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Tutaleni Asino, Roy B. Clariana, Yaozu Dong, Brittany Groff, General Ntshalintshali, Ellen Taricani, Chakorn Techatassanasoontorn, and Wu Yu

All members' affiliation:
Learning Design and Technology program (formerly Instructional Systems)
The Pennsylvania State University
314 Keller Building
University Park, PA 16802

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Signature (Roy Clariana)

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Michael R. Simonson
Editor
Proceedings
Instructional Technology and Distance Education
Nova Southeastern University
Fischler Graduate School of Education
1750 NE 167th Street
North Miami Beach, FL 33162
simsmich@nova.edu
954-262-8563

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Abstract

This investigation considers the effects of Interdependent and Independent group collaboration on the flow of information elicited as concept maps before (Premap), during (Group map), and after (Postmap) collaboration, and on the source, extent, and quality of Postmaps. Participants were undergraduate students (N = 37) randomly assigned by group (tetrads and a few triads) to the Independent condition who read and 'mapped' an entire textbook chapter as homework or to the Interdependent condition who read the whole chapter but mapped either the first half or second half. After completing their Premaps out of class, group members collaborated face-to-face in class to further learn the content by creating a group concept map on a large sheet of newsprint. Then immediately, students individually drew their Postmap from memory. The Independent condition participants' Postmaps had more idiosyncratic terms and were more like their Premaps relative to the Interdependent participants' Postmaps, and the Interdependent participants' Postmaps were considerably more like their Group maps. Further, the Interdependent participants' Postmaps were relatively more like the expert maps (62% vs. 52%) mainly due to a greater number of terms from the second half of the chapter, a possible primacy effect. Regarding knowledge convergence, the Interdependent Postmaps were relatively more like the Postmaps of others in their group (38% vs. 30% overlap). In this case, Interdependence resulted in less homework but nearly equivalent group maps and better and more similar Postmaps.

Introduction

People learn, formally and informally, and work in the company of others. In fact, collaborating in groups is a critical 21st century job skill (Kozma, 2008) that has a natural fit with and a growing role in both face-to-face and online instruction. Group factors such as social cohesion and individual factors such as motivation, cognitive elaboration, and possibly developmental considerations (Slavin, 2010) all influence learning in groups. Much research and theory on group memory has originated in history, anthropology, and sociology, while group collaboration has been investigated by social psychologist and learning scientists with a strong orientation on describing and influencing group-level process variables such as roles and argumentation patterns. Recently there is a surge of interest by cognitive scientists and educational psychologist on the influence of group collaboration on individual cognitive activity such as retrieval, rehearsal, and forgetting (Rajaram & Pereira-Pasarin, 2010). Combining these approaches is consistent with Salomon and Perkins (1998) call to distinguish between the effects with and effects of collaborative learning. This present investigation is our beginning step to understand the flow of information pieces (as structural knowledge) in group collaboration as a way to look at how activity in the group influences individual cognition (note: our follow-up investigations already in progress employ video analysis of the group collaboration in an online setting to extend this line of research).

Previous research has identified two counter-intuitive, negative, and perhaps even startling findings for group work. First, although the recall of a collaborative group is greater than that of any one member (Hinsz, Tindale, & Vollrath, 1997; Yuker, 1955), individuals working together in a group remember less than if they work individually and then pool their work. This is a well-established effect called collaborative inhibition. Second, Stasser and Titus' (1985) seminal article on the hidden-profiles methods where group members are intentionally provided only partial and different information that if combined provides a complete picture, found that group discussion tends to focus on information that members already share before the discussion and so members tend to perpetuate and even strengthen their initial knowledge at the expense of attaining a 'fuller' understanding from the unique information brought by others. Frankly, these two well-established findings clearly suggest that group work would not be as effective as working individually and so these effects of working in groups must be qualified or moderated in order to recommend or design group work during instructional design.

How does this play out? Almost certainly individuals enter into every group collaboration with both commonly shared information and also new unique information. A recent meta-analysis by Lu, Yuan, and McLeod (2012) summarized findings from 65 studies (101 Independent effects, 3,189 groups) that replicated previous findings that common information (i.e., information that is already held by several group members *before* the group collaboration) is mentioned more frequently than unique information (i.e., information held by one member of the group *before* the group collaboration) by two standard deviations more common information than unique information.

