less than 30 students in each condition and because the assumption of normality was not met in each condition. The test, which was corrected for tied ranks, was not significant, $\chi^2$ (3, $N$ = 95) = 1.65, $p$ = .6481, α = .01 (see Table 3). This result indicated that there was no statistically significant difference in students' pre-existing content knowledge among the four conditions.

Table 3: Kruskal Wallis Test case summary table.

| Condition | *n* | Mean Rank |
|---|---|---|
| Individual Map & Teacher Modeling of Prompts | 27 | 52.31 |
| Individual Map only | 15 | 65.47 |
| Lists & Teacher Modeling of Prompts | 25 | 53.10 |
| List only | 28 | 55.77 |

## Tests of Equality of Proportions

### Main Effects of Teacher Modeling of Prompts vs. No Teacher Modeling of Prompts and Individual Preparation of Concept Maps vs. Lists

We collapsed the four different conditions into the two factors as per our 2 x 2 design to test the effect of each of the two factors. We performed two, two-tailed planned pairwise comparisons for the two factors to test the equality of proportions of Level 2 connections versus Level 1 connections. We focused on comparing the different conditions according to the frequency of Level 2 connections because we had designed the two forms of support to encourage deep and elaborated science connections on students' concept maps. For this study, we did not examine the frequency of connections assigned a score of zero because a score of zero could indicate multiple issues such as misconceptions, ambiguous or no connections, thereby making comparisons between groups problematic to interpret.

We created two, two-way contingency tables to examine the proportion of Level 2 connections by condition (see Tables 4 & 5). The sample size for each of these comparisons was the total number of correct science connections from all concept maps in the study (N = 491). The null hypothesis for these two comparisons was that the groups in the two conditions within each factor would not differ in the proportions of Level 1 and Level 2 connections on their concept maps. The alternate hypothesis was that the groups in the two conditions within each factor would differ in their proportions of these connections.

The first comparison examined the proportion of Level 1 versus Level 2 connections within the first main factor, teacher modeling of prompts vs. no teacher modeling of prompts. The second comparison examined the proportion of Level 1 versus Level 2 connections within the second main factor, individual preparation activity of maps vs. lists. We used the Dunn method to control the Type I error rate at .01 across the two comparisons (reject if $Z \leq -2.81$ or $\geq 2.81$). Both comparisons were statistically significant and confirmed our first two hypotheses. For the first factor, the groups that received teacher modeling of prompts generated a higher proportion of Level 2 connections on their concept maps than the groups that did not ($Z = 3.12$, $p < .01$). For the individual preparation factor, the groups that prepared individual concept maps prior to the collaborative activity generated a higher proportion of Level 2 connections on concept maps than the groups that prepared individual lists ($Z = 5.70$, $p < .01$).

Table 4: Contingency table displaying frequency and proportion of level 2 connections on maps within teacher modeling of prompts factor.

| Level of Connection | Modeling Of Prompts | No Modeling of Prompts | Total |
|---|---|---|---|
| Level 1 | 160 (.81) | 268 (.92) | 428 |
| Level 2 | 38 (.19) | 25 (.09) | 63 |
| Total | 198 | 293 | 491 |

Table 5: Contingency table displaying frequency and proportion of level 2 connections on maps within the individual preparation factor.

| Level of Connection | Lists | Maps | Total |
|---|---|---|---|
| Level 1 | 244 (.94) | 184 (.79) | 428 |
| Level 2 | 15 (.06) | 48 (.21) | 63 |
| Total | 259 | 232 | 491 |

## Effects of the Combination of Teacher Modeling of Prompts and Individual Preparation Activity

Because we found significant differences with our main factors, we decided to delve in further to uncover which conditions may have supported students better in creating high-quality group maps. We set up six, two-tailed pairwise comparisons to study each combination of the two factors and compare the proportions of Level 1 versus Level 2 connections among the four conditions (see Table 6). The sample size for each of these comparisons was the total number of correct science connections from all concept maps in the pairwise comparison groups. The first analysis compared the individual map + teacher modeling of prompts condition to the individual list only condition (N = 291). The second analysis compared the individual map + teacher modeling of prompts condition to individual list + teacher modeling of prompts condition (N = 198). The third analysis compared the individual map + teacher modeling of prompts condition to the individual map only condition (N = 232). The fourth analysis compared the individual list only condition to the individual list + teacher modeling of prompts condition (N = 259). The fifth analysis compared the individual list only to the individual map only conditions (N = 293). The sixth analysis compared the individual list + teacher modeling of prompts condition to the individual map only condition (N = 200).