Does collaborative inhibition occur in ordinary group collaborative learning? And do group members in collaborative learning predominately share common information relative to unique information? And what strategies, tactics, scaffolds, inducements, and incentives can instructional designers use to optimize collaborative learning for all members? Obviously one investigation cannot answer all of these questions. This investigation considers the flow of common and unique information before, during, and after group collaboration using a modified jigsaw method that resembles the hidden profiles approach.

Jigsaw (Aronson, 1971) is a group approach that is popular and intuitively appealing but is time consuming and perhaps not always effective. In this approach, members are assigned different parts of a topic to study, and then they join a group discussion with others who have the same topic in order to more fully develop that topic. Then members rejoin their initial group where they become the group 'expert' for that topic and members of the group 'coteach' each other the various topics. Jigsaw is thus a form of hidden profiles since different group members enter the group collaboration with different profiles or portions of the information. Jigsaw establishes interdependence between group members, since members must depend upon other members. Interdependent group tasks (i.e., from Social Interdependence Theory) typically engenders greater member interaction which can lead to more similar knowledge structure (Roseth, Saltarelli, & Glass, 2011, p. 812).

Engleman and Hesse (2010) investigated interdependence in computer-supported collaborative learning. In their investigation, all the members of 40 triads (N = 120) initially individually studied partial information (i.e., hidden profiles) regarding how to control pests that are destroying pine trees in a forest, no one member within a triad had the full solution to the problem but the three members together would have enough information to solve the problem. The triads were randomly assigned to the Interdependent and Independent conditions. All triads met synchronously online to create a collaborative concept map using *CmapTools* software while talking via *Skype*, the Independent triads had access to all of the partial information given to the other two members of their triad while the Interdependent triads could not see the other members' partial information. The Interdependent and Independent conditions interacted differently online and obtained different learning outcomes. The Interdependent triads on average spent 12.1 minutes creating a fully elaborated concept map before shifting focus to solving the pest problem, while the Independent triads spent only 3.9 minutes elaborating their map before focusing on solving the pest problem. Regarding learning, the Independent triads outscored the Interdependent triads on the solution to the fertilizer portion of the problem, although there was no difference between the two conditions on the pesticide portion of the problem. Analysis of the content and structure of the Group maps showed that the Interdependent triads' maps were larger and more fully elaborated relative to the Independent triads' maps. Specifically the Independent triads' map had relatively fewer terms and links between terms, and those terms focused on the solution to the problem and left out information that was relevant but not directly problem related. Thus interdependence more fully drew out the partial information from each of the triad members, although ultimately those fuller map representations were less likely to prompt a solution to the pest problem.

This findings for the Interdependent group (i.e., that they shared almost all of their unique information with the group) are notable since it is the opposite pattern of what would be expected regarding common and unique information based on Stasser and Titus' (1985) that group discussion tends to focus on information that members already share before discussion. This may have occurred due to the use of concept maps as the group collaboration tool (Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2007). In this present investigation, we desired to measure the flow of shared and unshared (unique) information before, during, and after group collaboration in order to explain or reconcile this pattern.

In the present investigation, instructional treatments were developed to mimic a hidden profiles strategy (i.e., before group collaboration, learners focus on either the first half, last half, or all of a textbook chapter). The learning strategies were sensitively negotiated with the course instructor to be learner appropriate in terms of content, level, task difficulty, and activity. In this we sought to bridge research and practice by establishing ecological validity in a real classroom while measuring information flow at an elemental level (Nathan & Alibali, 2010). Concept maps (actually mind maps without relational link terms) were selected because of their utility as a note-taking device, as a semiotic tool for collaboration that can function as a "convergence artifact" (see Suthers et al., 2007), and as a measure that has concurrent validity with many measures of interest. Besides measuring the extent of knowledge in these pre, group, and post maps, we also measured the omnibus 'structure' of the maps as graph centrality (Clariana, Draper, & Land, 2011).

Graph Centrality as a measure of Knowledge Structure

Concept mapping consists of several distinct cognitive activities including recalling important terms (the extent of knowledge), sorting terms closer together or farther part (associational knowledge), linking highly related terms (relational knowledge), and labeling the links (propositional knowledge). This investigation considers the extent of knowledge as the concepts present in Premaps, Group maps, and Postmaps. In this report, we have not yet analyzed relational, associational, or propositional knowledge although we do provide graph centrality as one alternate measure of relational and associational aspects of knowledge structure (Clariana et al., 2011).

Specifically, Kinchin, Hay, and Adams (2000) have proposed that the overarching visual layout of a concept map, designated as spoke (star), chain (linear), and network (tree), provides a classification of cognitive structures that is a typology of thought (also Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, 2005). Hay and Kinchin (2006) further propose that spoke structures are indicative of a naïve epistemology, chain structures are indicators of goal-orientation, and networks are indicators of expertise. Clariana et al. (2011) quantified these four network graph layout forms using graph centrality as an omnibus numerical measure of concept map structure, with 0.1 representing linear form, 0.4 a tree form, 0.6 representing a network form, and 1.0 representing a star form (see Figure 1).

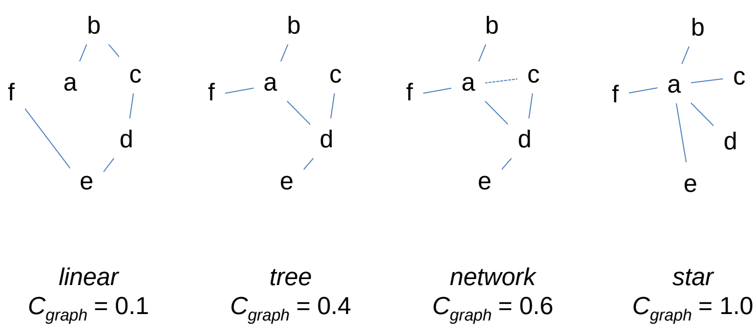

Figure 1. Graph centrality calculated for four concept map forms from Clariana et al. (2011).

Using graph centrality, Clariana et al. (2011) reported that Subaru employees in the field who learned together for several months in an online community of practice had a greater and highly similar graph centrality (C_{graph} = .45, 66% overlap) for their written response to a problem-based case compared to participants who were not in the community of practice (C_{graph} = .25, 33% overlap). Thus the visual form of the participants' knowledge structure in the community of practice strongly 'converged' (Weinberger, Stegmann, & Fischer, 2007). Their findings support the use of graph centrality as a measure of knowledge structure.

Purpose

The present investigation seeks to describe the influence of task interdependence on learners' extent of knowledge as measured by Premaps, Group maps, and Postmaps and also the structure of their knowledge as measured by graph centrality. A follow up study underway now will replicate this approach online and will include video analysis of the group collaboration in order to describe the collaborative group process.

Method

Participants. This investigation was conducted in a face-to-face section of CAS 250, Small Group Communication, at a large public Northeastern university. This is a required course for Communications majors. Eligibility criteria included course membership and voluntary participation with signed consent. The participants in this investigation were mostly sophomore undergraduate students between 19 and 22 years old, 60% were male. Students received course credit for completing the activities. Two students did not complete at least one of the activities and one chose not to participate, so the final sample is n = 37. The investigation was reviewed by the university's institutional review board (IRB #38101). The 10 intact groups were randomly assigned to receive either the Independent condition or the Interdependent condition.

Materials and Procedure. This investigation was conducted in weeks 9 and 10 of a 16 week semester. The students had worked in groups of four for most of the semester and so were familiar with each other and were accustomed to group work in class (ecological validity).

During a class session in week 9, the principal investigator who is not the course instructor explained the investigation and led a group concept mapping practice session where the students read a 450-word text on a course related topic, "Social influence in groups" and then students worked in their existing groups of four to create a Group map of this content on large newsprint pads using yellow stickies and magic markers.

Working alone as homework, participants in the Independent condition were asked to map all of Chapter 8 (from the course textbook), while participants in the Interdependent condition were asked to map only the first or last half of the chapter. All were told to "do your map in order to support your team". All were given this same list of 31 terms from the chapter that they could use for their homework Premaps. The handout for both the Interdependent and the Independent conditions stated, "Use any appropriate words in your concept map, but here are a few important words that we noticed in Chapter 8 that you could use too if you get stuck." And it then listed these terms from Chapter 8, 18 terms for Reading 1 and 18 for Reading 2. Reading 1 (pp. 228-234) included: *conflict, myths, disagreement, address or avoid, controversy, communication, idea deviance, group cohesiveness, influence, participation/ involved, consensus, decision making, goals, task conflicts (substantive), relational conflicts (affect), CMC trajectory, group think, group norms,* and *values*. Reading 2 (pp. 235-244) included: *management style, competitive, relational conflict, compromise, collaborative, integrative, avoidance, accommodation, appeasement, partial win-lose, win-lose, consensus, group norms, fairness, my needs, other's needs, disagreement, influence,* and *group cohesiveness*. Five of the terms were in both lists, including: *disagreement, group cohesiveness, group norms, influence,* and *relational conflict.*