Table 6: Summary contingency table displaying the frequency and proportion of level 1 and level 2 connections on group maps by condition.

| Sophistication of Connection | Individual Map + Modeling of Prompts | Individual Lists Only | Individual Lists + Modeling of Prompts | Individual Maps Only | Total |
|---|---|---|---|---|---|
| Level 1 | 81 (.70) | 165 (.94) | 79 (.95) | 103 (.88) | 428 (.87) |
| Level 2 | 34 (.30) | 11 (.06) | 4 (.05) | 14 (.12) | 63 (.13) |
| Total | 115 | 176 | 83 | 117 | 491 |

The null hypothesis for all six comparisons was that there would be no difference in the proportion of Level 1 and Level 2 connections on the maps between the conditions. The alternate hypothesis was that groups in the different conditions would differ in their proportions of these connections. We used the Dunn method to control the Type I error rate at .01 across all six comparisons (reject if $Z \leq -3.15$ or $\geq 3.15$). The first three pairwise comparisons were statistically significant. The groups in the individual map preparation + teacher modeling of prompts condition generated a higher proportion of Level 2 connections as compared to the groups in the individual list only condition ($Z = 5.02$, $p < .01$), individual list preparation + teacher modeling of prompts condition ($Z = 5.1$, $p < .01$), and the individual map only condition ($Z = 3.38$, $p < .001$). The remaining three comparisons were not statistically significant (see Table 7). These results supported our third hypothesis that the groups in the individual map preparation + teacher modeling of prompts condition would generate the highest proportion of Level 2 connections.

Table 7: Results for six pairwise comparisons testing proportion of level 2 connections between different conditions.

| Comparison | Z Score | p-value |
|---|---|---|
| Individual Map + Modeling of Prompts vs. Individual Lists Only | 5.02 | < .01 |
| Individual Map + Modeling of Prompts vs. Individual Lists + Modeling of Prompts | 5.1 | < .01 |
| Individual Map + Modeling of Prompts vs. Individual Maps Only | 3.38 | < .01 |
| Individual Lists Only vs. Individual Lists + Modeling of Prompts | .504 | > .01 |
| Individual Lists Only vs. Individual Maps Only | -1.62 | > .01 |

| | | |
|---|---|---|
| Individual Lists + Modeling of Prompts vs. Individual Maps Only | -1.89 | > .01 |

$$Z = \frac{P_1 - P_2}{\sqrt{\frac{P_1(1-P_1)}{N_1} + \frac{P_2(1-P_2)}{N_2}}}$$

P = Proportion of Level 2 Response

## Discussion

While research on collaborative learning has shown that student collaboration can provide opportunities to facilitate students' knowledge construction (e.g., Choi et al., 2005; Weinberger et al., 2006), some studies show that students often struggle to construct meaning through discourse and may not always collaborate effectively (Gnesdilow et al., 2010; So, 2007). In attempting to address this issue, we investigated two forms of support to facilitate students' knowledge building during collaborative concept mapping in a science classroom. We provided students with an individual preparation activity to help them reflect on the science content they could contribute to their collaborative activity and teacher modeling of prompts to help them engage in elaborate science discussions. We found that the groups that engaged in the meaningful initial preparation of making individual concept maps generated more elaborated connections on their collaborative maps than groups that prepared individual lists of concepts. We also found that the groups that received teacher modeling of prompts generated higher quality concept maps than the groups that did not. While we found significant main effects for these two factors, a closer examination of the pairwise comparisons revealed that prompts with teacher modeling and individual preparation of concepts maps were significantly more effective only when they co-occurred. The groups that both engaged in individual preparation of concept maps and received teacher modeling of prompts generated the greatest number of elaborated connections on their collaborative maps than all other groups. Thus, our findings show that it was the *combination* of the two forms of support that was the most effective in helping students generate deep and elaborated connections on their collaborative concept maps.