In the next regular class meeting, students met in their groups for about 45 minutes and created a Group map of the Chapter 8 content. When done, students handed in their Premaps and Group maps, and then individually completed a post assessment that consisted of creating from memory a concept map of the Chapter 8 content. The handout stated, "From memory draw a concept map of the chapter. Sometimes it helps to list the 4 or 5 most important words and place those first, then add to those as needed. Shoot for about 20 to 30 most important terms. Be sure to write your name on the page. You may use any appropriate words in your concept map, but here are a few important words that we handed out before that you can use if you get stuck." (This is the same list handed out for the Premap above.)

Results

Five analyses are presented here: (1) the extent of knowledge measured as the number of concepts within groups across the Premap, Group map, and Postmaps; (2) the contribution of concept terms from members Premaps to their Group maps; (3) the contribution of concept terms from members Premaps and Group maps to their Postmap; (4) structural knowledge across groups measured as graph centrality describing Premaps, Group maps, and Postmaps; and (5) extent of knowledge convergence as measured by the average Postmap percent similarity of concept overlap of the members in each group.

(1) Extent of Postmap knowledge flow from Premaps to Group maps to Postmaps

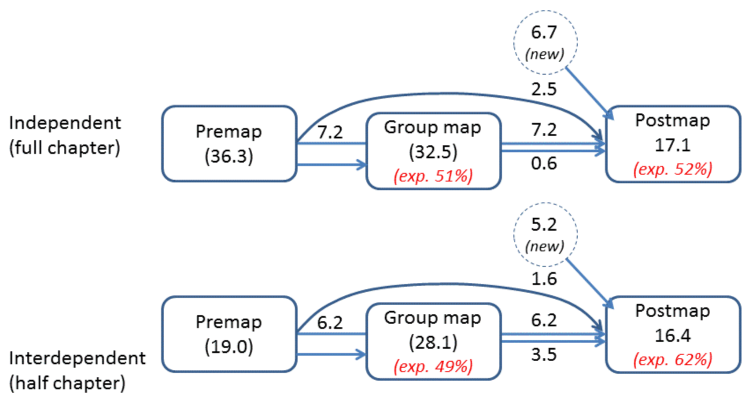

Figure 2. The average flow of Posttest concepts for each condition across Premaps, Group maps, and Postmaps. (note: Values shown in parentheses are comprised of all terms in the maps, not just Postmap terms).

The average extent of Posttest knowledge for the Independent and Interdependent conditions in each concept map activity is shown in Figure 2. Many Posttest terms that had occurred in the Premaps (i.e., Ind. = 57%, Int. = 47%) were also present in the Group maps (i.e., Ind. = 42%, Int. = 39%). The Interdependent and Independent Group maps agreement with the expert were equivalent (i.e., 49% vs. 51%), although the Interdependent group Postmaps were a bit more like the expert maps (not significant) than were the Independent Postmaps (i.e., 62% vs. 52%).

(2) The contribution of concept terms from members Premaps to their Group maps

To analyze Group map terms, a 2 x (3 x 5) repeated measures ANOVA was conducted with the between subjects factor Treatment (Interdependent and Independent) and the two within subjects factors Quality (Group map term occurs in Reading 1 expert map, Reading 2 expert map, or not in either expert map) and Premap (Group map term occurs in 0, 1, 2, 3, or 4 Premaps of that group). The interaction of Treatment and Premap was significant, $F(4,32) = 3.956$, $MSe = 6.890$, $p = .010$; this interaction is shown in Figure 3. As would be expected, since the Interdependent treatment members only mapped half of the chapter, most of the terms in their Group maps were only present in 1 or 2 of their Premaps (i.e., the same half of the chapter). Independent group members were instructed to map the entire chapter as homework, and most terms in their Group maps were present in 3 or 4 of their Premaps. It is important to note that the Treatment between subjects factor was not significant, Independent and Interdependent Group maps had equivalent quality and pretest source, although the Independent group maps were a little more like the expert maps (51%, refer back to Figure 2) than were the Interdependent group maps (49%).

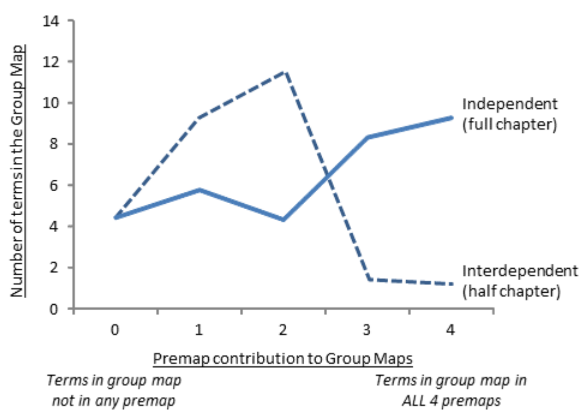

Figure 3. The Group map significant interaction of Treatment and Premap.

(3) The contribution of concept terms from members Premaps and Group maps to their Postmap

A 2 x (3 x 2 x 2) repeated measures ANOVA was conducted on Postmap terms with the between subjects factor Treatment (Interdependent and Independent) and the three within subjects factors Quality (Postmap term occurs in Reading 1 expert map, Reading 2 expert map, or not in either expert map), Premap (Postmap term occurs in that individual's Premap or not), and Group map (Postmap term occurs in that individual's Group map or not). Only treatment-related significant results are presented here due to space limitations.

The interaction of Treatment and Quality was significant, $F(2,70) = 4.524$, $MSe = 1.570$, $p = .014$; this interaction is shown in the left panel of Figure 4. The Treatment and Quality interaction (left panel) shows that the two treatments had an equal number of important terms in their Postmaps from Reading 1. But for Reading 2, those who mapped half of the chapter as homework (the Interdependent treatment) had more of the important terms from Reading 2 in their Postmaps relative to those who mapped the entire chapter as homework (the Independent treatment). A follow-up analysis showed a significant interaction F(2,34) = 3.137, MSe = 3.68, p = .05, of Treatment (Interdependent first half of chapter, Interdependent last half of chapter, and Independent) and Quality (Reading 1 expert map and Reading 2 expert map) and indicates that this posttest improvement in Reading 2 terms was due to those who mapped Reading 2 as homework, a primacy memory effect for reading and mapping (see the right panel of Figure 4). The good news is that this did not impair the posttest performance of those students who mapped only Reading 1 as homework, since their performance was equivalent to those who mapped the entire chapter as homework. And finally, the Independent groups' posttests had more idiosyncratic terms (i.e., not in either expert map) compared to the Interdependent groups.

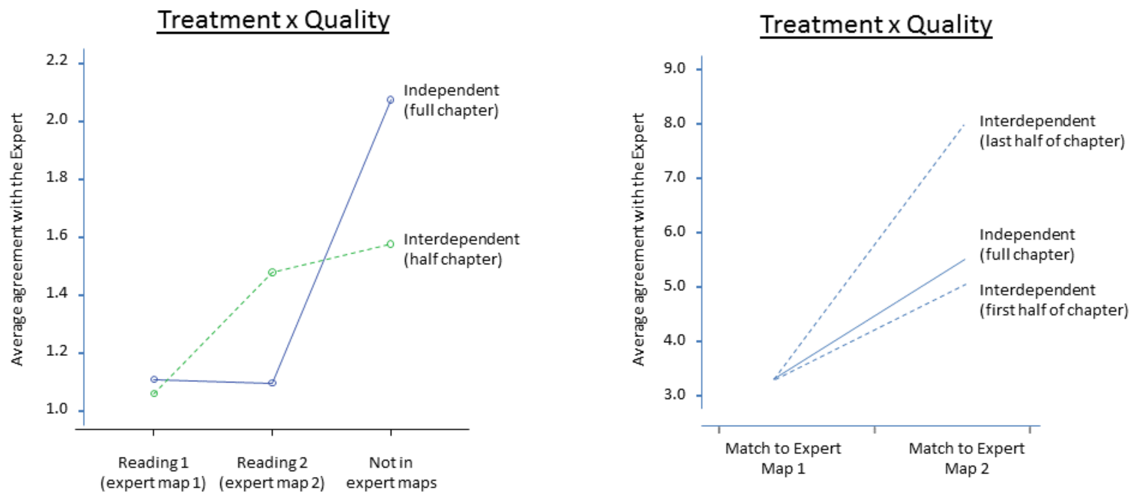

Figure 4. The Postmap significant interactions of Treatment and Quality (left) and follow-up analysis (right).