In the absence of an analysis of students' discourse, we can only offer tentative explanations about the underlying reasons for why the combination of individual concept map preparation and teacher modeling of prompts was most effective. Previous research in classroom collaboration and CSCL has identified the important role of the teacher in facilitating students' discourse (Mercer, 2000; Schwarz et al., 2009). We designed the teacher modeling of prompts from a socio-cultural perspective to provide students with models of effective science conversations as social and cultural tools and practices. Whereas one might expect that teacher modeling of prompts would be beneficial under any condition, this was not the case in this study. When teacher modeling of prompts was combined with lists as an individual preparation, we found no statistically significant difference from the conditions where there was no modeling. Instead there seemed to be a synergistic effect when the teacher modeling of prompts and individual preparation of concept maps were combined. We surmise that having students engage in a meaningful individual preparation of content prior to their collaboration may promote students' metacognitive processes, such as reflecting on, organizing, and making connections between their science ideas, and may help them consider the ideas they could contribute to their collaboration. Additionally, the individual concept mapping may have *primed* the students to take full advantage of the prompts because the creation of the maps may have provided students with a *scaffold* or *template* to organize and structure their content knowledge (Novak & Cañas, 2008). Consequently, the students who were given time to individually prepare concept maps were in a better position to take advantage of the teacher modeling of prompts, perhaps enabling them to better articulate these previously reflected upon ideas. To test our tentative explanations, we plan to analyze students' dialogue during collaborative concept mapping.

Our investigation of students' collaborative concept mapping in a classroom follows from previous research in collaborative learning. Studies have addressed challenges in students' collaboration by providing students with prompts to generate explanations and questions, and with instruction and training in several collaboration skills (Coleman, 1998; King, 1999; Mercer, 2000) and software-based tools to help students construct elaborate explanations, online metacognitive support through tips and examples, and scripts to facilitate students' collaboration (Choi et al., 2005; Vattam et al., 2007; Weinberger et al., 2006). Our study shows that *multiple* forms of support for both the content and models for productive collaboration may be necessary to more effectively guide students' dialogue and to help them reflect on their own ideas prior to their dialogue.

Consistent with the theme of this conference, our findings can also be used to inform teachers' practice. The emphasis on multiple forms of support may be pertinent for younger middle school students in complex collaborative settings, where facilitating both the content and the nature of their dialogue may be critical to enhance their learning. Furthermore, the multiple supports we have designed can be integrated in various curricula, are amenable to the teacher's implementation in a relatively straightforward manner, and can also be easily adapted for CSCL and online settings.

## Conclusions and Future Research

We conducted this study with four classrooms of a single teacher and our findings represent a modest first step in exploring ways to support students' collaborative learning and concept mapping. Whereas our quantitative analyses helped us explore differences in the quality of concept maps among the four conditions, we plan to conduct a detailed qualitative analysis of students' dialogue in the different conditions to understand how the multiple forms of support influenced students' collaborative interactions, and how these interactions were related to the quality of the concept maps. Future research could also investigate the effects of individual preparation of concept maps before different types of collaborative activities and explore other forms of meaningful individual preparation prior to collaboration and conditions for which giving prompts with teacher modeling may be most beneficial. While we investigated collaborative concept mapping, future research could study these supportive measures for a variety of collaborative activities. Finally, our study showed the benefits of meaningful individual preparation and teacher modeling of prompts for a single collaborative learning session. Future research could examine these supportive measures over sustained periods of time.

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* The first two authors listed contributed equally to the writing of this paper and appear alphabetically.

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