Next, the interaction of Treatment and Group was significant, F(1,35) = 6.661, MSe = 2.151, p = .014; this interaction is shown in Figure 5. The figure shows that the Interdependent group members had more posttest terms that also occurred in their Group map relative to the Interdependent group, who strikingly had posttest terms that were NOT in their group's map. This suggests that the Independent group members paid less attention to their group's map, their Postmap was more dependent on their Premap and their own unique knowledge than on their Group map (refer back to Figure 2).

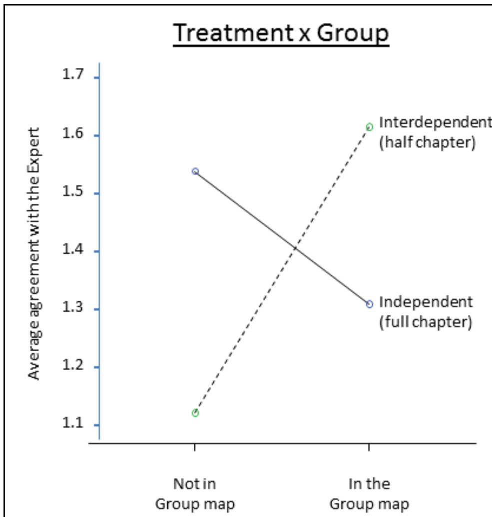

Figure 5. The Postmap significant interaction of Treatment and Group.

Next, the interaction of Treatment and Group was significant, $F(1,35) = 6.661$, $MSe = 2.151$, $p = .014$; this interaction is shown in Figure 5. The figure shows that the Interdependent group members had more posttest terms that also occurred in their Group map relative to the Interdependent group, who strikingly had posttest terms that were NOT in their group's map. This suggests that the Independent group members paid less attention to their group's map, their Postmap was more dependent on their Premap and their own unique knowledge than on their Group map (refer back to Figure 2).

(4) Structural knowledge (as graph centrality)

Graph centrality values were calculated for all of the homework Premaps (37), Group maps (10), and all of the Postmaps (37). The Premap and Group maps were more *linear* in form (range .16 to .20, see Table 1) while the Postmap forms were somewhat *tree* form (.27 and .31). We suggest that the smaller centrality values for the Premaps are likely due to the fact that the students were using these Premaps for "note" taking. People tend to take notes in a linear way, reading a paragraph and mapping it, reading the next paragraph and mapping it, and so on. The smaller values of the Group maps may also be a reflection of this note-taking effect, group members have their Premaps out during group mapping and so may be reflecting the structure of their Premaps onto their Group maps. Alternately, perhaps Group maps just tend to have this form of structure if members contribute larger or smaller "chains" of information in chunks to the group map.

The Postmaps obtained a larger centrality value (i.e., .27 and .31) than the Premaps and Group maps (significant). Recall that participants did not have any notes or maps when drawing their Postmap, Postmaps were drawn from memory. Perhaps maps drawn from memory tend to obtain this level of centrality innately or this specific content may interconnect more when drawn from memory (i.e., larger centrality).

Table 1. Average graph centrality (standard deviation shown in parenthesis) and correlations for each Condition and Task.

	Average Graph Centrality		
	Premap	Group map	Postmap
Interdependent (n = 18, 5 groups)	.20 (.10)	.17 (.12)	.27 (.17)
Independent (n = 19, 5 groups)	.18 (.13)	.16 (.09)	.31 (.20)

(5) Extent of Knowledge Convergence

The Postmap percent similarity for members within each group was calculated as the ratio of terms in common between two Postmaps divided by the average total terms in the two Postmaps (see Table 2). Then these values were averaged to obtain the group's Postmap average percent similarity (not the same as graph similarity).

Table 2. Postmap average percent similarity for the members in each group.

Interdependent		Independent	
Group 2	28%	Group 1	22%
Group 3	49%	Group 5	31%
Group 4	38%	Group 6	36%
Group 8	33%	Group 7	30%
Group 9	41%	Group 10	31%
M =	**38%**		**30%**
SD =	0.08		0.05

The Interdependent condition average percent similarity is 38% and for the Independent, the average percent similarity is 30%, an effect size of 1.03 (t-test p =.11). Although this difference is not significant, the trend is in the anticipated direction that Interdependent groups' members' knowledge extent converges more relative to the Independent group as reflected in more similar post-lesson concept maps.

Discussion

This investigation considered information flow in Interdependent and Independent task collaborative group work measured using Premaps, Group maps, and Postmaps. For the Premaps, not surprisingly map sizes were on average about half as large for the Interdependent condition (19.0 terms) compared to the Independent condition (36.3 terms). This is consistent with mapping half of the chapter versus mapping the whole chapter. Group maps were approximately equivalent in terms of quality and size, Interdependent group agreement with the expert was 49% for 32.5 terms compared to 51% for 28.1 terms for the Independent group maps. But flow of terms from Premap to Group maps varied by condition, the Interdependent Group map terms had only occurred in 1 or 2 members' Premaps while the Independent Group map terms had mainly occurred in 3 or 4 members' Premaps. Simply stated, the members brought forward to the group terms form that part of the text that they had previously studied (read and mapped). Regarding Postmaps, first the Group maps were considerably larger than the Postmaps. Next average Postmaps for each condition were approximately equivalent in terms of size but not in terms of quality, the Interdependent agreement with the expert was 62% for 16.4 terms compares to 52% for 17.1 terms for the Independent group maps. The improvement in quality for the Interdependent condition appears to be due to a relative increase in Postmap terms from the last half of the chapter. This suggests a primacy effect for reading and mapping where what is covered first is better recalled. The quality of the Independent maps was also reduced due to the increase in idiosyncratic or unique Postmap terms that were not in the expert's maps.

These findings indicate that the Interdependent group members must have learned the other half of the chapter that they had not studied through the group collaboration and what they learned in the group tended to be of higher quality. Specifically, 21% of the terms in the Interdependent groups Postmaps came exclusively from their Group maps while only 4% of the Independent group members' terms came exclusively from their Group maps.

Another striking difference is the large percent of Posttest terms that were in neither the individual's Premap or their Group map, 39% in the Independent condition and 32% in the Interdependent condition. This suggests that individuals have idiosyncratic information that is not 'active' enough to include in their Premap or to share in the Group map but that was worthy of including in their Postmap. A parsimonious explanation is that this low activity unique information in all individuals is slightly suppressed at Postmap by Interdependent group collaboration (rather than that it is enhanced in Independent group collaboration). The bigger question is why do members share some of their information but not all of it? This seems important, so it needs further analysis to determine what kind of information this is.

This investigation has a number of limitations. First, this investigation used open-ended concept maps where participants may use any terms they. Open-ended concept maps are the gold standard but are notoriously difficult to analyze due to factors that introduce analysis error such as having to manually standardize concept terms across all maps to control for synonyms and metonyms (a big and daunting task), and analysis comparison problems due to the highly varied map sizes (in this study map size ranged from 6 to 23 terms in the Interdependent Postmaps and from 10 to 29 in the Independent Postmaps) that effect math calculations (e.g., imagine the complexity of analyzing multiple-choice posttests where participants answered very different numbers of question: 5 out of 5 would be 100% while 7 out of 10 would be 70%, so who did better? 5/5 or 7/10?).

The expert's maps of readings 1 and 2 used as the benchmark to evaluate the quality of all maps are also a limitation. How good are the expert maps? Different expert maps produce different quality values for every student map. So these quality measures reported here must be interpreted with caution and be viewed only as general estimates of map quality.

Another substantive limitation is the use of only concept maps, other measures of post-group knowledge are needed in order to describe the learning effects of these strategies and the possible relationship between the map measures and these other measures. The graph centrality measures used here are very speculative, more research is needed to establish this approach as a valid and operational measure of knowledge structure.

Also, these findings for information flow in this face-to-face group collaboration may not generalize to online collaboration, which is our main research interest.

<u>Contribution to practice</u>. These tentative findings suggest that this modified jigsaw strategy does lead to quality knowledge sharing in group collaboration and requires less homework overhead (e.g., map half the chapter for homework rather than the whole chapter). Thus this co-teaching group collaboration approach may be very appropriate for online courses that cover required textbook content.

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